

Climatology of blizzards over Schirmacher Oasis, east Antarctica

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सार – एंटार्कटिक के मौसम में निरंतर और अचानक परिवर्तन होते रहते हैं। एंटार्कटिक में तेज हवाएँ और हिम झंझावात बहुत अधिक चलते हैं। झोंके के साथ हिम का बहना, झंझा, बल पवन और बहुत ही क्षीण दृश्यता को सामान्यतः हिम झंझावात कहते हैं। शिरमाशर मरुद्यान को प्रभावित करने वाले हिम झंझावातों के जलवायविक लक्षणों को पता लगाने के लिए वर्ष 1990–2005 की अवधि के दौरान रिकॉर्ड किए गए हिम झंझावातों के संबंध में भारतीय एंटार्कटिक स्टेशन मैत्री में रिकॉर्ड किए गए मौसम विज्ञानिक आँकड़ों का अध्ययन इस शोध पत्र में किया गया है।

मैत्री में रिकॉर्ड किए गए हिम झंझावात का संबंध मुख्यतः बहि-उष्णकटिबंधीय तूफानों से रहा है जिससे पहले सामान्यतः वर्षा होती है। पूरे वर्ष के दौरान औसतन 45 दिन स्टेशन को लगभग 21 हिम झंझावात प्रभावित करते हैं। अप्रैल से अगस्त के महीनों के दौरान स्टेशन को 3 से 4 हिम झंझावातों ने प्रभावित किया। अगस्त के महीने में सबसे अधिक संख्या में लगभग 7 दिन हिम झंझावात आए। हिम झंझावात के दौरान औसत पवन गति लगभग 52 नॉट रही परंतु कुछ अवसरों पर 100 नॉट तक बढ़ गई। इसकी अवधि 25 घंटों की औसत से घंटों से दिनों तक हो सकती है। जून 1997 में 168 घंटों की सबसे लंबी अवधि रिकॉर्ड की गई। ऐसे 12 अवसर हैं जब हिम झंझावात 72 घंटे से अधिक तक रहा। हिम झंझावात के दौरान अधिकतम पवन गति और तापमान में वृद्धि के बीच कोई सहसंबंध नहीं पाया गया है और इस अवधि के दौरान गति का भी दाब प्रत्यंतर से कोई सहसंबंध नहीं पाया गया है।

ABSTRACT. Weather in Antarctica is subject to frequent and sudden changes. Strong winds and blizzards dominate Antarctic weather. A combination of blowing snow, gale force wind and very low visibility is normally defined as blizzard. Meteorological data recorded at Indian Antarctic Station Maitri, in respect of blizzards recorded during the period 1990-2005 has been studied to find out climatological features of blizzards affecting Schirmacher Oasis.

At Maitri the blizzard is mostly associated with extra-tropical storms and is normally preceded by precipitation. On average during the year about 21 blizzards affects the station for 45 days during the year. During the month of April to August 3 to 4 blizzards affects the station. Maximum number of blizzards occurs in the month of August with about 7 blizzard days. Average wind speed recorded during the blizzard is about 52 kt but it exceeded 100 kt on several occasions. The duration may vary from hours to days with average of 25 hours. Longest duration of 168 hours was recorded in June 1997. There are about 12 such occasions when blizzard lasted more than 72 hours. No correlation has been found between maximum wind speed and temperature rise during blizzard and the speed is also not correlated with pressure departure during the period.

Key words – Antarctic Meteorology, Climatology, Blizzards.

1. Introduction

The Antarctic continent is a dome of ice with 14×10^6 km² in area ranges in height from sea level to

more than 4 km with mean altitude exceeding 2 km, sloping towards its perimeter to sea level. Although there is much variation in continental feature including exposed mountain chain, dry valleys and coastal oases, more than

