Meteorological Studies During the Fourth Indian Scientific Expedition to Antarctica: December 1984 to March 1986

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ABSTRACT

During the Fourth Indian Scientific Antarctic Expedition, meteorological observations were carried out to obtain information on the Antarctic weather and to find out its possible effect on different weather systems influencing the lower latitudes of Southern/Northern Hemisphere, if any. In addition vast amount of data was collected in order to study the radiation balance, radiation flux in the upper atmosphere, the heat transfer in various layers, the temperature inversion in the lower levels of the Antarctic atmosphere and its role in causing blizzards. Further, studies on thermal structure of the Antarctic atmosphere and the atmospheric electricity over Antarctica were also carried out.

The studies were planned and executed in three different phases. In the present paper, on the basis of the data collected, during the expedition one year climatology of the station (Dakshin Gangotri) has been prepared. In addition daily/monthly variation of various meteorological parameters and some important weather phenomenon observed like blizzard etc. have also been discussed.

INTRODUCTION

The Fourth Indian Scientific Antarctic Expedition comprising of 82 members from various scientific institutions, viz., India Meteorological Department, National Institute of Oceanography, National Physical Laboratory, Bharat Heavy Electricals Limited, Geological Survey of India, Air Force, Navy and Army set out for Antarctica on 4th December, 1984 and arrived there on 28th December, 1984. After carrying out a lot of useful scientific studies/experiments the expedition members returned to India leaving behind 13 persons in Antarctica as the second wintering party. During this period, a lot of vital information/data have been gathered, so as to get an insight into the various meteorological phenomena which engulfed the icy continent.

As a matter of fact there is unlimited scope for exploration/investigation in various fields of science in Antarctica. As such Antarctica has attracted a great deal of attention of large number of explorers and scientists since long time. Subsequently a number of expeditions went to Antarctica from time to time from different countries. The outstanding scientific events of the pre International Geophysical Year (IGY-1987) period are the Byrd Antarctic Expeditions 1928-1930, 1933-1935 and 1939-41, mainly with respect to Ross Sea; the Norwegian-British-Swedish Expeditions 1949-52 in the Maudheim Area and the French Expeditions to Adelie Land 1949-52. Naturally in the post IGY period there is a long list of Antarctic expeditions and the Fourth Indian Scientific Expedition to Antarctica is of course one of them.

So far as the meteorological disturbances are concerned, they do not obey any political boundaries. Therefore, to know and predict the behaviour of atmosphere of a place one ought to know the different weather elements and their spatial/temporal changes of a much larger area irrespective of political boundaries. In short, the knowledge of global meteorology is utmost essential for a proper understanding of various weather phenomena encountered on our earth. In the present paper various meteorological programmes undertaken at Antarctica are presented. Moreover, from the

observed meteorological data, one year climatology of Dakshin Gangotri (India's Antarctic Research station) has been presented. In addition daily/annual variation of different meteorological parameters and some important weather phenomenon observed at Antarctica like blizzards etc. have also been discussed.

Meteorological studies by the Indian Scientists have been carried out in all the three earlier expeditions. Published accounts include Katyal and Upadhyay (1983); Desa et al., (1983); Sreedharan and Sharma (1985); Singh et al. (1986) and Rizvi (1986a). The report on the meteorological studies undertaken during the first wintering period (1984-85) and the second wintering period (1985-86) at the manned station Dakshin Gangotri have been published by Rizvi (1986b) and Lal (1987) respectively.

MAIN OBJECTIVES OF METEOROLOGICAL PROGRAMME

If one wants to correlate the Antarctic weather with any other part of the globe, it is very much desirable, in the first instance, to study the Antarctic weather itself in great detail, keeping this in view, meteorological programme was carefully planned. In the following few paragraphs, the main objectives of the meteorological programmes as well as its planning and execution are presented.

Some of the main objectives of the programme were as follows:

(i) Installation of new equipment.

(ii) Maintenance of meteorological equipment already installed.

(iii) Issue of meteorological forecasts for day to day activities of Air Force, Navy and other parties of expedition.

(iv) To see feasibility of installing Data Collection Platform (DCP) - unmanned weather station in Antarctica.

(v) To collect the meteorological data while on cruise as well as in Antarctica in order to make the following studies:

- **(a) The Antarctic weather and its possible effect on different weather system influencing the lower latitudes of Southern/Northern Hemisphere if any.**
- **(b) The radiation balance in Antarctica.**
- **(c) Radiation flux in the upper atmosphere and the heat transfer in various layers.**
- **(d) Temperature inversion in the lower levels of the Antarctic atmosphere and its role in causing blizzards.**
- **(e) Thermal structure of the Antarctic atmosphere.**
- **(f) Atmospheric electricity over Antarctica.**

Meteorological Programme

To achieve above objectives the programme was planned and executed in the following three phases:

Phase 'A'-On cruise (while going) from 4th December to 28th December 1984-Experiments Planned and Instrumentation.

S.No.	Experiment	Instrument used
1.	Surface wind measurement at synoptic hours.	Finals equipment already installed on the ship.
2.	Surface temperature/humidity measurements at synoptic hours.	Whirling Psychrometer
3.	Visibility and cloud at synoptic hours.	Manually
4.	Upper air wind, temperature, humidity and pressure measurements (Total 18 ascents)	OMEGA Sonde
5.	FAX charts reception (4 to 6 per day on an average)	Finnis equipment already installed on the ship.
6.	Automatic recording and transmitting surface meteorological data to MDUC New Delhi via INSAT-B (recorded at every full hour GMT).	D.C.P. (Various Met. Sensors).

It is worth mentioning here that for the first time India Meteorological Department installed Data Collection Platform (DCP) on board on a trial basis. This automatic weather station recorded/ transmitted hourly surface meteorological data like pressure, temperature, humidity, wind speed and direction and duration of bright sunshine via INSAT-IB to MDUC, New Delhi. This experiment was a total success enroute as well as in the Antarctic waters.

Phase 'B'-At Antarctica (From 28th December 1984 to February 1985).

(i) Refurnishing of Meteorological Observatory: The meteorological observatory which was established at Indian Antarctic Station Dakshin Gangotri (Lat 70° S: Long. 12° E), during the third expedition was refurnished with new equipment. As the old wind mast was hurried under the ice, therefore, a new wind mast was installed. Most of the old meteorological equipment sensors e.g. temperature, humidity, wind etc. were replaced by new one.

(ii) New Installation: Two new equipment were installed, for receiving cloud imageries from polar orbiting satellites like NOAA-8 and 9. Out of which one was Automatic-picture Transmitter (APT) and another one a Surface Potential Gradient Equipment (PG) for studying the atmospheric electricity at D.G.

(iii) After the installation of these two equipment the following measurements were taken with the help of instruments mentioned below:

S.No.	Experiment	Instruments	No. of observations
(i)	Surface wind measurements	Anemometer and wind wane	Taken on daily basis on synoptic hrs. and continuous.
	Surface temperature and humidity measurements.	Rod thermistor of humicap	-do-
(iii) (iv)	Visibility and cloud conditions.	Manually	Taken on daily basis on synoptic hours.
	Surface pressure measurement	Barograph	Continuous
(v)	Solar radiation measurement	Pyranometer	Continuous
(vi)	Surface electric potential gradient measurement	Potential gradient equipment	-do-

(vii)	Upper air measurement of pressure, temperature and humidity.	401-MHz radio sonde ground equipment and radio meter sonde.	Total 48 ascents.
(viii)	Measurement of upper air radiation flux and heat transfer in various layers.	401-MHz radiosonde ground equipment and radio meter sonde.	Total 11 ascents during the stay.
(ix)	Reception of FAX charts.	DEBEG FAX equipment	4 to 5 (surface and upper air) daily.
(x)	Reception of cloud imageries.	APT (ALDEN equipment)	On an average 2 to 3 daily.

Phase 'C'-On cruise (while returning)-3rd March, 1986 to 24th March, 1986.

(i) Round the clock three hourly surface observations were maintained.

(ii) 11 Radio sonde ascents were taken.

(iii) On an average 4 facsimile surface and upper air charts were taken.

RESULTS AND DISCUSSIONS

On the basis of meteorological data collected at D.G. (Lat. 70°S, Long. 12°E) during our stay from 19 February, 1985 to February, 1986 year climatology of the station has been prepared, which is given in Table I in nutshell.

TABLE 1

Some important meteorological observations (1985-86) based on 3 hourly observation.

Month	Temperature in °C					No. of blizzards	Total blizzards days	Duration of longest blizzard days	Mean wind speed in knots	Max. wind speed in knots	Mean pressure (mb)	Duration of sunshine in hrs per 24 hrs
	Average	Mean	Extreme Min.	Mean Max.	Extreme Max.							
Feb., 85 (From 19)	-9	-13.0	-23	-6.6	0	2	3	2	18.0	50	980.5	9
Mar.	-12.8	-16.0	-26	-10.0	-4	-4	14	5	17.2	105	985.8	12
Apr.	-16.0	-18.7	-32	-13.0	-4	5	13	4	21.4	70	983.2	8
May	-25.7	-28.8	-36	-23.0	-13	5	11	3	21.2	110	988.5	4
June	-23.0	-26.0	-34	-20.4	-10	3	18	13	25.0	65	987.1	Nil
July	-28.0	-32.0	-46	-24.6	-10	8	15	5	20.8	105	970.6	2
Aug.	-31.4	-34.6	-52	-28.1	-14	6	8	4	12.1	85	984.3	6
Sept.	-26.6	-30.2	-43	-23.6	-14	7	13	4	21.5	75	973.0	12
Oct.	-18.9	-22.7	-33	-15.9	-10	5	12	6	22.0	55	977.9	16
Nov.	-12.8	-16.5	-27	-9.4	-3	7	9	2	15.3	70	976.0	20
Dec.	- 5	- 8.6	-16	-1.9	+6	8	10	3	15.9	60	981.5	24
Jan.	- 3.2	- 6.4	-14	-0.9	+4	4	8	3	14.2	45	986.9	23
Feb. (Upto 19)	-5	-9.0	-18	-2.4	0	2	5	3	12.7	30	986.5	9

It may be seen from the table that on an average January is found to be the warmest and August is the coldest month. It is interesting to note that June experienced maximum number of blizzard days (18) though the total number of blizzards were minimum (3). During this month a spell of the longest blizzard of 13 days duration at a stretch was recorded.

Air temperature

Antarctica is most feared for its appalling cold and extremely low temperature. Therefore, the study of the air temperature in Antarctica is very important not only from the point of view of human comfort but also for the behaviour of different materials, instruments, machines and in particular the different types of vehicles and the lubricants used for them in the continent.

Extreme Values of minimum air temperature

Only a few of the stations near the sea level north of 70°S have observed absolute minimum below-40°C but on the ice shelves the limit is close to -60°C. In the interior of the continent a temperature minimum as low as -80°C is witnessed once in 10 years. At the higher elevation of the central plateau the ever observed absolute minimum stands at —88.3°C which was recorded at Vostok in August, 1960. The absolute range amounts to—45° to—55°C for the coastal stations. The absolute minimum temperature -52°C was recorded on 16th August 1985 at 1630 GMT, which in 1984 it was -50.5°C on 3rd August (Rizvi, 1986).

Frequency distribution - minimum temperature

Fig. 1 shows the frequency distribution of minimum air temperature. For the sake of comparative study, the data of 1984 and 1985 have been plotted on the same diagram.

In the beginning of summer, i.e., in the December, the frequency of occurrence of minimum temperatures between 0°C and -5°C is low. As the summer advances, it increases and becomes maximum in January-the peak summer month. With the further advance of the season it starts decreasing and becomes less and less by the end of February. As the year advances the range of minimum temperature increases towards lower temperatures and by August, the frequency of minimum temperature lies between—35°C and -45°C. After August this trend reverses. August is recorded as the coldest month wherein minimum temperature fluctuates on quite a few occasions from -50°C to —55°C. Another interesting feature which can be noticed from the figure is that the minimum temperature in the months of August, May and September never fell below — 15°C. Comparative study of 1984 and 1985 reveals on an average that May and September in 1985 were colder than that of the corresponding period of 1984. This is because, in 1985 there were less number of blizzards and more clear days than in 1984 during these months.

Frequency distribution — maximum temperature

Frequency distribution of maximum temperature is given in Fig. 2. It can be seen from the diagram that January is the warmest month where in 50% cases maximum temperature fluctuates between +5°C and -5°C. The highest temperature of 6.0°C has been recorded on 21st December, 1985 at 1600 GMT. Comparative study for May and September, for the years 1984 and 1985 shows that these months were warmer in 1984 than in 1985.

