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A case study of katabatic winds over Schirmacher Oasis, east Antarctica

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सार – ऊँचे भूभागों की समीपवर्ती घाटियों और निचले क्षेत्रों में रात के समय और सुबह तड़के अवरोही पवनें नियमित रूप से बहती हैं। अंटार्कटिका में भूखंड का आकार पठार के रूप में बर्फ से ढका रहता है और दक्षिणी ध्रुव से यह समुद्र तट तक चारों तरफ से ढालू होता है। धरातल के निकट वायु के ठंडे होने के साथ–साथ तटीय पट्टी में प्रायः पठार के ढलान की ओर तेज़ हवाएँ चलती हैं। इस अध्ययन में, नौवें भारतीय अंटार्कटिक अभियान 1990–91 के दौरान एकत्र किए गए आँकडों का उपयोग करते हुए शिरमैशर मरूद्वीप पर मैत्री में "अवरोही पवनों" की जाँच की गई है। प्रारंभिक परिणामों से यह पता चलता है कि अन्य ऋतुओं की अपेक्षा शीत ऋतु के सभी महीनों में अवरोही पवनें उच्चतर आवृतितायों और प्रबलता के साथ देखी गई है। धरातलीय तापमान और मौसम की अवस्थाओं से जुड़ें परिवर्तनों के साथ और पवन की दिशा के आधार पर शुद्ध अवरोही पवन और असाधारण अवरोही पवन के मध्य अंतर बताया गया है।

ABSTRACT. Katabatic winds are a regular feature during night and early morning hours over valleys and low lying areas adjacent to high terrains. In Antarctica, the mass of the earth in the form of plateau is covered with full of ice and has a downslope from the South Pole everyside upto the coast. Due to cooling of air near the ground as well as due to pressure gradient, the coastal belt often experiences strong winds blowing down the slope of the plateau. In this study "katabatic wind" at Maitri over Schirmacher Oasis has been examined using the data collected during the 9th Indian Antarctic Expedition 1990-91. The primary results show that katabatic winds are observed in all the months with higher frequency and strength in winter compared to other seasons. A distinction between pure katabatic wind and extraordinary katabatic wind is done based on the wind direction and associated changes in the surface temperature and weather conditions.

Key words – Katabatic wind , Maitri, Radiation cooling, Ground inversion, Extra-tropical front and Gravity force.

1. Introduction

On cloudless nights, air near the surface often begins to flow down the slopes of mountains and hills, as due to radiation cooling it becomes denser than the surrounding air and is pushed down by the force of gravity. This type of air flow is called katabatic wind (WMO No.266) and is related to ground inversion, fog formation and even early morning thunderstorms (Forecasting Manual Report No.III-2.2, 1974).

Katabatic winds are a characteristic feature of the climate of Antarctic coastal regions (Tauber, 1960). East Antarctic katabatic winds are widely studied by Schwerdtfeger (1984). The cooling of air by radiation along the slopes of ice covered plateau makes it flow down the slopes whose strength is further modified by the local orographic features like shape and steepness of the slope of the plateau.

Lal (1990) has observed katabatic winds at Maitri (Lat. 70° 45' S, Long. 11° 44' E) during 20-27 January 1987 during 6th Indian Scientific Expedition to Antarctica. Bhukan Lal (1987) has also observed katabatic flow at Dakshin Gangotri, about 100 km. north of Maitri.

In this paper, an attempt has been made to study the katabatic winds at Maitri over Schirmacher Oasis and its influence on the surface temperature, pressure, weather etc. during January 1990 to January 1991.

2. Data

For this study, wind (speed and direction), surface air temperature and pressure during the period March 1990 to January 1991 as recorded by self recording instruments are used. Also the 3 hourly synoptic observations from January 1990 to January 1991 are utilized to examine the influence of moving frontal

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TABLE 1

Comparison between pure katabatic winds and extra-ordinary katabatic winds at Maitri during January 1990 - January 1991

Month & year	Pure katabatic wind ≥ 20 knots		Extra-ordinary katabatic wind ≥ 25 knots		No. of low pressure systems crossed over the station
	No.of days	Max.wind speed	No.of days	Max. wind speed	
Jan 1990	2	22	3	40	2
Feb1990	3	20	11	62	2
Mar 1990	12	51	12	72	2
Apr 1990	18	55	9	60	2
May 1990	11	53	15	61	4
Jun 1990	17	49	7	62	2
Jul 1990	13	58	23	70	2
Aug 1990	16	61	3	42	2
Sep 1990	9	46	7	50	1
Oct 1990	11	45	14	85	2
Nov 1990	12	47	10	50	1
Dec 1990	10	40	7	41	0
Jan 1991	8	45	10	62	3