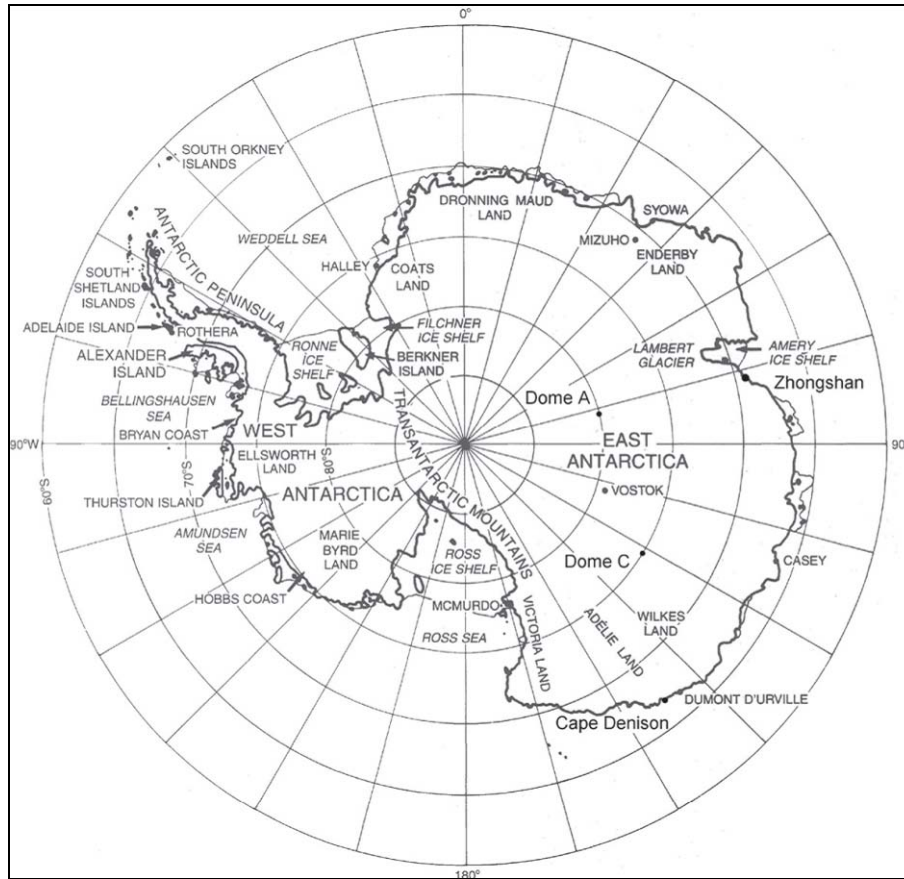


Fig. 1. Location map of Antarctica depicting Queen Maud Land, East Antarctica

95% of the total area is covered by snow and ice. The continent is very cold windy, over much of its area very dry. It has profound effect on southern hemisphere weather system. Location of different geographical features and stations is shown in Fig. 1 (Turner and Sahah, 2007).

The Schirmacher Oasis is one of the smallest East Antarctic oases and is considered to be a typical oasis near the shore. It is a small, hilly oasis region of Queens Maud Land area, where rocks get exposed during the local summer season. Other geographical features of the area have been discussed by Boremann and Fritzsche (1995). It has a maximum width of 3.5 km, a length of about 20 km. It is oriented approximately in east-west direction with approximate area of about 35 sq km. The coordinates of the oasis are (70° 46' 04" - 70° 44' 21" S) and (11° 49' 54" - 11° 26' 03" E). The elevation of oasis ranges between 0 to 228 m with an average of 100 m. There is a 200 to 500 m thick and about 100 km wide ice shelf slab north of Schirmacher oasis and approximately 1000 m thick and 50 km wide firn basin glacier in the south. On the

southern edge of the Schirmacher oasis, it terminates as a 10 to 40 m high escarpment while it shows a smooth transition to ice shelf both east and west of the area. The climatic zone of influence in the Schirmacher oasis extends to about 1000 sq km. The Indian Antarctic station, Maitri (70° 45' 57" S/11° 44' 09" E) and Russian Antarctic Station, Novolazarevskaya are situated over the Schirmacher region, Princess Astrid Coast, east Antarctica (Fig. 2).

The Antarctic is the windiest continent on Earth, with many of the coastal research stations affected by strong surface winds. The strength and persistence of the near-surface winds was noted by many of the early explorers (Mawson 1915), and this feature has been perhaps the most intensively studied climatological element since then (Dare and Budd 2001; King 1989; Parish 1982; Parish 1988; Parish and Bromwich 1987; Parish and Waight 1987; Murphy and Simmonds 1993). Winds in the coastal region of East Antarctica are driven by mesoscale katabatic winds and synoptic-scale cyclonic