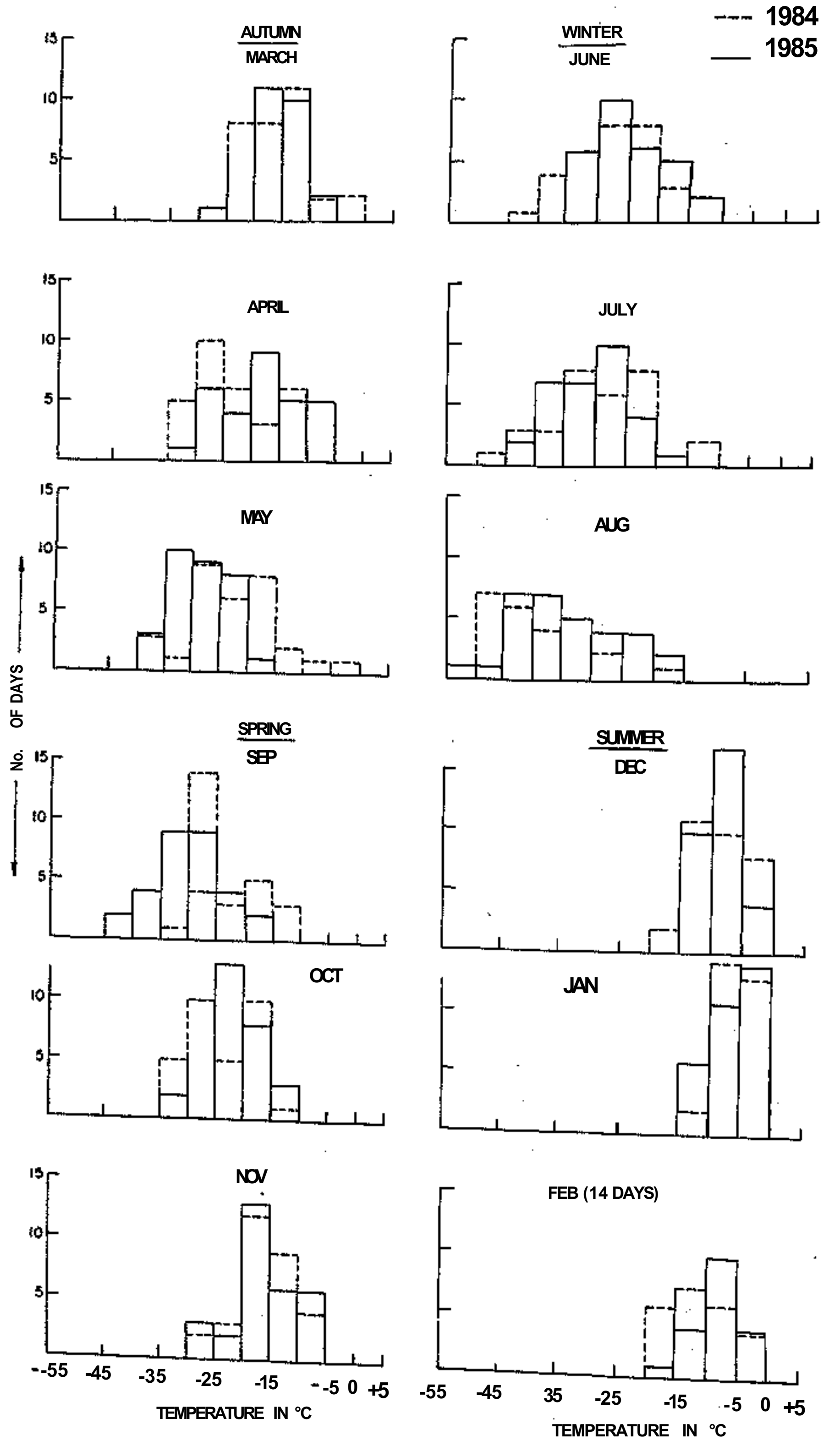

Fig.1. **Frequency distribution of daily minimum air temperature.**

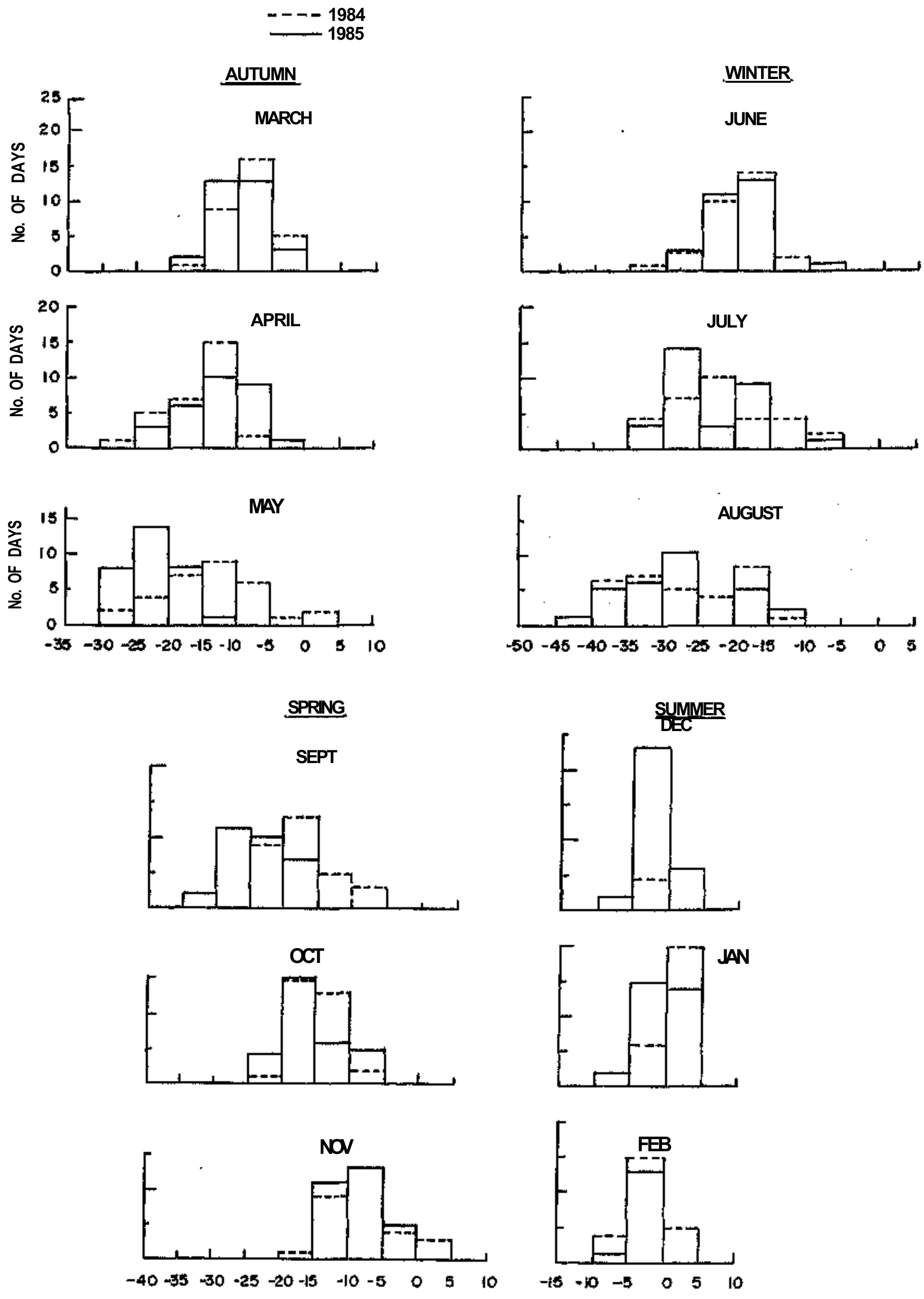

Fig. 2. **Frequency distribution of maximum air temperature.**

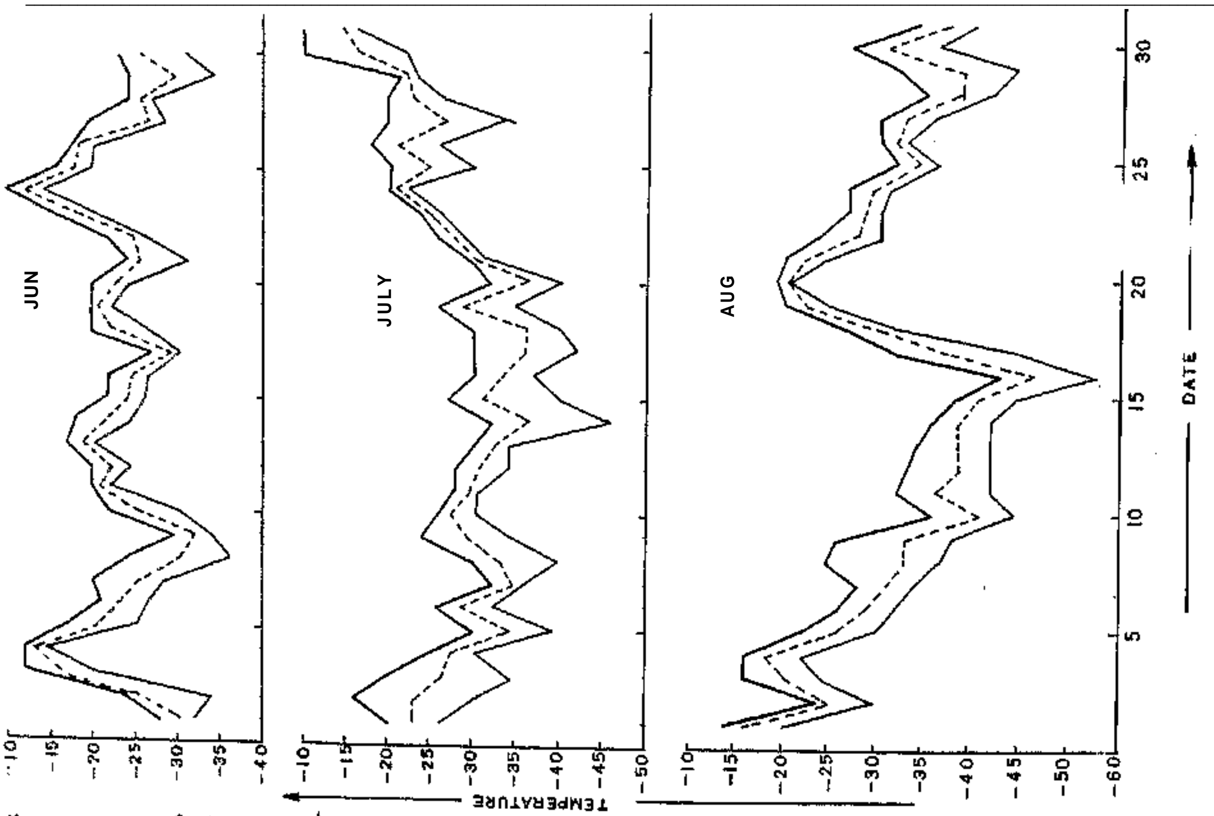

Fig 3(b). **Daily temperature variation (Winter, 1985).**

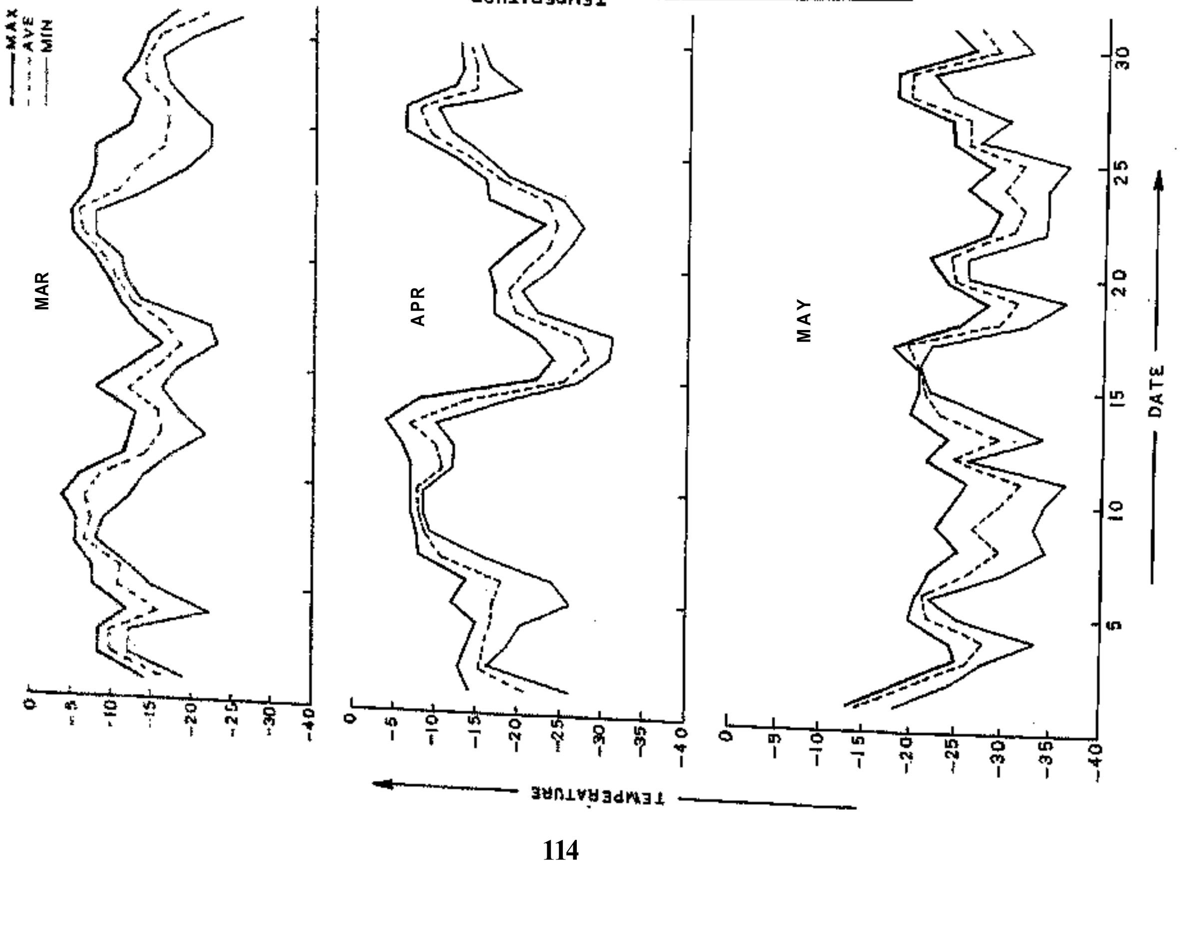

Fig. 3(a). **Daily temperature variation (Autumn, 1985).**

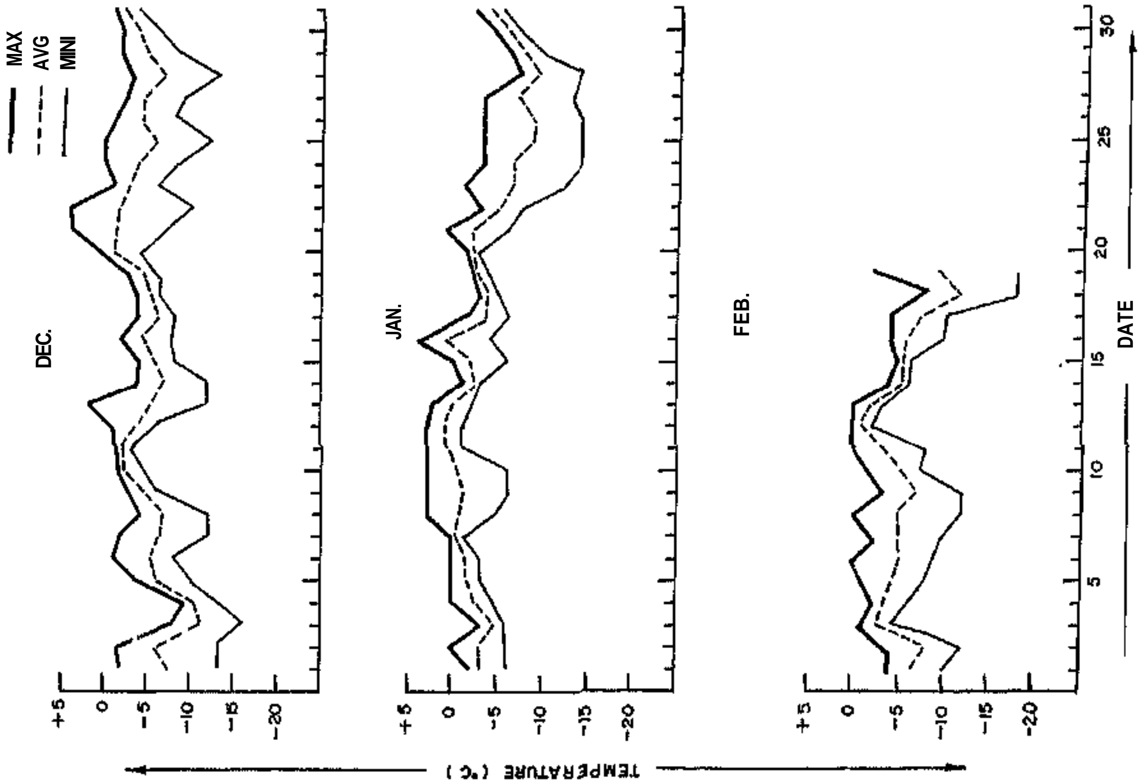

***Fig 3(d).* Daily temperature variation (Summer, 1986).**

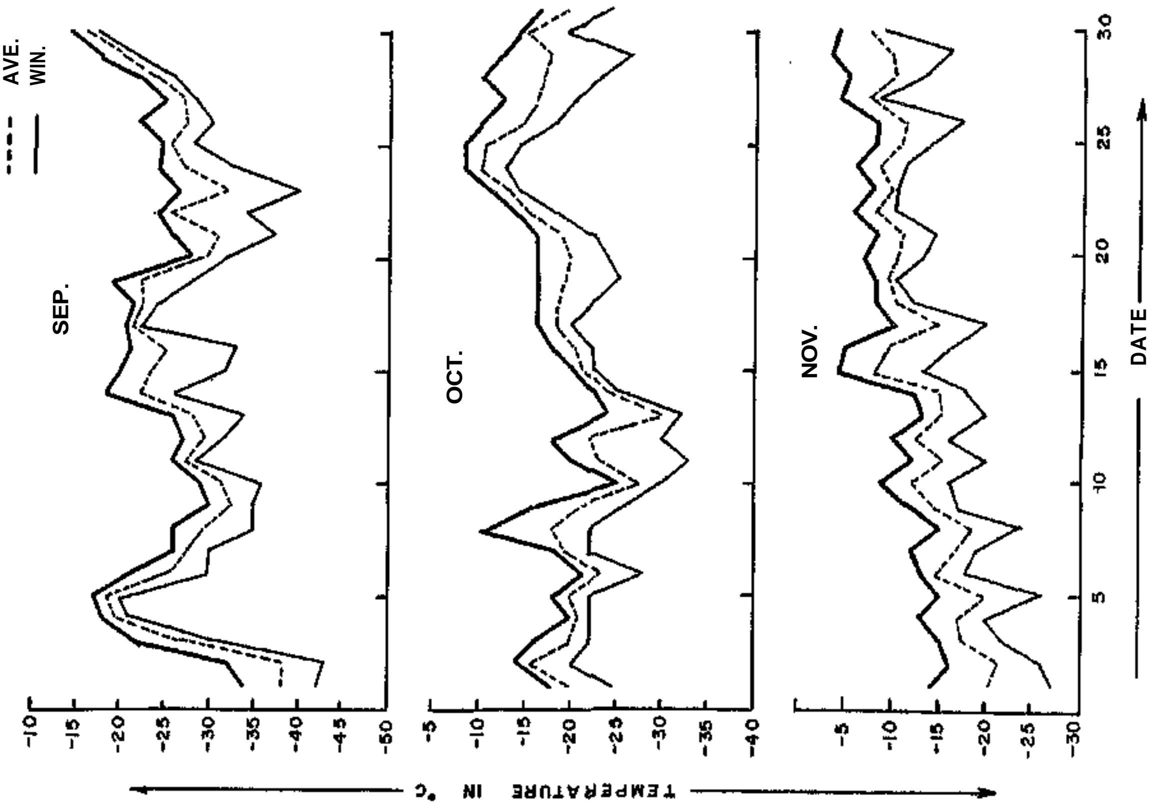

***Fig.3(c).* Daily temperature variation (Spring, 1985).**

Daily variation of temperature

In order to get an insight into the deviation of daily maximum and minimum temperatures with respect to daily average temperature, all the three temperatures are plotted on the same diagram for each month and the months are grouped together to represent for seasons. Figs.3a-3d give the diurnal variations of maximum, minimum and average temperatures for Autumn, Winter, Spring and Summer seasons respectively. During the summer season the maximum temperature fluctuates between +5°C and - 10°C and minimum between -3°C and -18°C while in winter the maximum temperature ranges between -12°C and -43°C/-44°C and the minimum temperature -15°C to -52°C. The deviation of daily maximum/minimum with respect to average temperature is less in case of prolonged cloudiness or blizzard activity while it is larger during the fair weather period.

Mean monthly variation of temperature

Mean monthly variation of temperature is shown in Fig. 4. It is seen that August is the coldest and January is the warmest month. In January the mean temperature is found to be of the order of-3°C while in August it is estimated as-31°C.