TABLE 2

Hourly wind direction of easterly and southerly components at Maitri during January 1990 - January 1991

Month	No. of hours recorded						Total No. of observations
	E	ESE	SE	SSE	S	SSW	
Jan 1990	48	41	30	13	11	2	262
Feb1990	26	165	62	27	16	0	345
Mar 1990	72	237	122	105	91	1	744
Apr 1990	32	178	101	120	111	29	720
May 1990	33	161	226	57	105	3	744
Jun 1990	4	76	230	81	187	11	720
Jul 1990	27	147	313	64	135	11	744
Aug 1990	8	25	81	65	263	17	744
Sep 1990	37	113	135	82	129	13	720
Oct 1990	15	175	262	72	98	3	744
Nov 1990	49	117	178	56	129	5	720
Dec 1990	63	149	113	49	106	7	744
Jan 1991	56	156	230	74	62	9	744

systems on the katabatic winds. The 3 minutes average speed has been taken as the wind speed for the given time in this study.

3. Classification of Antarctic katabatic winds

Katabatic flow at Antarctica can be classified into two categories: (*i*) Ordinary pure katabatic wind which is due to radiation cooling of air mass near the high plateau covered by ice that flows down under the influence of gravity force. This usually comes from southerly direction and there is a significant fall of surface temperature. The duration of this pure type of katabatic flow is short about 5-10 hours in a day. It is invariably associated with inversion at the lower levels and clear sky condition and (*ii*) The second type of katabatic flow is the

TABLE 3

Percentage of easterly and southerly components of wind direction at Maitri during January 1990 - January 1991

Month	No. of observations		Percentage	
	Easterly component	Southerly component	Easterly component	Southerly component
Jan 1990	119	26	45	10
Feb 1990	253	43	73	12
Mar 1990	431	197	58	26
Apr 1990	301	260	42	36
May 1990	420	165	56	22
Jun 1990	310	279	43	39
Jul 1990	487	210	65	28
Aug 1990	114	345	15	46
Sep 1990	285	224	40	31
Oct 1990	452	173	61	23
Nov 1990	344	190	48	26
Dec 1990	325	162	44	22
Jan 1991	442	145	59	8

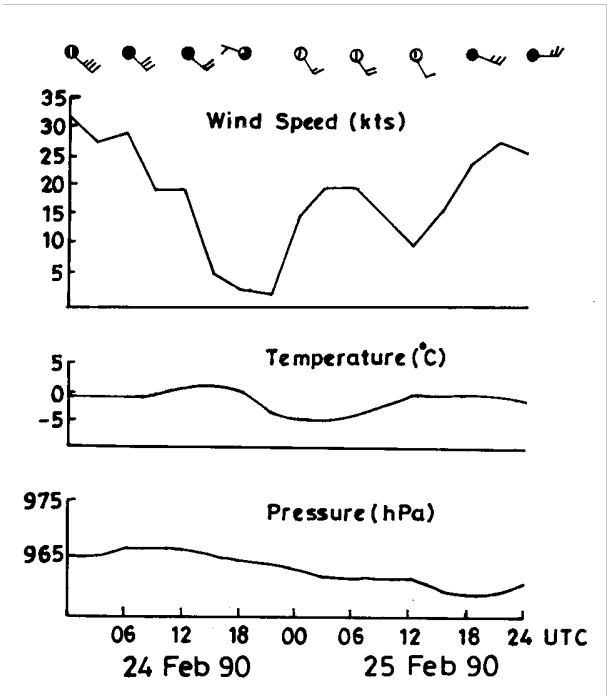


Fig. 1. Variation of wind speed, air temperature, station level pressure and sky conditions at Maitri during 24-25 February 1990

"Extra-ordinary katabatic wind" which is due to the presence of extra-tropical low pressure system in the vicinity of the region between 0° and 30° E longitude. This type of katabatic wind has direction mainly between east and southeast and persists for a number of days. These winds are gusty and the surface temperature gradually rises over the station. Since this type of katabatic flow is in association with frontal systems, generally cloudy sky condition prevails over the station and even bad weather may occur.

In this study, the strength of pure katabatic flow is taken as 20 knots or more and the flow direction is from SSE to SSW whereas for extra-ordinary katabatic wind, the strength is taken as 25 knots or more and the direction is from east to southeast.

Table 1 shows a comparison between pure katabatic winds and extra-ordinary katabatic winds during January 1990 to January 1991 . It may be noted that the strength of extra-ordinary katabatic wind is much higher than that of pure type in all the months except in August. The station experienced a maximum of 18 days of pure katabatic flow in April 1990 whereas in the month of August 1990 the maximum strength was 61 knots. July 1990 had a maximum of 23 days of extra-ordinary katabatic flow, where as the maximum strength of 85 knots occurred in October 1990. In general, the period March to August 1990 had more days of pure katabatic flow compared to other months and even the wind strength was larger in this period.