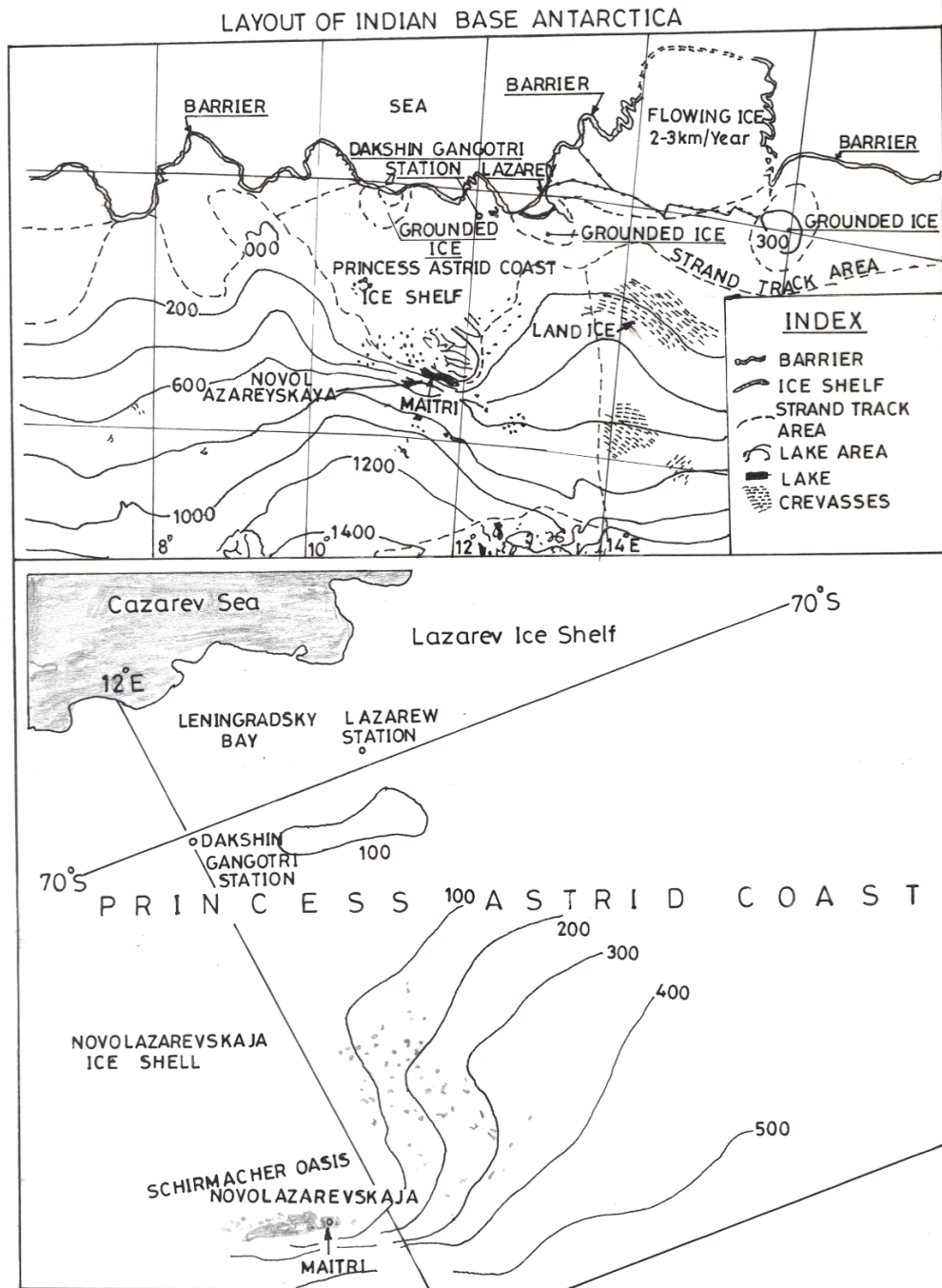


Fig. 2. Location Map of Schirmacher Oasis, and Indian Antarctic station, Maitri

systems (Schwerdtfeger 1984; Streten 1963) that superimpose gradient winds over the low-level mesoscale flow. The strongest winds are generally forced by offshore cyclonic vortices that move primarily “around the coast” from west to east, as components of the semi-permanent

trough of low pressure that encircles the Antarctic continent. When in the appropriate location, these depressions can reinforce the drainage flow at the coast (Ball 1960; Streten 1968). Prolonged periods of strong winds are associated with synoptic disturbances, in

TABLE 1

Annual frequency of blizzards over Maitri for the period 1990-2005

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Jan	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
Feb	0	0	0	0	0	1	0	1	0	0	0	0	0	1	2	0	5
Mar	3	1	5	0	1	0	3	0	1	4	3	1	3	1	0	1	27
Apr	3	1	4	1	5	2	4	2	0	3	2	1	3	5	1	2	39
May	4	4	2	3	3	5	6	3	5	6	1	1	4	3	0	0	50
Jun	1	4	1	2	0	1	5	2	2	4	2	3	1	2	5	1	36
Jul	2	2	3	6	4	2	6	2	4	2	1	2	2	5	1	4	48
Aug	0	0	2	2	5	4	2	5	3	6	5	1	2	3	2	2	44
Sep	1	2	2	3	2	2	6	4	5	6	1	1	2	1	0	0	38
Oct	3	1	3	2	4	2	2	1	1	2	2	4	1	2	0	0	30
Nov	0	0	1	1	0	2	1	3	0	0	3	0	0	1	0	1	13
Dec	0	0	1	0	0	1	2	0	0	1	0	1	0	0	1	0	7
Total	17	15	24	20	24	22	38	23	21	34	20	15	18	24	12	12	339

contrast to pure drainage flow, which does not persist for extended periods due to exhaustion of the upstream supply of air.

Blizzard is a typical Antarctic phenomenon which occurs when drifting snow is picked up and blown along the surface by violent wind. It creates blinding conditions *i.e.* an object even 3 feet away may not be visible and it becomes difficult to the scientists in carrying out their day to day research work outside the station. The blizzard over Maitri is reported when the surface wind speed is more than 23 kt accompanied with moderate to heavy drifting or blowing snow reducing visibility to less than 1000m. A few studies of climatological features of Schirmacher oasis has been reported using meteorological data recorded at Maitri (Lal 2006; Srivastava *et al.* 2003). Kulandaivelu and Dang (2003) discussed case study of katabatic winds using one-year data. Rasal (2003) used one-year data to describe some features of Blizzards over the area whereas Kulandaivelu *et al.* (2005) discussed synoptic features of some blizzards experienced during 1996 at the station. These studies suggested that blizzard winds over Schirmacher Oasis are usually relatively warm and moist and are associated with cyclones that are situated to the north or northeast of the station, directing upper-level air from the east, resulting in surface wind directions that are generally from the southeast fall line by about 110-140. Winds are strong and the corresponding cloud amounts are large. In this paper climatological study of blizzards experienced at Schirmacher oasis has been

discussed using instrumental and visual observations recorded at Maitri during the years 1990 to 2005

2. Data and methodology

During third expedition, a permanent scientific station "Dakshin Gangotri" (69° 59' 23" S/11° 56' 26" E) was established in 1983 in Lazarev Sea area of Queen's Maud Land and functioned there till 1989. Thereafter second Indian Antarctic Station, Maitri (70° 45' 57" S/11° 44' 09" E) was established in 1989 in the Schirmacher Oasis of East Antarctica. The Indian Antarctic station, Maitri was occupied as summer camp site in 1985 and later converted as second permanent Indian Antarctic station on 9th March 1989. The elevation of the station is 117 m above mean sea level. Since establishment of these observatories all the meteorological observations such as pressure, temperature, wind speed and direction, were taken at Dakshin Gangotri (WMO station index No.89510) 1984 to 1989 and at Maitri (WMO station index No.89514) since 1990 onwards

Weather in Antarctica is subject to frequent and sudden changes. Strong winds and blizzards dominate Antarctic weather. When wind speed exceeds 23 knots with drifting/blowing snow reducing the surface visibility to less than one kilometer then the weather phenomenon was defined as Blizzard for our study purposes. For the study of climatology of blizzards over Schirmacher Oasis monthly weather reports of Maitri station, which is a

TABLE 2

Monthly frequency of blizzards over Maitri for the period 1990-2005

Months	Total number of blizzards	Percentage frequency	Average	Average number of days with blizzard
Jan	2	0	0.1	0.3
Feb	5	1	0.3	0.5
Mar	27	8	1.7	3.0
Apr	39	12	2.4	5.3
May	50	15	3.1	6.3
June	36	11	2.3	4.8
July	48	14	3.0	6.1
Aug	44	13	2.8	6.6
Sep	38	11	2.4	5.1
Oct	30	9	1.9	4.0
Nov	13	4	0.8	2.1
Dec	7	2	0.4	0.9
Total	339	100	21.2	45.0