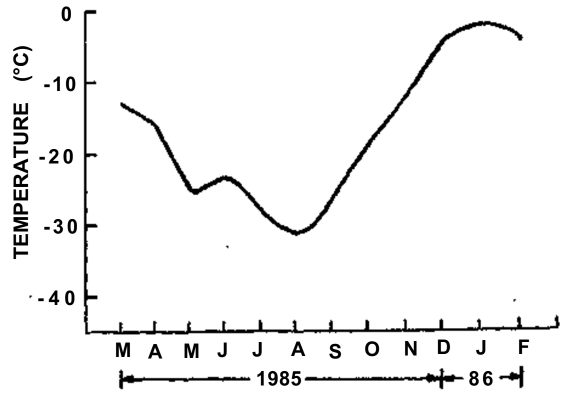

Fig. 4. **Mean monthly variation of temperature.**

Surface wind

Knowledge of winds is essential because the entire planning and success of the Antarctic field programme depends upon the prevailing surface wind direction and its strength. It affects the day to day activities at Antarctica in many ways. Transportation either by vehicles or by helicopters is affected by winds. Strong wind and its gustiness may damage different types of aerials used for communication/meteorological purposes. Strong wind causes snow particles to fly with the wind upto great heights. As a result visibility reduces to almost zero. There is a potential risk to ones life if one dares to go out in such situations. Wind data are also required to estimate the Wind Chill factor a very important factor to decide the human comfort level in Antarctica. To set the orientation of runway of an air strip or any permanent structure, the wind direction speed has to be taken into consideration. Therefore, the study of seasonal variation of wind direction speed is of vital importance.

Frequency distribution of maximum wind

Fig. 5 gives the details of frequency distribution of daily maximum wind speed. March, May and July are the three months in which the range of maximum wind touches 100-110 kts. But the frequency of their occurence is rather limited. August is the calmest month when on an average the wind speed largely fluctuates between zero and 10 kts.

Daily variation of wind

Variation of daily average and maximum wind is given in figs. 6a-6d for Autumn, Winter, Spring 1985 and Summer 1986 respectively. Season-wise no clear cut picture emerges. However, it is

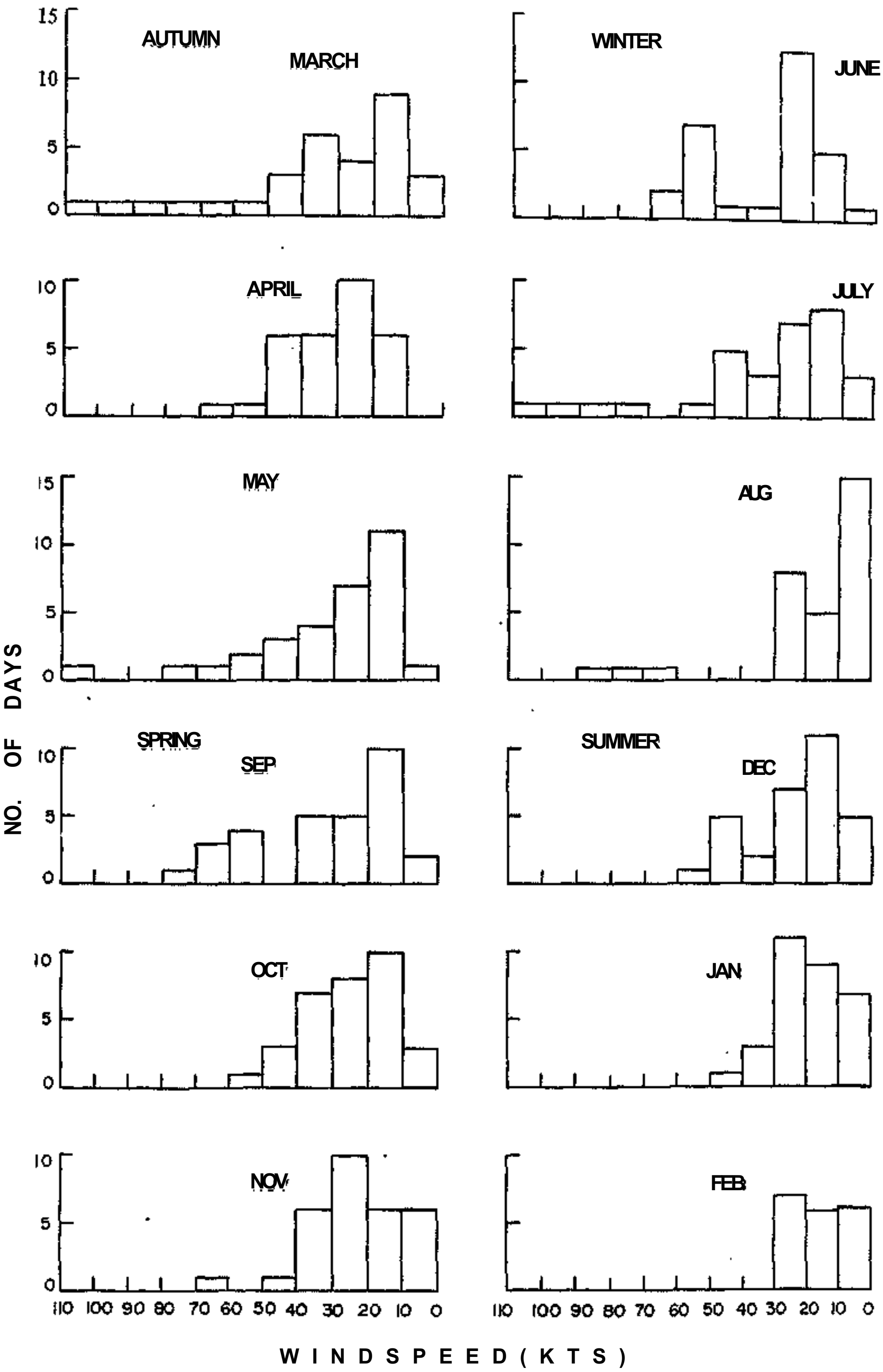

Fig. 5. **Frequency distribution of daily maximum wind speed.**

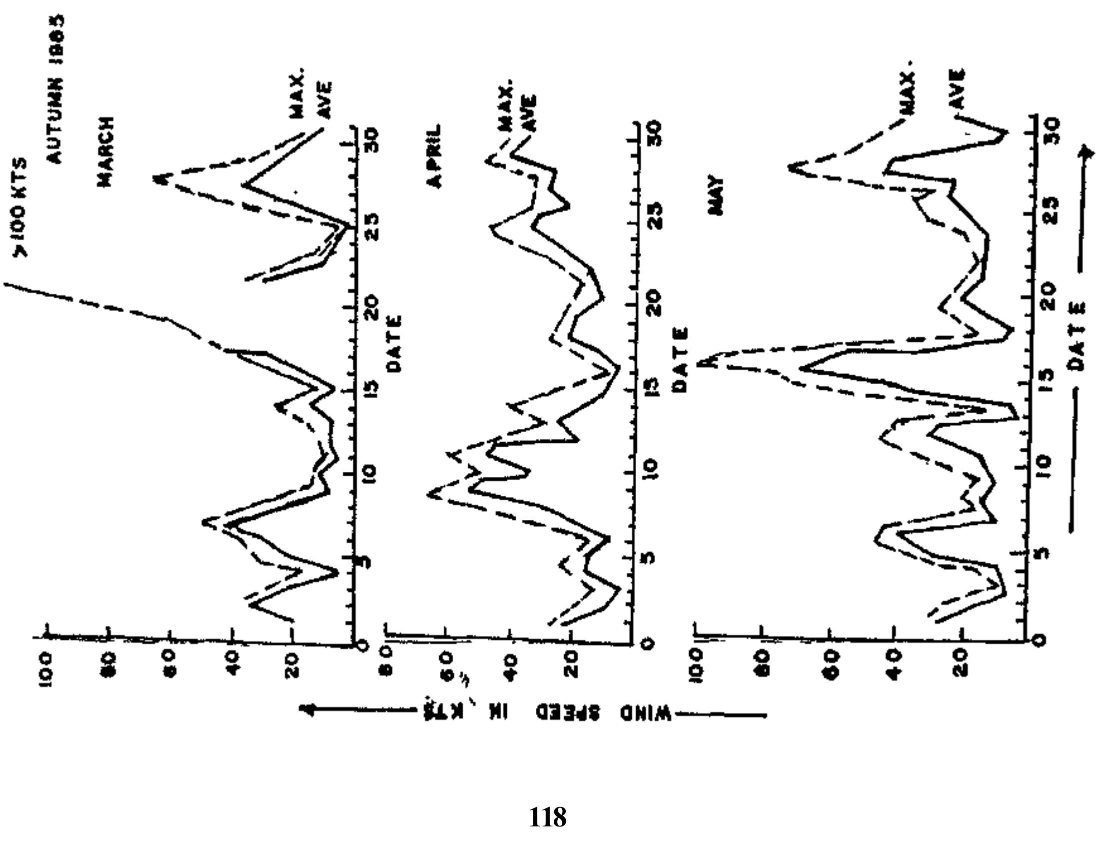

Fig. 6(a). Daily variation of wind speed (Autumn, 1985).

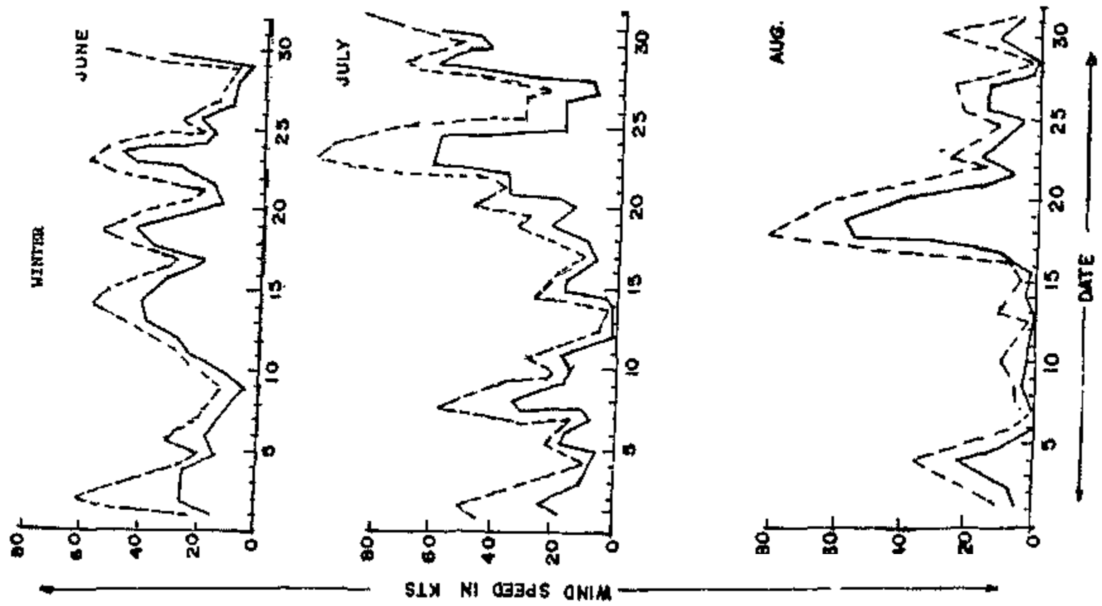

Fig. 6(b). Daily variation of wind speed (Winter, 1985).

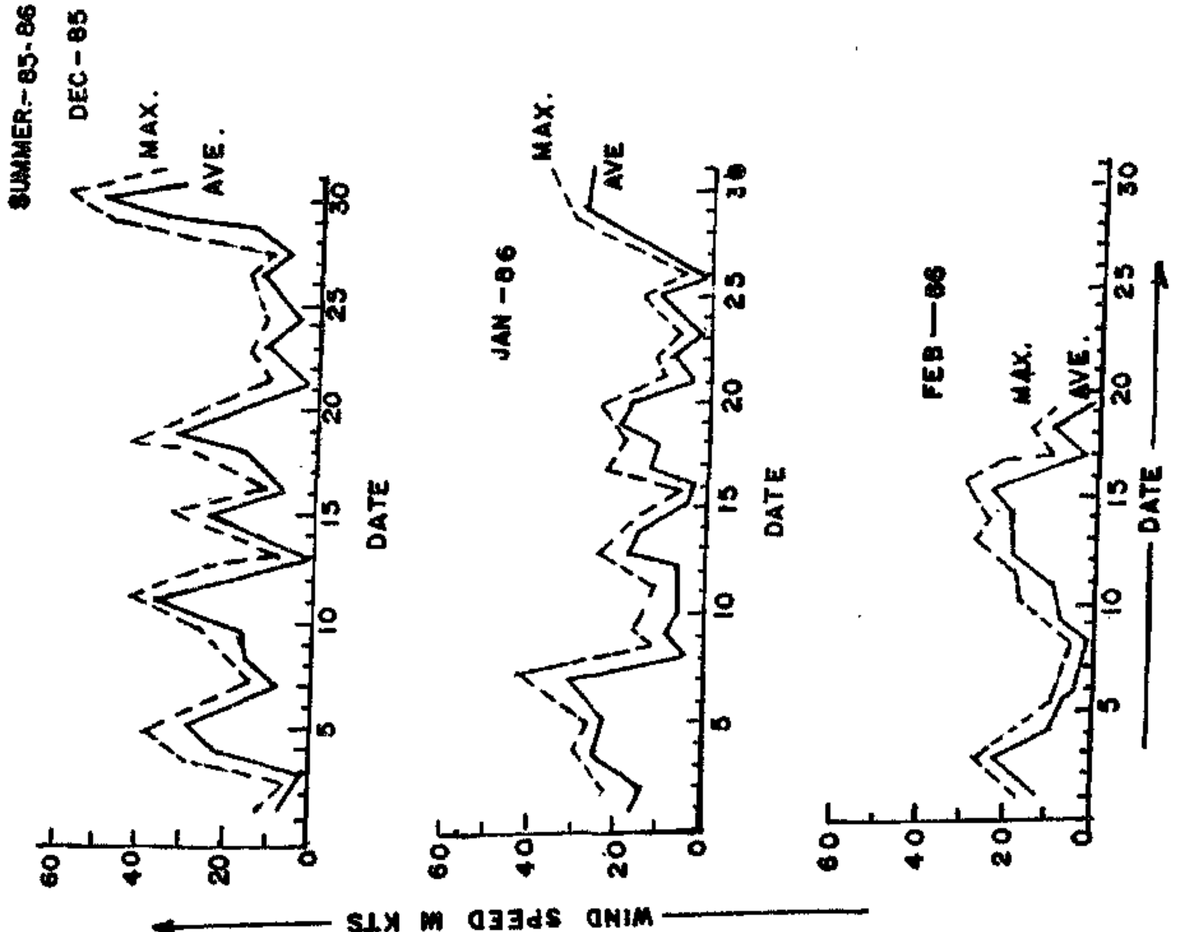

Fig. 6(d). **Daily variation of wind speed (Summer, 1985-86).**

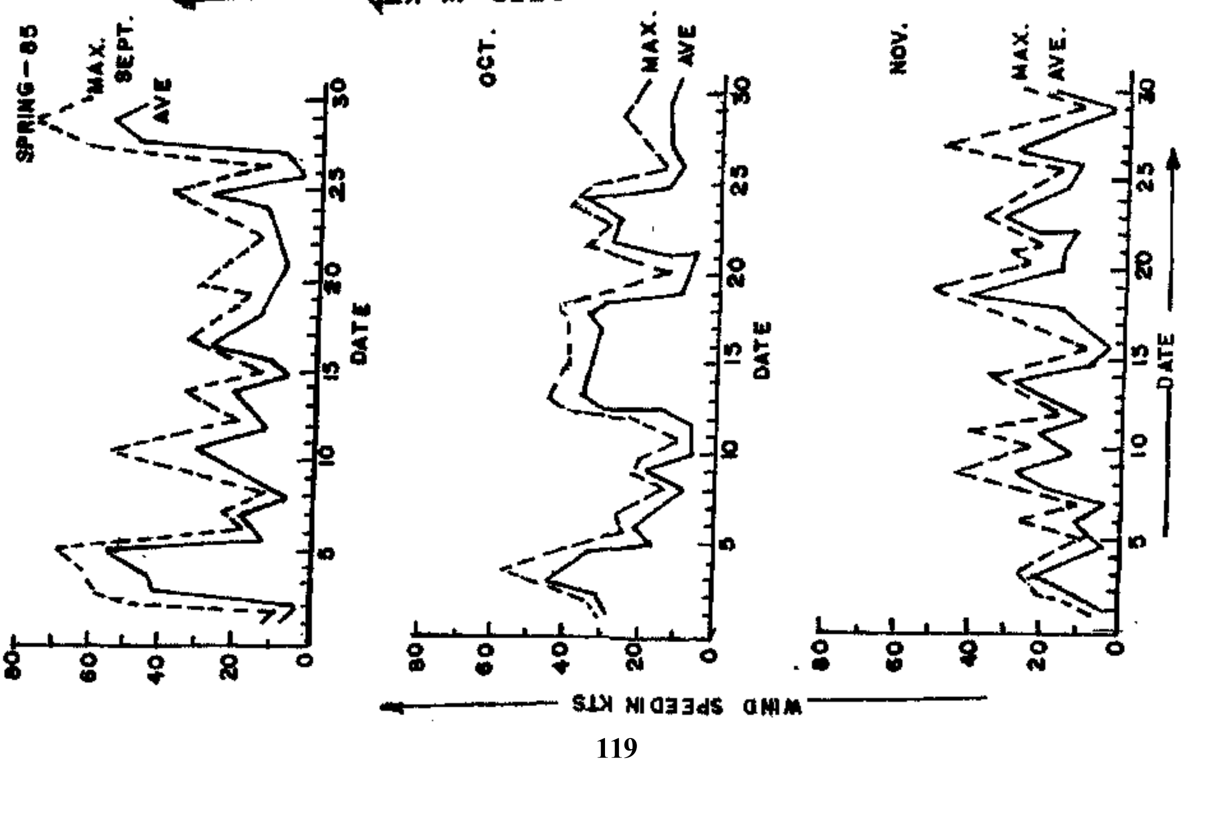

Fig. 6(c). **Daily variation of wind speed (Spring, 1985).**

noticed that the windiest and the calmest months are June and August respectively. On the three occasions, maximum wind speed crossed 100kts, once each in July, May and March. Of these the last one is worth metioning. From 17th March to 21st March Dakshin Gangotri station was affected by very intense blizzard when wind speed crossed 100 kts on 18th March. Wind mast was teard off by stormy winds and fell down. Anemometer, windwane, temperature and humidity sensors were damaged considerably. The entire building wad trembling in roaring blizzard. Perhaps the wind speed might have crossed 150 kts. Unfortunately there were no means to measure it.

Mean monthly variation of wind

Mean monthly variation of wind is shown in Fig. 7. There are two peaks of mean wind, one in June when the mean wind is of the order of 25 kts and another in September/October when it is 22 kts. Calmest month is August.

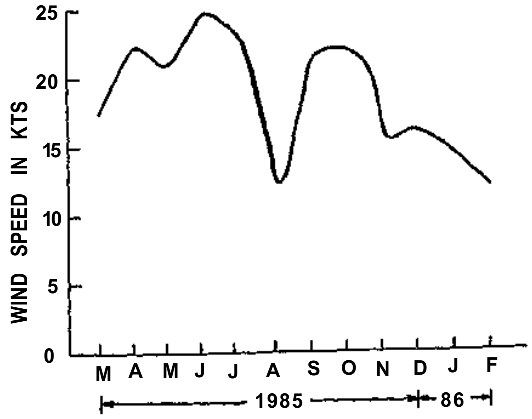

Fig. 7. Mean monthly variation of wind speed.