TABLE 3

Monthly frequency of blizzards over Dakshin Gangotri for the period 1984-1989

Months	Total number of blizzards	Average number of blizzards	Percentage frequency	Average number of days with blizzard
Jan	9	1.8	3.5	5.2
Feb	21	4.2	8.2	9.6
Mar	27	4.5	8.7	11.5
Apr	30	5.0	9.7	10.7
May	28	4.7	9.1	12.0
June	27	4.5	8.7	12.8
July	33	5.5	10.7	10.2
Aug	26	4.3	8.3	8.0
Sep	22	3.7	7.2	9.3
Oct	31	5.2	10.1	10.5
Nov	31	5.2	10.1	9.5
Dec	18	3.0	5.8	5.3
Total	303.0	51.5	100	114.6

representative meteorological station of the area, have been used. The reports are available with the archives of India Meteorological Department (IMD) New Delhi. History of each blizzard reported at the station is recorded using instrumental observations of pressure, wind and

temperature and visual observation of visibility, weather phenomenon and cloud cover. For each blizzard, time of commencement, cessation, maximum and minimum MSL pressure, minimum and maximum temperature during the blizzard and maximum wind speed reported is during

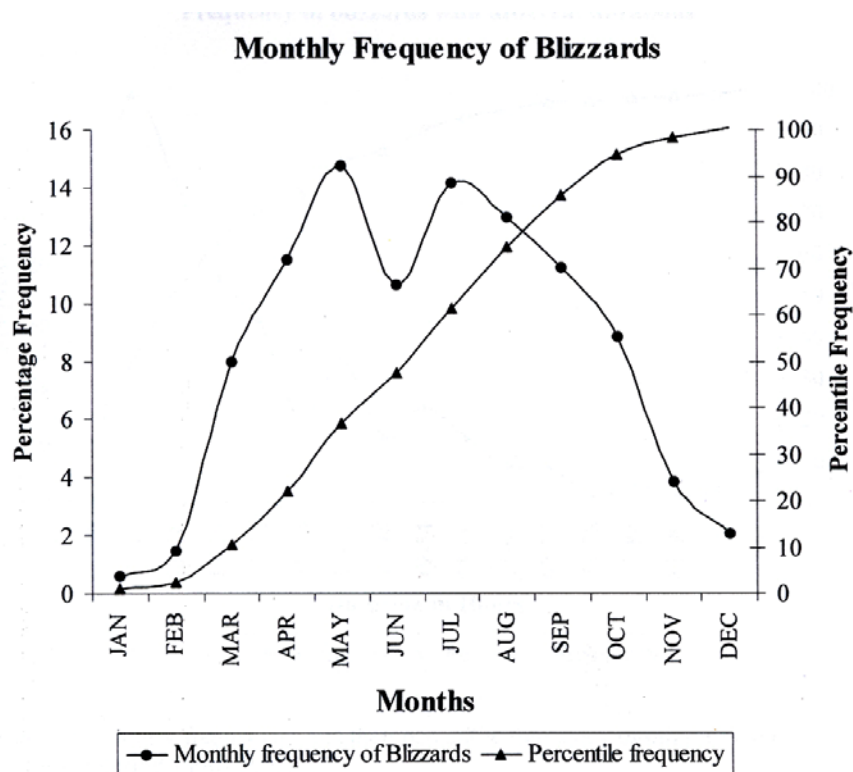


Fig. 3. Monthly frequency of blizzards over Maitri during the period 1990-2005

blizzard is recorded. Meteorological data for a period of 16 years from the year 1990 to 2005 has been used for this study. The history of blizzards recorded at Dakshin Gangotri was not available except number of blizzards and number of days affected by blizzards for the period 1984 to 1989.

The data was tabulated, checked for quality and various climatological features regarding occurrence of blizzard and associated meteorological parameters has been derived. There were 339 blizzards of varying duration and intensity during period of 16 year from 1990 to 2005 recorded at Maitri. Some features of these blizzards have been discussed in subsequent sections.

3. Results and discussion

3.1. Frequency of blizzard

Blizzard has occurred on 303 occasions during period of 6 years from 1984 to 1990, with an average of 51 blizzards per year at Dakshin Gangotri and on 339 occasions during period of 16 years from 1990 to 2005, with an average of 21 blizzards per year at Maitri. Maximum number of blizzard (38) occurred in 1996, and

minimum number of blizzard (12) in 2005. The standard deviation (SD) and coefficient of variation (CV %) are 7 and 33 respectively. Actual monthly and annual distribution of blizzards for each year under study is given in Table 1. Monthly average frequency and average number of days with blizzard for each month for both the stations is given in Table 2 & Table 3.

On an average about 21 blizzards affect the station lasting for 45 days during the year at Maitri. Percentage frequency of blizzards for each month along with cumulative percentile frequency is shown in Fig. 3. The frequency of blizzard is maximum in the month of May followed by July then by August, April and September and is minimum in the month of January followed by February, December and November. During the period under study 85% of total blizzard occurred during April to October and only 15% during January, February, March, December and November. It has been observed that the frequency of blizzard increases in late winter and early spring. From May to September 64% of total blizzard occurs with frequency of 3 to 4 blizzard per month. It is seen from these results that the blizzards are more frequent in winter months. On an average during the year about 52 blizzards affect Dakshin Gangotri for 115 days during the year.