Atmospheric pressure

It is the most important parameter to know the behaviour and intensity of the approaching meteorological disturbance. Though at Antarctica it is a very deceptive parameter. Normally significant fall of pressure in a short period of time is an indication of bad weather, but there were many occasions when even 39 mb pressure drop in 36 hours did not cause any bad weather, not even a single speck of cloud. Such an example of rapid pressure fall occurred from 28th to 31st August, 1985 (see Fig. 10). There were days when a little drop in pressure brought about very severe blizzards. In view of this, the forecasters in Antarctica are advised to use this parameter as a forecasting tool with extreme caution.

Daily variation of pressure

Figs. 8a-8b give the daily variation of maximum and minimum station level atmospheric pressure for Autumn. Winter, Spring and Summer. Lowest value of 940 mb pressure was recorded on 2.7.1985 and the highest 1005.5 mb on 18.4.1985.

Mean monthly variation of pressure

Fig. 9 Shows the mean monthly variation of atmospheric pressure reduced to mean sea level. Lowest pressure reaches in July while the highest exhibits two peaks of almost equal magnitudes, one in May and another in January.

Temperature inversion

The most conspicuous characteristic of the Antarctic temperature regime, besides the low temperatures of the interior, is the surface temperature inversion. Excepting the two summer months December, January, it is an almost ever-present feature over the high plateau and a frequent one

over the rest of the continent. Surface temperature inversion occurs between 100 m to 1000 m. It appears, however, that there is a real annual variation in height above the ground of the average tropospheric temperature maximum, with the lowest values (<300 m) in Summer and the highest (>500 m) in winter (Phillpot and Zillman, 1969).

Inversion and surface temperature

Strong surface inversion is brought about as a result of intense radiation heat loss from the surface under the geographical and atmospheric conditions prevailing in Antarctica. At 70°S latitude the sun remains above the horizon from 19 November to 26 January and below the horizon from 23 May to 19 July. Therefore, at Dakshin Gangotri (70°S, 12°E) the durations of day and night are approximately of two months. It is interesting to note that the maximum temperature is achieved during December/January when the sun is above the horizon whereas as expected the minimum is not achieved in June/July when the sun is below horizon. It is achieved during the second or third week of August when the sun remains above the horizon for a long period of time. This contradiction

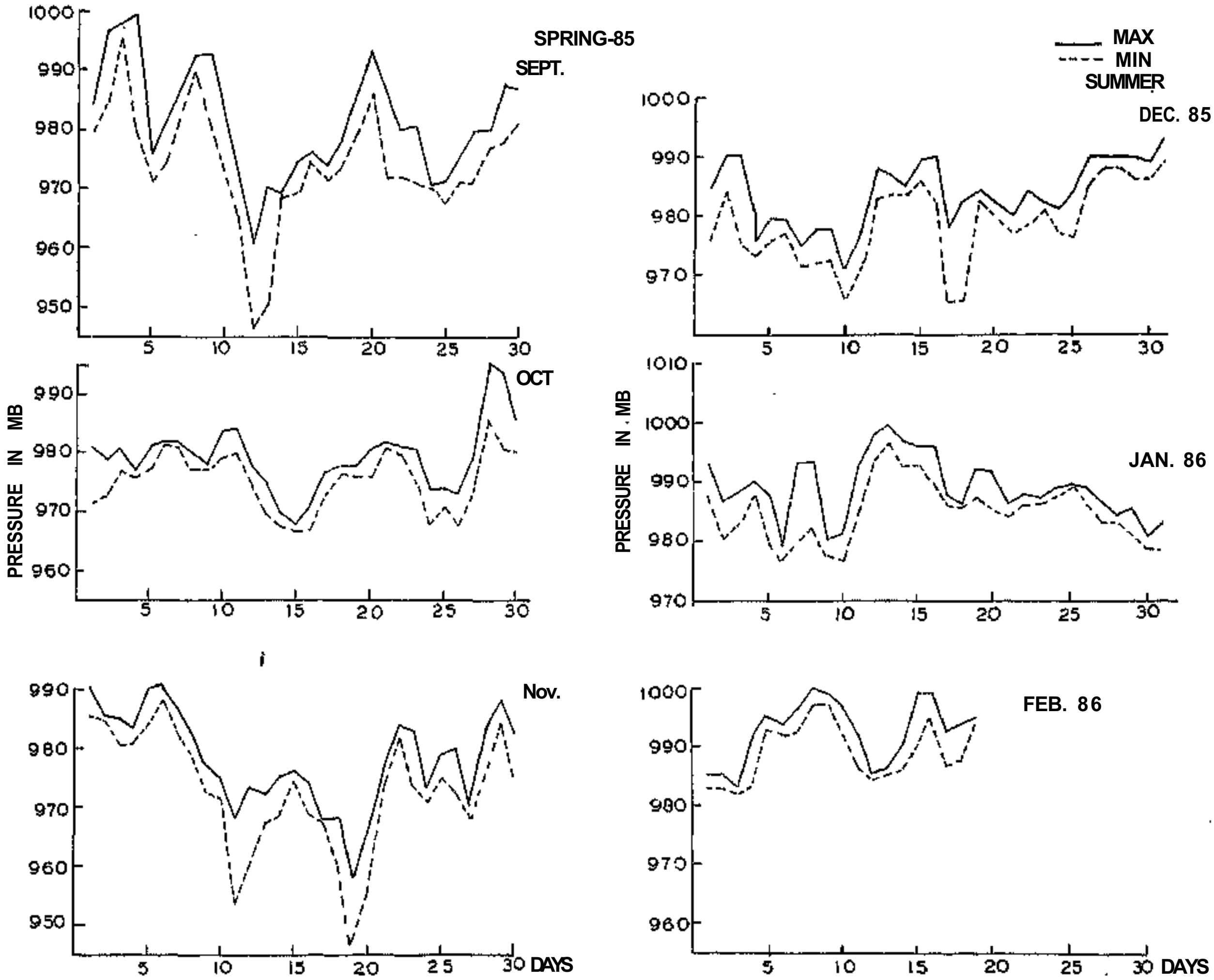

Fig. 8(a) Daily variation of pressure.

deserves some comments. When the sun goes below the horizon, the surface loses heat rapidly in the form of long wave radiation greater than the atmospheric radiation (back radiation). This process is enhanced further when the sky becomes clear after a period of cloudy weather. The surface temperature goes on falling. But how long and how far this can happen (?) there is always a limit and this limit is brought about mainly by inversion. With the decrease in the surface temperature the outgoing heat flux diminishes and the back radiation form the atmosphere particularly from the inversion layer goes on retentivity to hold the moisture. As such, it can absorb more outgoing long wave radiation and will return a greater amount of radiation. Consequently, an equilibrium state is established between outgoing and returning radiation. This state reaches some time in August when inversion reaches its maximum strength.

Inversion and katabatic winds

Katabatic winds are a characteristic feature of the climate of coastal Antarctic regions. The origin of these winds is connected with the cooling of the air due to radiation along the slope of the ice plateau and its movement, under the force of gravity, down the slope. Local orography and particu-

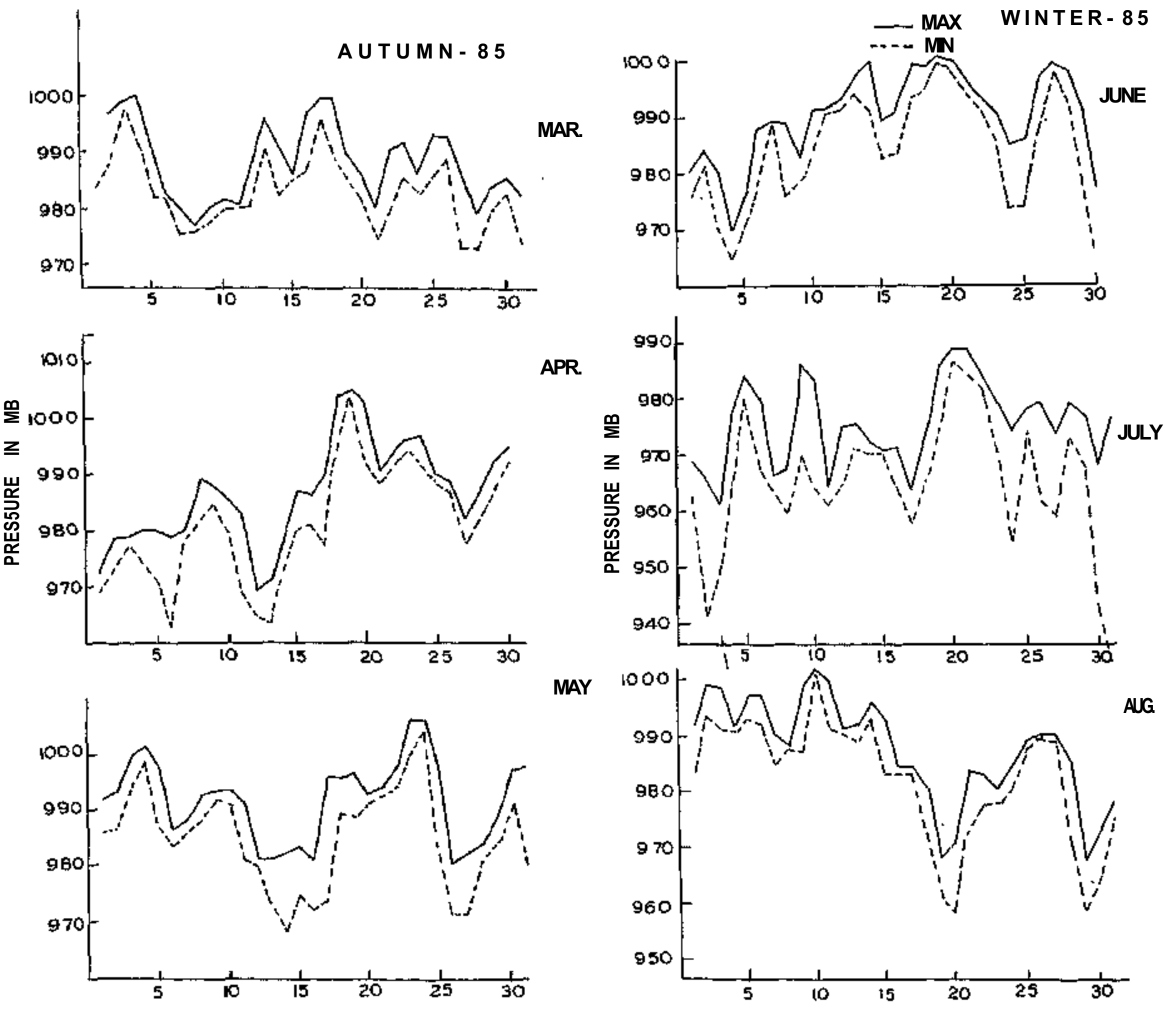

Fig.8(b). Daily variation of pressure.

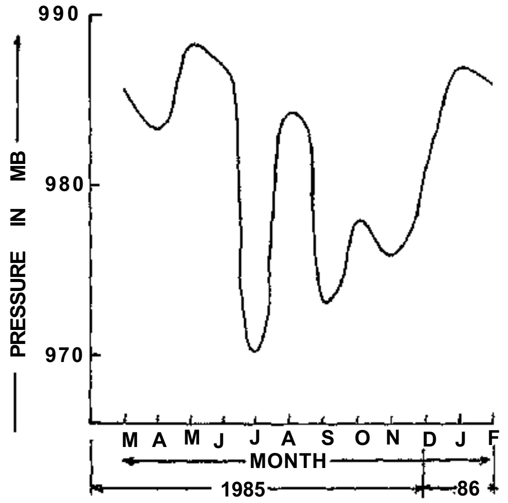

Fig. 9. Mean monthly variation of mean sea level pressure.

larly the shape of the surface of the slope have a considerable influence on the strength of katabatic winds and determine their direction.

The vertical extent of katabatic winds is determined by the thickness of the layer in which air is cooled due to radiation. Therefore, katabatic winds are always accompanied by an inversion over the ice surface.

An analysis of the data from the Antarctic Stations shows that in comparison to the normal winds (that is, not distorted by orographic influence), the wind speed is twice as great in the areas because of the katabatic air movement. It is two and a half times as great in areas where katabatic air movement is very pronounced. Normal wind speed has been calculated from a large number of observations and was found to be 5.5 m/sec (Tauber, 1960; Hydro Meteorological Services of the USSR). The onset of the katabatic winds is accompanied with characteristic suddenness, i.e., in the wind speed often jumps instantaneously from calm to 30-40 kts and equally sudden cessations (lulls) appear. With the onset of katabatic flow, the humidity and cloudiness decrease and the weather becomes clear along the coast.

The intensity of the katabatic air movement depends upon the cyclonic activity over the ocean and near the coast. The increase in the meridional exchange during the development of cyclonic activity leads to an increase in the katabatic movement of cold air from the interior of the continent. Therefore, the highest intensity of katabatic wind is observed at the rear end of the cyclones moving along the coast. During the years 1984 and 1985, observations indicate that katabatic winds pure in nature at Dakshin Gangotri do occur (Rizvi, 1986). One such an example is shown in Fig. 10. The frequency of its occurrence is, however, quite low. There were 2-3 instances in August/September and 5-6 in October/November when it was recorded. In other months it was not observed.

In most of the cases, not much of gustiness was observed at the initial or final stages of the blizzard and there was a steady increase of wind speed. Gustiness was observed during its peak period. Steady increase of wind along with an increase of cloudiness, rise in temperature, fall in pressure, turning of the wind from south easterly to easterly give evidence or the influence of approaching meteorological disturbance.

It appears that strong winds observed at Dakshin Gangotri are a mixture of katabatic and gradient winds. To know the contribution of katabatic flow in causing blizzard, a study of the surface inversion becomes essential.