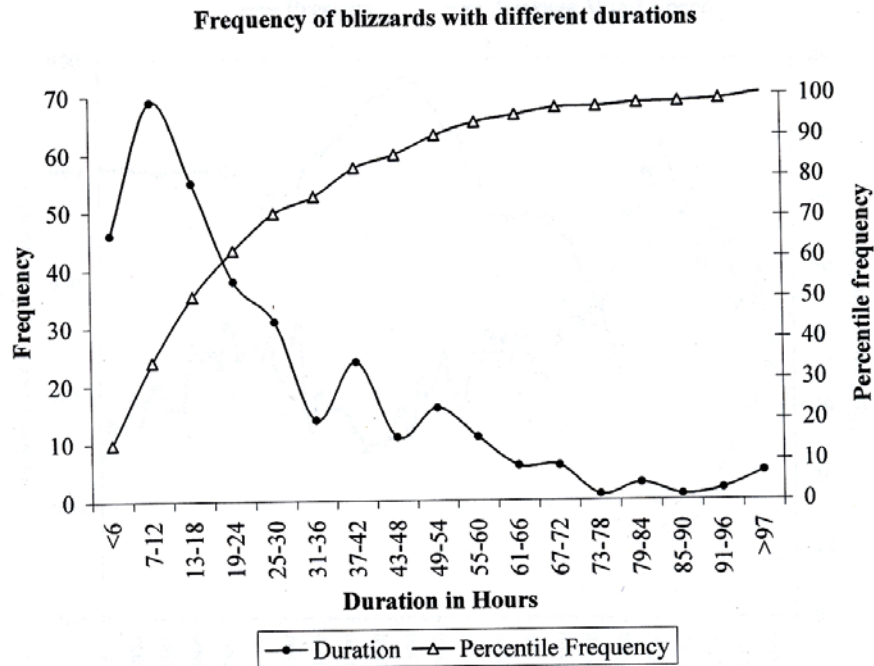


Fig. 4. Six hourly frequencies and their percentile frequency of blizzard over Maitri for the period 1990-2005

3.2. Duration of blizzard

Average duration of blizzards is 25.8 hours. There were only 15 occasions when blizzard lasted for more than 70 hours and only on five occasions it exceeded 100 hours. The longest duration of blizzard was of 168 hours it started from 2000 UTC of 12 June 1997 and ended on 2030 UTC of 19 June 1997 (7 days), followed by 149 hours from 0750 UTC of 22 May 2003 to 1230 UTC of 28 May 2003, then of 127 hours from 0840 UTC of 09 June 1993 to 1600 UTC of 14 June 1993. The blizzards of shortest duration, one hour each were observed on two occasions, first from 2200 UTC to 2300 UTC on 18 June 1999, second 0800 UTC to 0900 UTC on 23 March 1998.

In order to study the pattern in duration of blizzards all blizzard cases were divided in class interval of 6 hours duration and all cases where duration exceeded 96 hours were clubbed together. Frequency of each class along with cumulative percentile frequency is shown in Fig. 4. It is evident that about 70% blizzards last for the period less than 36 hours whereas the frequency of blizzards with duration more than 72 hours is less than 10%. This shows that as the duration increases frequency of blizzard decreases.

3.3. Maximum wind speed

The maximum surface wind speed recorded during blizzard was 110 kt and minimum was 25 kt during the period under study. The average wind speed was 54 kt with standard deviation 30. There were only three occasions on which maximum wind speed reached 100 kt or more. The maximum wind speed of 110 kt was recorded on one occasion in September 1999 when blizzard occurred for 34 hours duration, followed by 106 kt in July 1996 when blizzard occurred for 113 hours duration and 100 kt on 23 July 1999 and lasted for two hours duration. This was in succession of earlier blizzard, which lasted only few hours earlier and prevailing wind speed was more than 60 kt without blizzard. The blizzards of July 1996 were severest during the period under study in respect of intensity and duration.

During July 1996, a total of 6 blizzards were experienced at the 'Maitri' station (Antarctica) for 16 days, out of which the blizzard experienced during 19 to 24 July was the longest and strongest one covering a total period of 113 hours recording the highest wind speed of 68 knots (126 kmph) gusting to 106 knots (196 kmph). The hourly variation of station level pressure, average wind

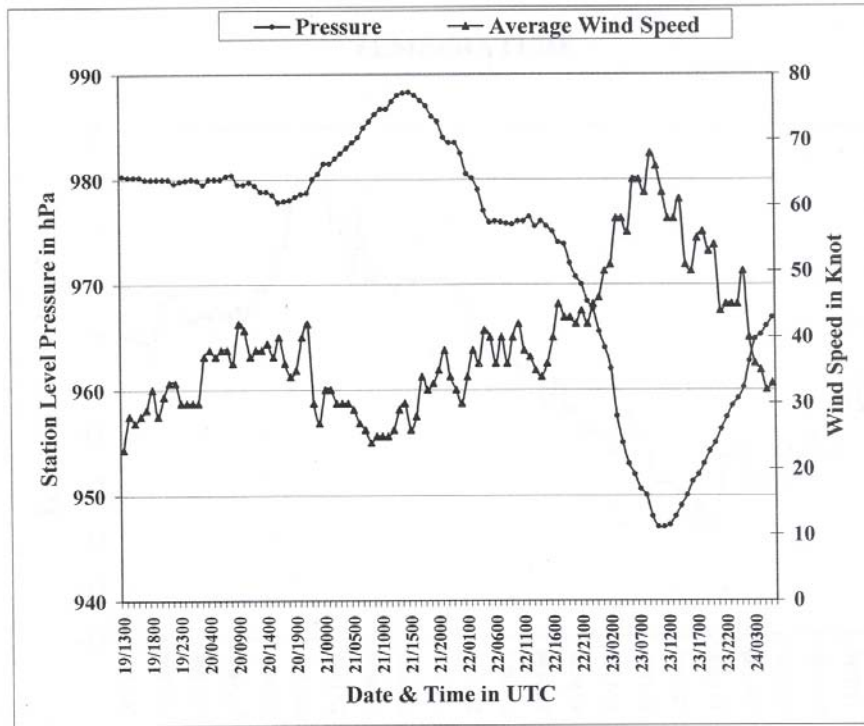


Fig. 5. The hourly variation of pressure and wind speed during July 1996 blizzard

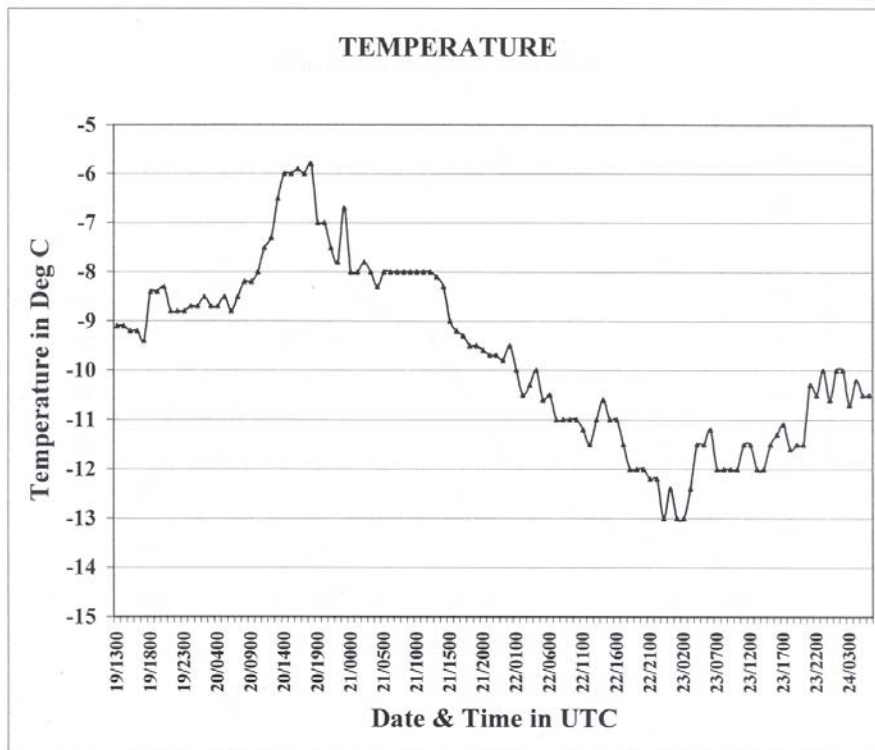


Fig. 6. The hourly variation of surface air temperature during July 1996 blizzard

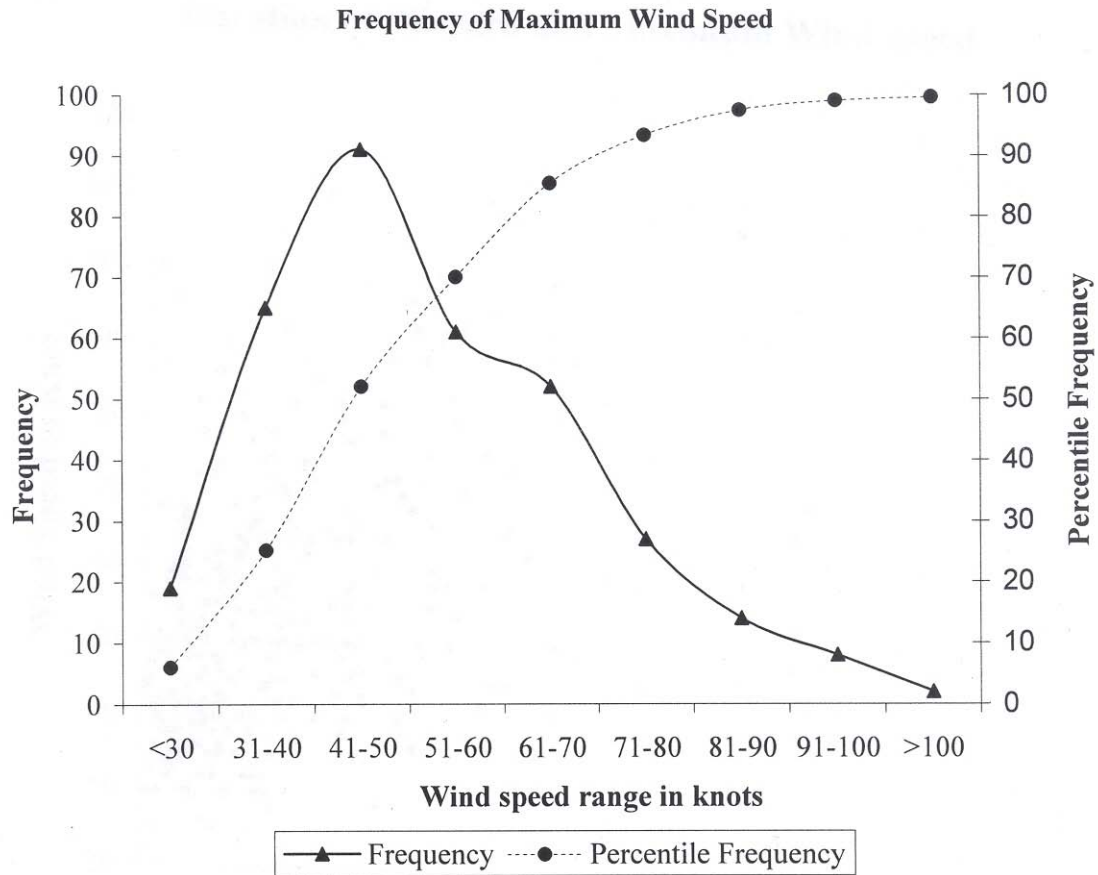


Fig. 7. Frequency of blizzards with different range of maximum wind speed recorded during blizzard along with percentile frequency at Maitri for the period 1990-2005

speed and surface air temperature recorded at the station during this blizzard is shown in Fig. 5 and Fig. 6.