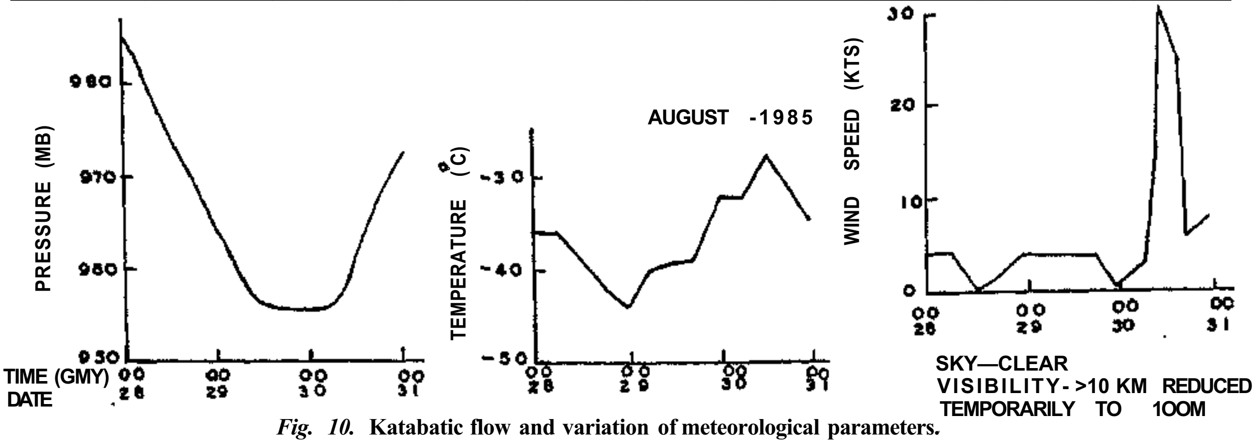

Fig. 10. Katabatic flow and variation of meteorological parameters.

Blizzards

Antarctica also known as the 'Home of blizzards' and the windiest of all the continent. The word 'Blizzard' however, is used quite loosely in the Antarctic literature to mean any thing from light drifting snow with clear skies to a snow storm with accompanying high winds. Under favourable conditions when the surface wind reaches a hurricane intensity, falling snow or disengaged ice from the surface is ground into the fine snow dust and blown to several hundred metres. Visibility in such situations is reduced to almost zero. Snow particles flying with tremendous speed penetrate through clothes, tents, building, etc. Such blinding snow storms lasting for more than 12 hrs have been considered as blizzards in this study.

Blizzards in Antarctica cause serious problems not only to the buildings and other types of constructions but also to surface travel and landing aircrafts. Once the wind speed crosses 70 kts it is not at all safe to go out into the blizzard. The blizzard can last as long as a week or even more; the longest blizzard observed during June, 1985 lasted for 13 days. Blizzard lasting for 3 to 4 days are very common, Table I gives the account of all the blizzards observed during the period.

Case study of a blizzard

Detailed study of the different meteorological parameters and synoptic situations has been carried out for the blizzard observed between 2nd to 6th September, 1985. Fig. 11 gives graphical representation of the behaviour of different meteorological parameters during the period.

On 2nd September (00 GMT) wind was light and the sky was clear as a result of which the surface was losing a lot of heat due to untrapped outgoing radiation and the surface temperature fell steadily by almost 7°C and reached -43°C by 0600 GMT. Shortly, after 0800 GMT, cirrus clouds appeared. These were followed by AC, AS, SC and by 18 GMT the sky became overcast. Wind was still light (4 to 6 kts) and it was blowing from SE. The appearance of clouds abruptly reversed the radiative loss and the surface temperature began to rise and increased by 5°C in less than 12 hours. From 00 GMT (3rd Sept) pressure fell by 5 mb and the wind turned from SEly to ESEly and finally, when its speed increased abruptly and reached 62 kts. the temperature dropped to—28°C. Visibility reduced to almost zero due to blowing snow. Then lull followed and during this period wind speed dropped from 62 kts to 30 kts. By 03 GMT of 4th September, the pressure rose by 8 mb in less then 12 hours while the temperature was still showing an increasing trend. From 00 GMT of 4th till 12 GMT of 5th, there was a rapid fall of pressure associated with an increase in both wind speed and temperature. The temperature rose up to-17°C and wind 70 kts at 09 GMT of 5th. Thereafter, there was a,

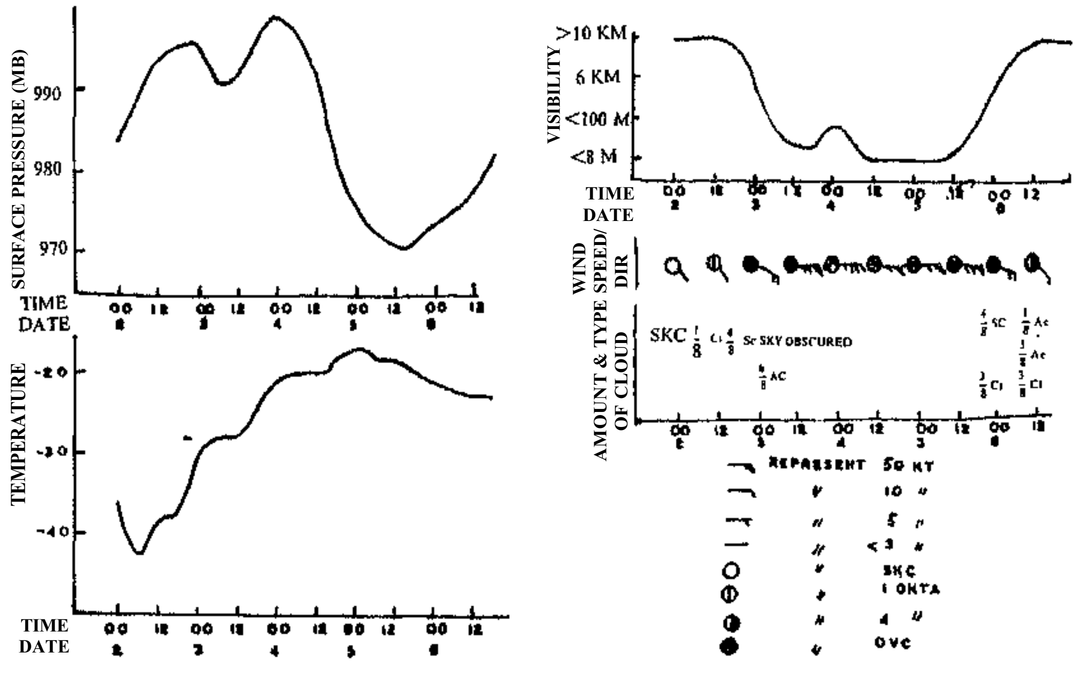

Fig. 11. Variation of different meteorological parameters during blizzard (September, 1985).

dramatic change in weather. Temperature and wind started decreasing and pressure increasing and clouds started dissipating. Finally by 06 GMT of 6th September weather became fine with excellent visibility, light SEly wind and almost clear skies.

Synoptic situation during the period

It is a well known that a series of low pressure move from west to east round the Antarctic coast along the sub-polar through which fluctuates both towards north and south, day to day as well as on the seasonal basis. These systems advect warm and moist air towards the south. As a result, a continuous rise in the temperature, an increase in cloudiness and fall in pressure are observed. These observations have already been discussed earlier. Normally these systems around Antarctica move with a speed of 10-12 longitude per day. It is interesting to note that the system which is discussed below moved very slowly but dissipated very fast.

1st September (Fig. 12a)

Sub-polar Antarctic trough marked by dotted line in Fig. 12a encircling Antarctica lies on an average between 65 to 67°S. There are many weak and strong systems embeded in it. Low pressure area 'A' as marked in Fig. 12a which caused blizzard at Dakshin Gangotri is of our interest.

3rd September (Fig. 12b)

By 00 GMT of 3rd September low 'A' (as in Fig. 12b), merging with the nearby lows intensified into a deep system. Low pressure 'B' (as in Fig. 12b) which was located at 57°S and 35°W on 00 GMT of 1st September moved to 52° S/12° Wpushing the anticyclone 'H' from 48°S/18°W to 52°S/20E (Fig. 12b). Anticyclone 'H' and its associated ridge ahead of 'A' blocked its movement further to the east.

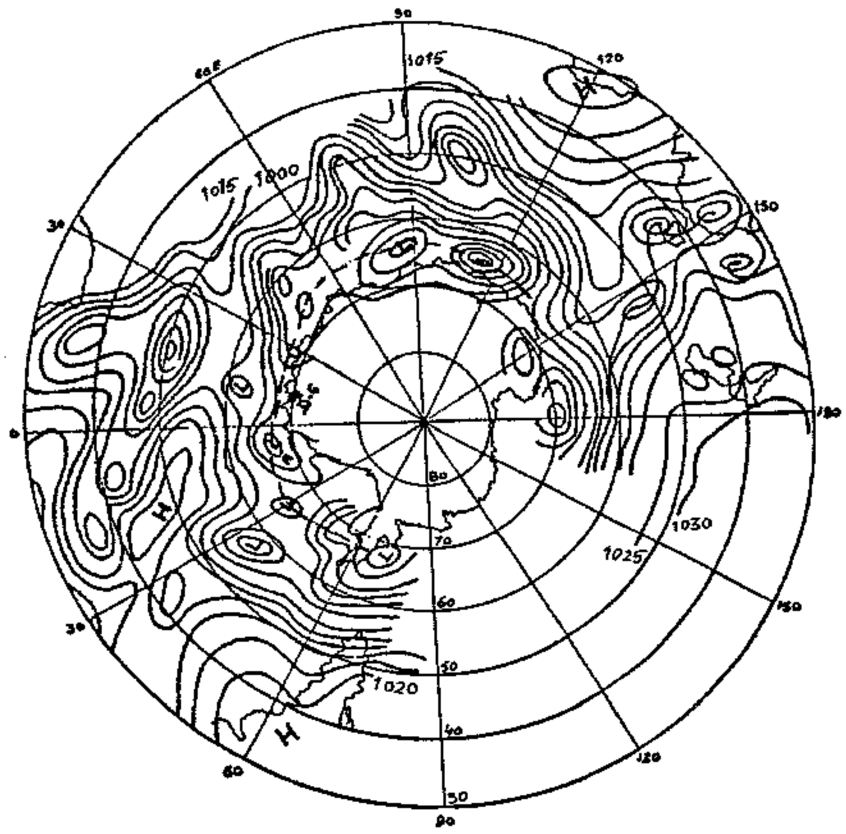

Fig. 12(a). AMC Molodyozhnaya surface analysis (1.9.85, 0000 GMT).

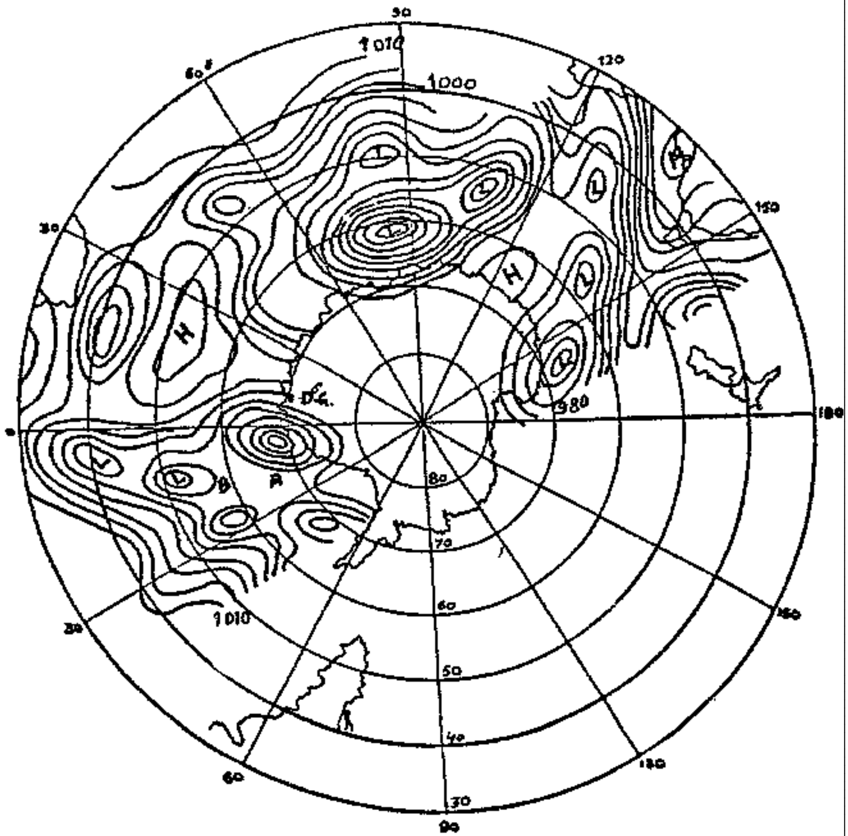

Fig. 12(b). AMC Molodyozhnaya surface analysis (3.9.85, 0000 GMT).