In order to study the pattern in duration of blizzards all blizzard cases were divided in class interval of 10 kt above 30 kt and all cases where wind speed exceeded 100 kt were clubbed together. Frequency of each class along with cumulative percentile frequency is shown in Fig. 7. This shows that the maximum frequency 27% of total blizzard occurred in range of 41-50 kt followed by 19% in 31-40 kt and then 18% in 51-60 kt. It has been found that 85% of total blizzard occurred with maximum wind speed reaching up to 70 kt.

To find out relationship between maximum wind speed and duration of blizzards a scatter diagram (Fig. 8) was plotted and it was found that no significant correlation

exist between duration of blizzard and maximum wind speed recorded during the blizzards.

3.4. Pressure

During the commencement of blizzards mean sea level (MSL) pressure starts decreasing and reaches to lowest value when the extra tropical cyclone under which influence the blizzard is activated crosses station longitude. Thereafter pressure rises steeply and continuously and maximum pressure is recorded nearly at the cessation of the blizzard. Average maximum pressure of 987.2 hPa and average minimum of 976.3 hPa has been recorded during blizzard. Lowest MSL pressure recorded during blizzard was 944 hPa during July 2005 blizzard.

The minimum pressure varies from 995 hPa to 955 hPa in maximum number of blizzards. It has been

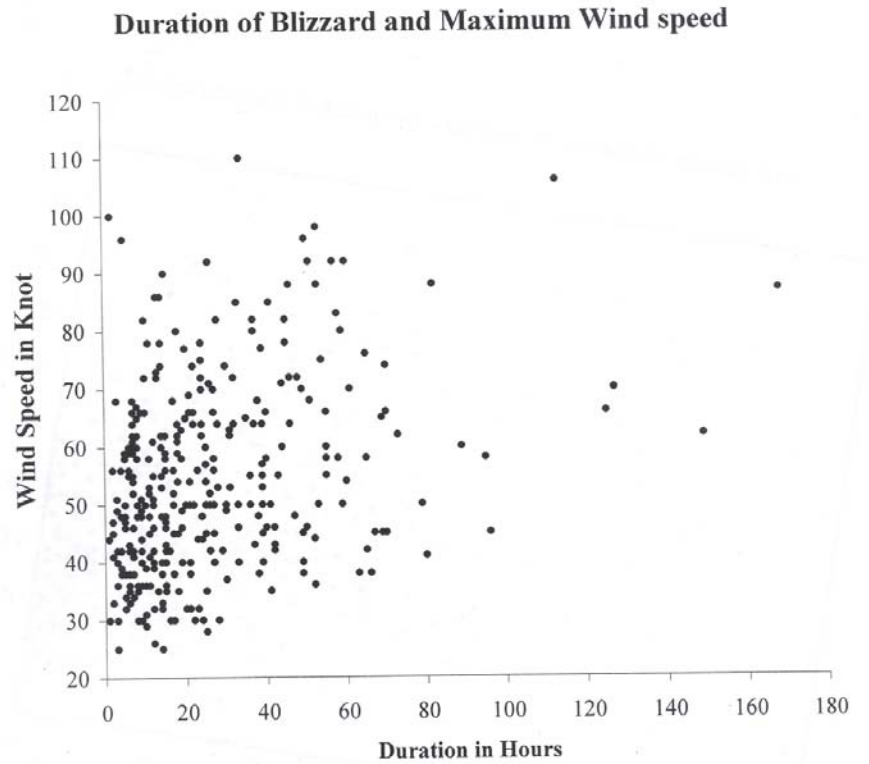


Fig. 8. Scatter diagram indicating distribution of duration and maximum wind speed recorded during blizzard

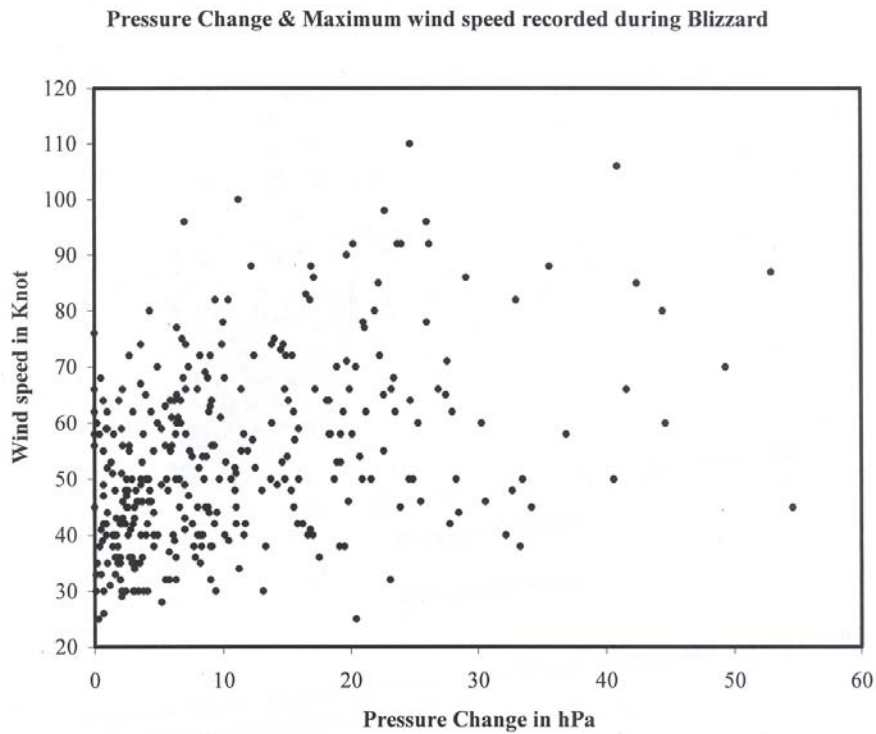


Fig. 9. Scatter diagram indicating distribution of pressure change and maximum wind speed recorded during blizzard

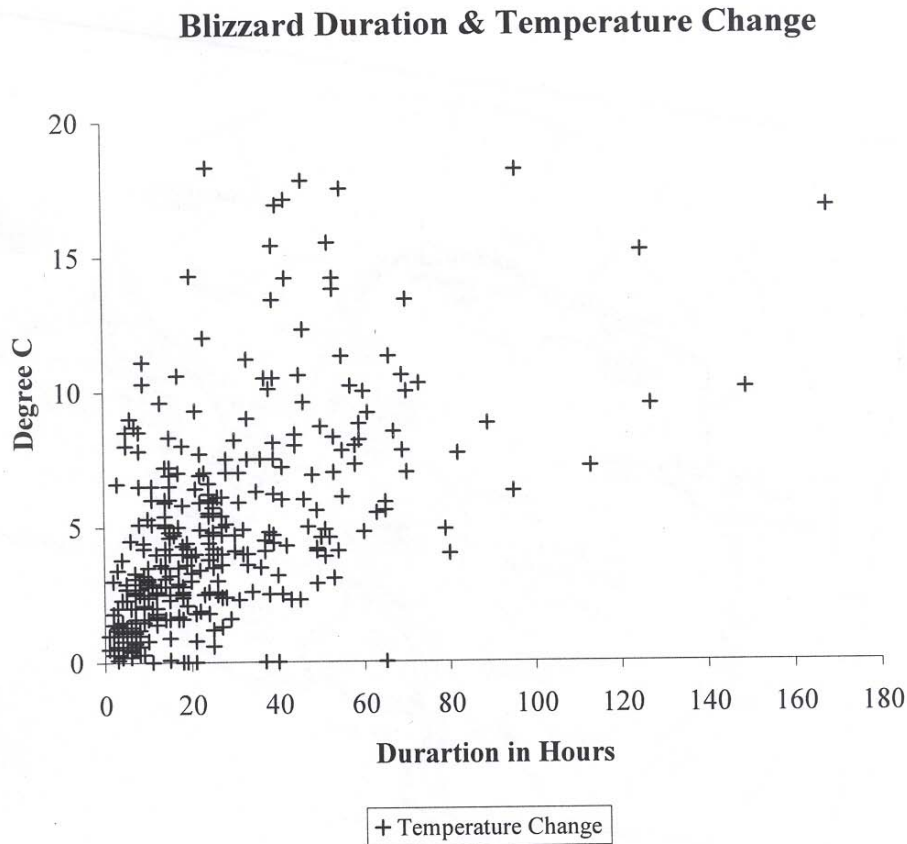


Fig. 10. Scatter diagram indicating distribution of duration and rise in surface temperature recorded during blizzards

found that the frequency of blizzard for pressure change of 40 hPa or more is very less (only 3%) and the frequency is very high for pressure change of order 10-20 hPa (97%). To find out relationship between pressure change and maximum wind speed recorded during blizzards a scatter diagram (Fig. 9) was plotted and it was found that no significant correlation exist between pressure change and maximum wind speed recorded during the blizzards.

3.5. Temperature

During the blizzards moist and warm air is transported towards the continent and this causes rise in surface temperature during blizzards and cyclonic activity at the station. Average maximum and minimum temperature recorded during blizzard were -8.1°C and -13.0°C respectively with average rise of 4.9°C .

It was found that frequency of blizzard was very high in the range 0°C to -15°C of maximum temperature. During the period under study only on 8 occasions the maximum temperature was positive. The highest and

lowest minimum temperature was 1.5°C and -28.2°C on 18 Feb 2003 and 15 Aug 1998 respectively. It has been found that frequency of blizzard is very high within range -5°C to -20°C of minimum temperature. It has also been found that, only on 2 occasions the minimum temperature was positive and in the order of 1.5°C and 0.9°C on 18 Feb 2003 and 31 Jan 1996 respectively, and on 8 occasions when temperature was less than -25°C .

To find out relationship between duration of blizzard and rise in surface air temperature during blizzards a scatter diagram (Fig. 10) was plotted and it was found that some correlation exist between duration of blizzard and rise in temperature recorded during the blizzards for duration less than 60 hours but no correlation exists for blizzards of higher duration.

4. Conclusion

At Dakshin Gangotri and Maitri the blizzard is mostly associated with extra-tropical storms and is

normally preceded by precipitation. This study indicates that on an average about 21 blizzards affect the station for 45 days during the year at Maitri and 51 blizzards affect Dakshin Gangotri station for 115 days per year. During the month of April to August 3 to 4 blizzards affects the station. Maximum number of blizzards occurs in the month of August with about 7 blizzard days. Average wind speed recorded during the blizzard is about 52 kt but it exceeded 100 kt on several occasions. The frequency of blizzard is highest for maximum wind speed in the range of 41-50 kt. On 85% of occasion's blizzard occurred with maximum wind speed in the range 25 to 70 kt and only in 15 % cases maximum wind speed exceeds 70 kt.

The duration of blizzard may vary from hours to days with average of 25 hours. As the duration increases the frequency drops abruptly. The frequency of blizzard is very high for 12 hours duration It has been found that total 327 number of blizzard have occurred (96%) for 72 hours duration. It has been observed that duration of blizzard and maximum wind speed recorded during the blizzard is not correlated. Similar case has been found with change in maximum and minimum temperature recorded during the blizzards.

The Climatology of Blizzards over Schirmacher Oasis gives several interesting indications concerning the climate of Schirmacher Oasis and the information is very useful in planning of different technical and scientific activities at Schirmacher oasis and neighborhood. In view of these facts it is apparent that continuing polar records of unchanging environment of Maitri will be extremely valuable in monitoring of the global climate in the foreseeable future.

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