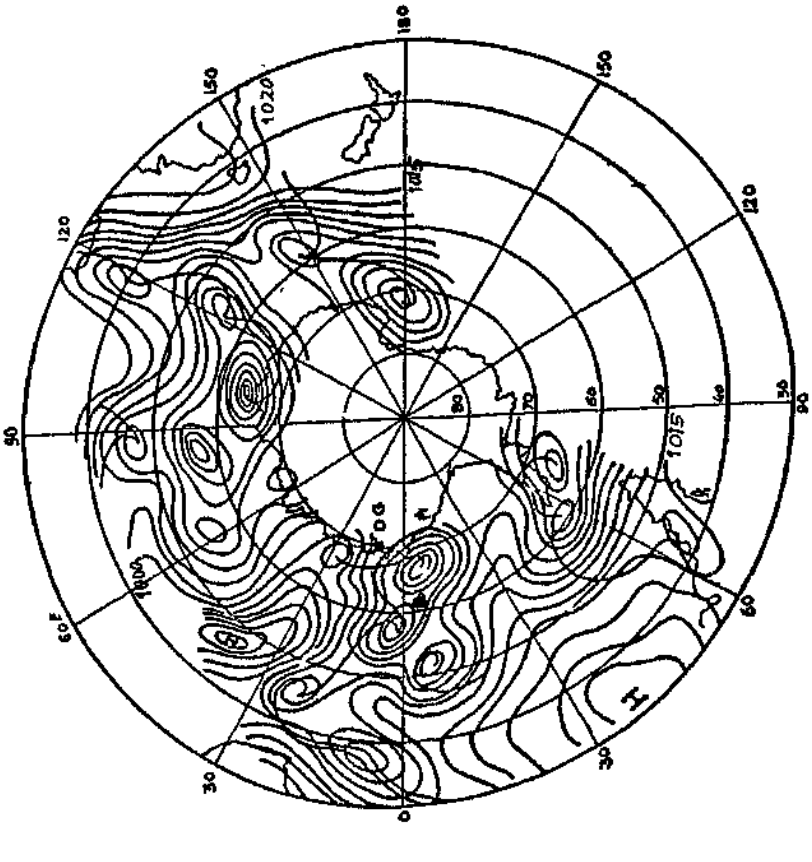

Fig. 12(c). **AMC Molodyozhnaya surface analysis (4.9.85, 0000 GMT).**

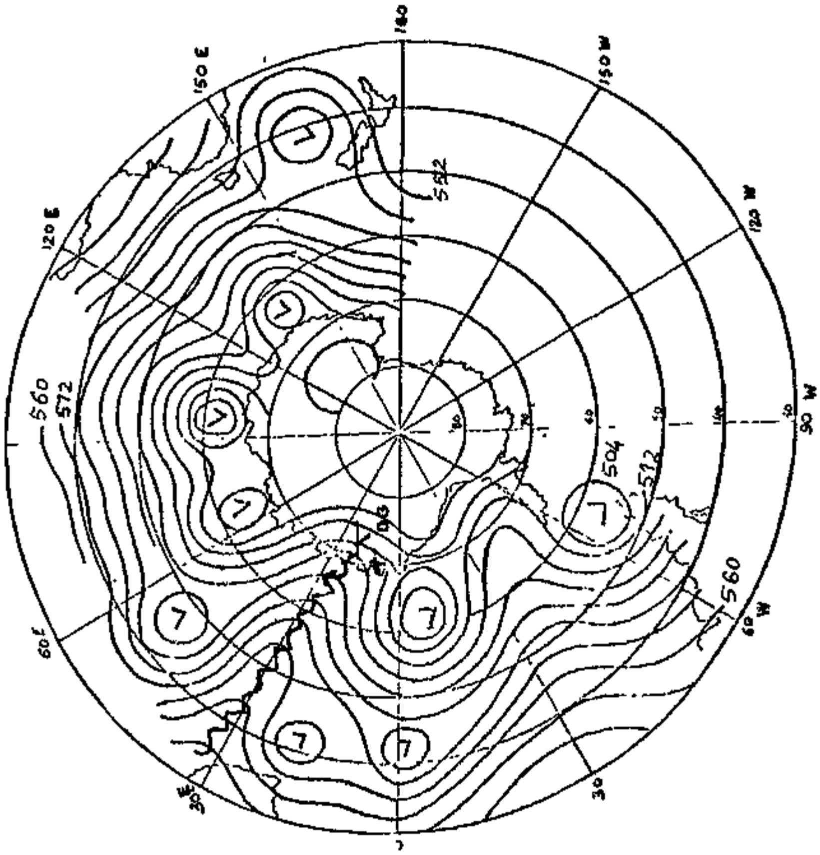

Fig. 12(d). **AMC Molodyozhnaya 500 MB analysis (4.9.85, 0000 GMT).**

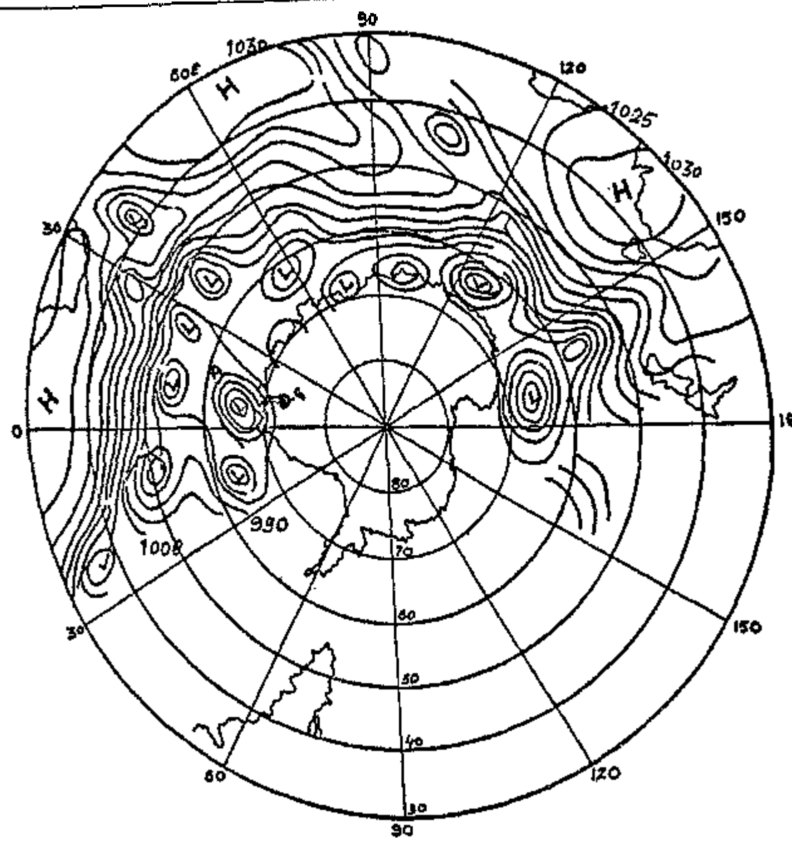

Fig. 12(e). AMC Molodyozhnaya surface analysis (6.9.85, 0000 GMT).

4th September (Fig. 12c)

Position 'B' as marked in Fig. 12c moved further ESE ward or rather SE ward and was located at 58°S/02°E while 'A' remained almost stationary. 'A' and 'B' merged together at 500 mb level (Fig. 12d) and were seen as a well marked system with two closed isobars. NE/SW oriented ridge ahead of it was also well marked. By 06 GMT'B' moved very fast to the east (about 10° in less than 6 hrs) pushing the anticyclone 'H' towards the east, while 'A' remained practically stationary and continued to intensify.

6th September (Fig.12e)

From 12 GMT of 5th 'A' (as in Fig. 12e) showed a sign of its movement towards NE, and by 00 GMT of 6th, it was located at 66°S/80°E. Dakshin Gangotri was affected by its periphery only. Afterwards, the system moved towards NE and became insignificant.

Satellite imageries

In the summer of 1985, the meteorological observatory atDakshin Gangotri (DG) got equipped with an Automatic Picture Transmission (APT) Unit. With the help of this unit cloud imageries were received on a routine basis from NOAA weather satellites. These cloud imageries helped a lot in studying the cloud and ice covers and in monitoring the different weather systems moving in and around Antarctica and affecting the weather at D.G. These cloud imageries served an important tool for the study of weather and to give a correct and timely forecast and for maintaining of weather safety

and success in various operations of the expedition in general and during the communication failure when no other meteorological information could be received from anywhere. As an example, two such instances are worth mentioning. Figs. 13 and 14 show the cloud imageries taken in the visible and infrared regions on 1.2.1986 (1600 GMT) and 28.5.1986 (1545 GMT) respectively.

In Fig. 13 the extratropical cyclone (ETC) is located at 63°S and 28°E. DG appeared to be out of the grip of this system on 1.2.86 but prior to this, i.e., on 31.1.86 under the influence of this D.G. experienced hazardous weather a brief account of which is given in Table II. The wind speed was touching 40 kts and the visibility was reduced to 100 m in blowing snow. During this period, except the cloud imageries no other meteorological information was available due to communication failure.

The ETC on 28.5.85 was centred at 66°S and 10°E at 1545 GMT. It was very well organised which is clear from the cloud imagery (Fig. 14). DG was badly affected by the intense blizzard associated with ETC for at least two days, which is obvious from the recorded synoptic observations shown in Table III. Wind at D.G. exceeded 65 kts on many occasions and the visibility reduced to 5 m. Though the communication was totally disrupted during the period yet the timely warning could be given to the expedition members based on these imageries which were received uninterrupted during the communication failure period.

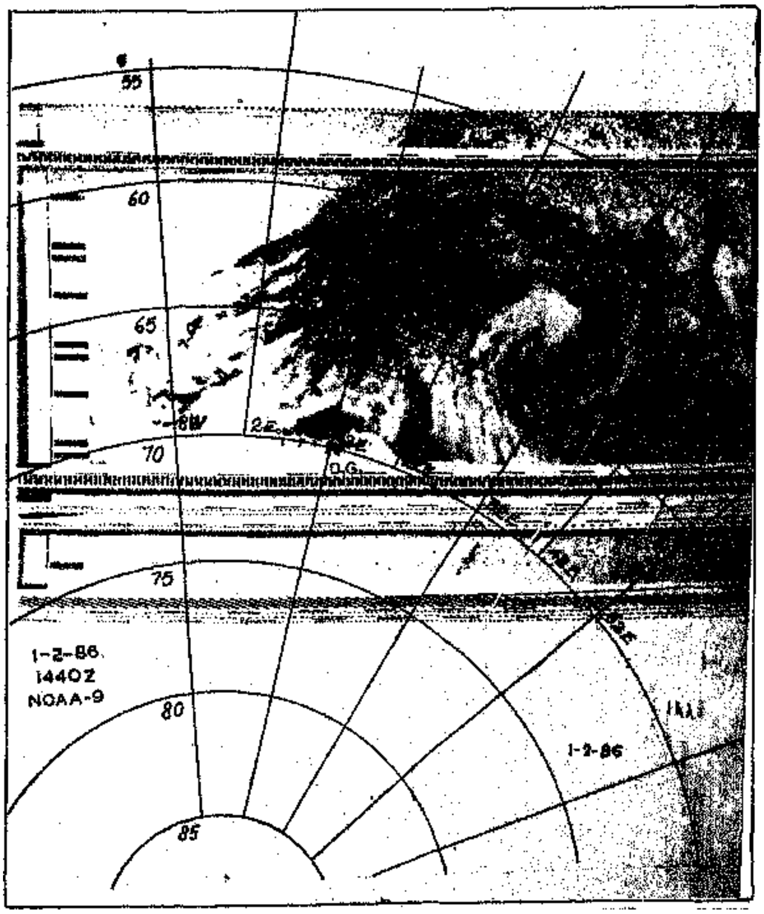

Fig. 13. **Satellite cloud imagery (visible) received as on 1.2,86 from NOAA-9.**

Atmospheric electricity

In the summer period of the fourth expedition a potential gradient equipment was installed at Dakshin Gangotri to keep a continuous record of the atmospheric surface potential gradient. The development of clouds, thunder-storms and other meteorological phenomena such as blizzards in Antarctica produce significant changes in the magnitude of the atmospheric electric field which in turn changes the surface potential gradient.

TABLE II

Synoptic observations.

31.1.86	Time in G.M.T.	Visibility	Sky condition	Wind direction/speed in Kts	Temperature °C	Pressure in mb
	00	100 m	Sky observed	080/25	-5.0	978.0
	03	200 m	"	080/35	-5.0	979.5
	06	100 m	"	080/40	-5.0	981.0
	09	100 m	"	080/35	-4.0	982.0
	12	400 m	"	080/20	-4.0	981.8
	15	100 m	"	080/32	-3.0	982.0
	18	500 m	Overcast	080/20	-2.0	982.6
	21	6km	"	100/15	-4.0	982.8

TABLE III

Synoptic observations.

28.5.85	Time in G.M.T.	Visibility	Sky condition	Wind direction/speed in Kts	Temperature °C	Pressure in mb
	00	400 m	Overcast	120/24	-24	982.8
	03	100 m	Sky observed	100/30	-22	983.3
	06	10 m	"	090/35	-20	983.8
	09	10 m	"	090/56	-18	984.0
	12	5 m	"	090/68	-18	982.5
	15	5 m	"	090/70	-18	981.5
	18	5 m	"	090/60	-18	982.0
	21	5 m	"	000/60	-18	983.0
29.5.85	00	5 m	"	090/60	-18	984.5
	03	5 m	"	100/48	-18	985.0
	06	10 m	"	110/45	-18	986.2
	09	50 m	"	110/35	-18	986.8
	12	500m	Overcast	120/27	-18	987.2
	15	6 km	"	130/18	-20	988.0
	18	10 km	Cloudy	130/12	-22	989.6
	21	10 km	"	Variable/05	-25	989.5

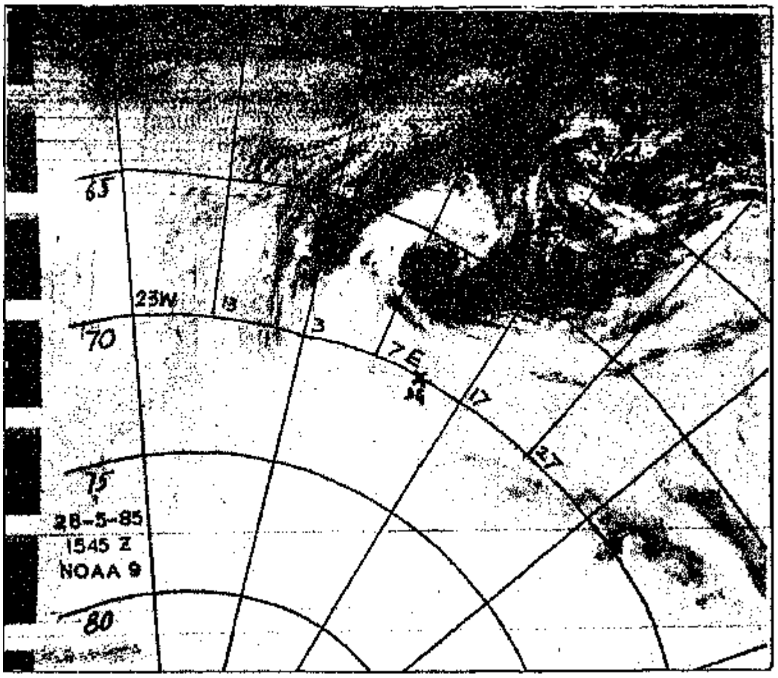

Fig. 14. Satellite cloud imagery (infra-red) received as on 28.5.85 from NOAA-9.

Blizzard and surface potential gradient

It was concluded from the surface potential gradient data collected at Dakshin Gangotri during the period that the average values of surface potential gradient during clear weather range from 250 volts/metre to 400 volts/metre and during the blizzard these go up to 900 volts/metre or even more. Table IV gives the account of the surface potential gradient values for some selected periods.

Data collection platform (DCP)

DCP was installed first on board the ship on a trial basis to record and transmit hourly surface data like pressure, temperature, humidity, wind and bright sunshine duration via INSAT-IB to MDUC, New Delhi. Encouraged by the success of this experiment, a DCP was installed on a permanent basis at Dakshin Gangotri during Summer 1986. In future, if need arises, it can act as an unmanned, weather station in Antarctica.

Upper air study

In order to study the vertical profile of pressure, temperature, humidity, wind and radiation flux over Antarctica and enroute in total, 88 upper air (18 Omega Sonde, 59 Radiosonde and 11 Radiometer Sonde) ascents were launched. These data are being processed. However, some results based upon preliminary computations on Antarctic tropopause and upper air humidity are discussed in the following sub sections.

Antarctic tropopause

It is important that we are able to describe if possible the main features of the Antarctic tropopause as well as its periods of variation with respect to height and temperature on the various time scales. This is important for forecasting the aircraft operations, as it is for various other reasons.

TABLE IV
Surface potential gradient (PG) at Dakshin Gangotri, 1985.

Date/Month	Weather	Surface-PG (volts/m)
21 March	Blizzard	780
10 April	Blizzard	780
11,12 & 13 April	Blizzard	900
5 May	Blizzard	900
29, 30 & 31 (upto 02Z)	Fair to snow	0-400
31 (03-18Z)	Blizzard	900

TABLE V
Temporal variation of tropopause height and temperature at Dakshin Gangotri, 1985.

Date/Month	Pressure (mb)	Height (KGPM)	Temperature (°C)
22 April	300	8.63	-47.1
11 May	317	7.87	-54.7
27 July	336	7.28	-62.7
7 November	280	8.86	-56.9
8 December	295	8.65	-52.7
26 December	287	8.75	-52.7

A study done by Pranter (1966) suggests that as winter approaches, the Antarctic upper troposphere continues to cool and the tropopause is found at higher altitudes and with lower temperatures than during either summer or spring. Winter tropopause is highest and coldest over the interior plateau region of the continent and it slopes down towards lower latitudes. In summer, the tropopause appears to be lowest over the interior and slopes up towards the coast.

The Antarctic tropopause assumes a wide range of values both spatially and temporarily. The largest month to month variations in tropopause height and temperature occur over the interior with generally smaller values occurring along the coast. Variation of tropopause height and temperature is summarised in Table V on the basis of radiosonde ascents taken at Dakshin Gangotri during 1985.

It is seen from the Table V that in July (winter) tropopause is lowest and coldest in comparison to other months. This is in confirmation with the findings of Prantner (1966).

Upper air humidity

The problematic nature of routine measurements of the moisture content of the air in the polar regions, and at low temperatures in general is well known. Humidity measurements at very low temperatures is a wide open field for research using modem instruments.

Humidity in the Antarctic atmosphere was found to be very low in all the seasons and particularly in winter. On an average, the Antarctic atmosphere is dry above 850/700 mb. However, during summer when the sea is not ice bound and the station is likely or being influenced by the extratropical system, the moisture extends upto 500 mb or even more. Such a case is shown in Fig. 15.

Visual observations

Cloudiness

The difficulties in making observation on clouds are particularly high in Antarctica where one constantly observes a thin layer all over the sky particularly in the interior parts. This layer is often so thin as to be hardly noticeable. The difficulty has then to be faced, whether the cloud amount is zero or eight octas. This problem was not so serious over Dakshin Gangotri excepting a few occasions.

Over the Antarctic plateau, i.e., over most part of the continent, the interpretation of the conventional names and definitions becomes problematic. In the south pole records, for instance, the most frequently used cloud name is Altostratus (AS) with its base less than 1000 m above the surface. At Dakshin Gangotri Ci, Cc, Ac, As, Sc and St clouds were quite common. However, cumulus mediocris could be seen in summer around noon at calm and otherwise clear days to the south of the station over Wholthat and Schirmacher mountain ranges.

The cloud base for all sorts of clouds (high, medium and low) was found to be quite low in comparison to tropical or sub-tropical regions.

Precipitation

The measurement of precipitation with rain gauges, snow bins, ombrometers or any other kind of collector has been found to be rather hopeless undertaking most of the time, over most of the continent. Only in the coastal regions, liquid precipitation is found though occasionally. But at Dakshin Gangotri precipitation was not observed in the form of rain even for a single day. It was always in the form of snow fall. In 90% of the cases, the snow fall was associated with winds strong enough to disengage the ice particles from the surface and raise them to considerable heights in the turbulent flow of air. These disengaged ice particles (when fall back) cause negative precipitation. This is the reason which makes the actual precipitation measurement difficult. Consequently, in Antarctica the emphasis is on determining the accumulation of ice instead of precipitation. This is one of the most intriguing problems of the seventh continent.

Fog

The frequency of occurrence of fog at the coastal and sub-Antarctic island stations and more so over the surrounding ocean, is clearly related to the advection of relatively warm maritime air over a colder surface. Occurrence of the advection fog was quite frequent especially in peak summer. It was low or zero in other seasons and particularly in the winter.

White out

White out like the fog is another aviation hazard which is observed in Antarctica quite often. In the white out there is no perception of depth or height. The sight of mirages due to super-refraction especially when the sun is at a low elevation and beautiful auroral lights with its colourful draperies are present, Antarctica more or less becomes a fairy land.

CONCLUSION

In short the following conclusions are drawn from the analysis of data recorded at DG during this expedition.

(i) January is found to be the warmest and August the coldest month which is in agreement with earlier findings (Rizvi, 1986b).

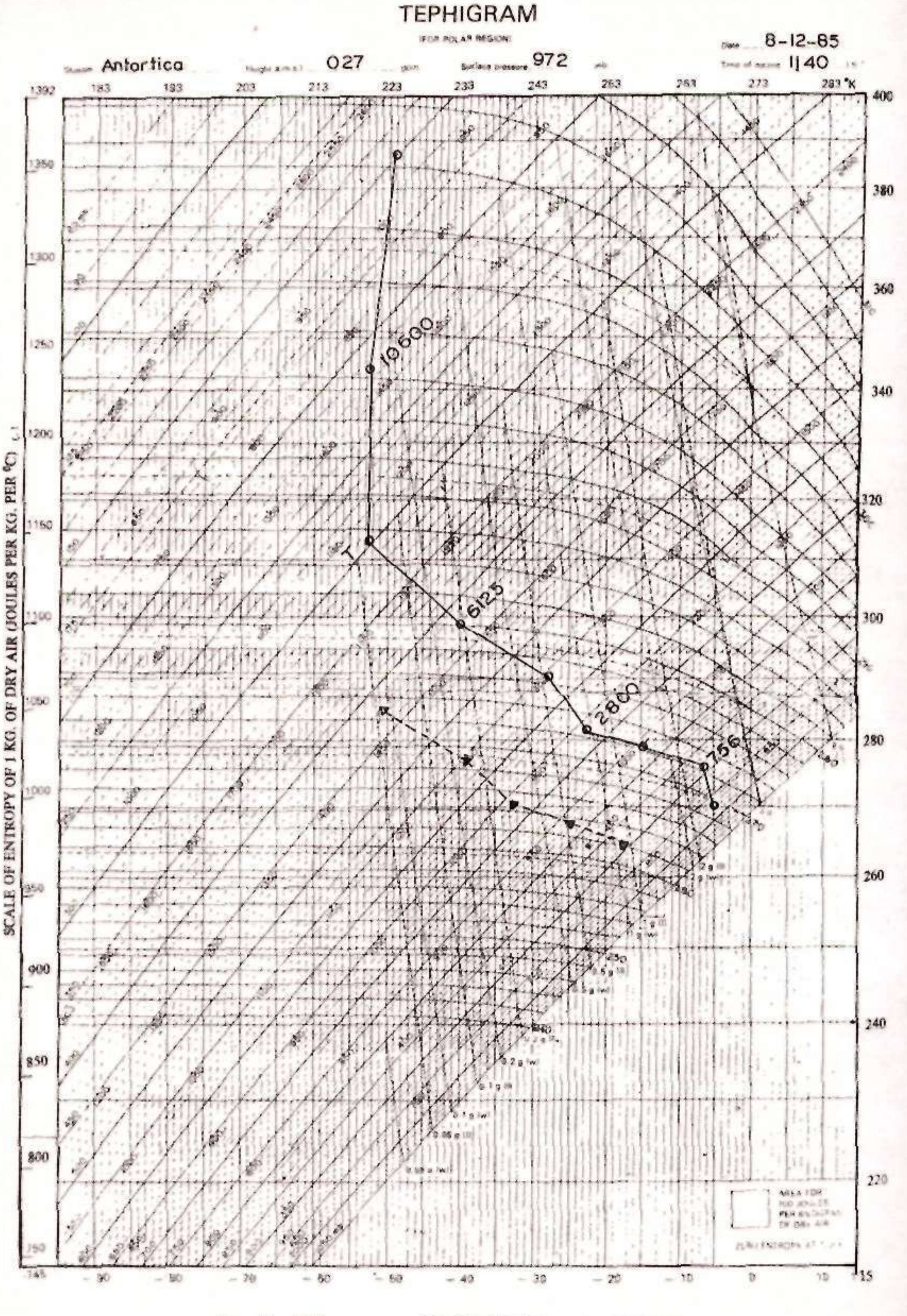

Fig. 15. T-Tropopause 295 MB/8650 (gpm)–52.7°C.

(ii) The lowest and highest temperatures of-52°C and +6°C were recorded on 16th August (1630 GMT) and 21st December (1600 GMT) 1985 respectively.

(iii) June and August were found to be the windiest and calmest months respectively.

(iv) It has been observed that katabatic winds pure in nature are very rare at Dakshin Gangotri.

(v) The stronger winds were always found to be ahead of the weather systems.

(vi) It is normally believed that if pressure falls significantly in short time duration one can expect bad weather; but at DG on number of occasions there was significant fall in pressure but no consequent bad weather.

(vii) Surface potential gradient increases tremendously (100 volts/metre) during blizzard.

(viii) The longest blizzard observed during our stay was of 13 days.

The meteorological data collected continuously round the year at Dakshin Gangotri will not only be helpful for planning the future Antarctic expeditions more efficiently, but will also add a new dimension to the understanding of the mysterious Antarctic weather and its role in the atmospheric general circulation. It is likely to throw light on the interaction of Antarctic weather with the weather features of lower latitudes of the Southern/Northern hemispheres. It is not exaggeration to say that the day will not be far away when we may be able to establish a relationship between the Antarctic weather and Indian monsoon provided that the process of collecting more and more meteorological information for many more years is continued.

The author has been fortunate to be a member of the second wintering party in Antarctica and to see its beauty and ferociousness from close quarters. After spending more than one year in icy continent the author is fully confident of India's capability to carry out high quality scientific work which will add a new dimension to the knowledge of this windiest, driest, coldest and the least accessible continent.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the then Shri S.K. Das, Director General of Meteorology for giving me the unique opportunity to participate in the fourth Indian Scientific expedition to Antarctica and stay with the second wintering team to acquire knowledge of the meteorological features of the icy continent.

I would like to express my sincere gratitude to Dr. S.Z. Qasim, Secretary, Department of Ocean Development for his continued interest in the scientific work and for the generous help rendered during the entire expedition.

I gratefully acknowledge the able leadership of Prof. B.B. Bhattacharya, Leader of the fourth expedition and also of Col. P. Kumaresh, Station Commander of the second wintering team.

I owe everything to my wife Mrs. Sudha Lai for her for bearance and patience during the period of my stay in Antarctica. It is worth mentioning that though she underwent a major surgery in my absence, she did not give even a slightest indication to me of her sickness and operation just to keep my moral high.

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