The hourly wind direction of easterly and southerly components for the period January 1990 to January 1991 have been presented in Tables 2 & 3 for southerly components SSE, S and SSW directions are taken into consideration, the presence of easterly component is higher than the southerly component in all the months except in August where the southerly component (pure katabatic wind) has higher percentage (46%) while the easterly component (extra-ordinary katabatic flow) is only 15%. Also the percentage of pure katabatic wind is significant in all the months except January and February. This may be due to the incidence of solar radiation for longer duration (nearly 22-23 hours per day) and as such the cooling of surface may be negligible in these months.

4. Case study of katabatic winds in different seasons

(*i*) *Transition period – Autumn (24-25 February 1990)*

The sky had been overcast in the forenoon hours on 24th February and the winds were from SE. In the evening the clouds dissipated and hardly one octa medium cloud prevailed till the forenoon of 25th February (Fig. 1). This

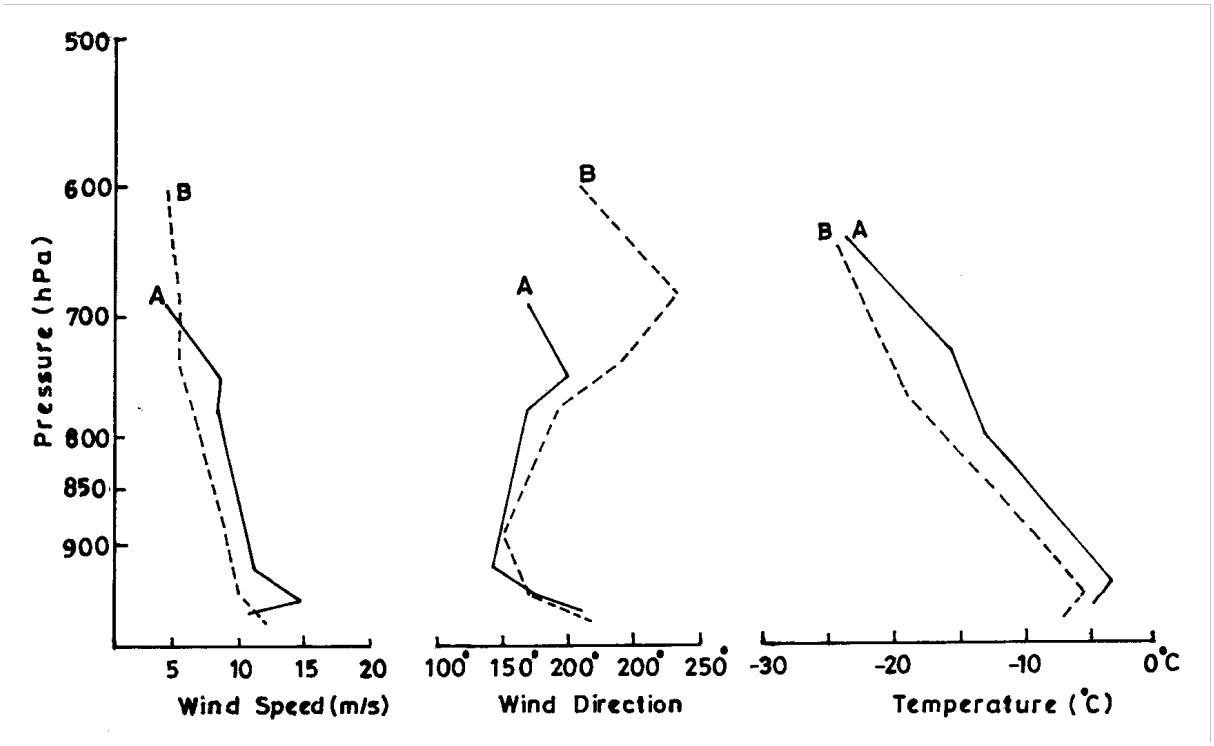


Fig. 2. Profiles of wind (direction & speed) and temperature on 25 February 1990 (curve A) and on 1 March 1990 (curve B) at Schirmacher Oasis

resulted in radiation cooling during night times and as a consequence pure katabatic flow started as evident from the change in the direction (SE to SSE) and increase in the strength of the wind. Further, the surface temperature fell sharply (from +1° C to –5° C) and as a result, an inversion occurred from surface to 954 hPa on 25th at 0000 UTC (Fig. 2).

On 28th February, observation (Fig. 3) showed that in the forenoon the sky was partly cloudy with medium clouds which dissipated to one octa by the afternoon. The radiation cooling in the late evening caused pure katabatic flow by midnight which can be noted from the change in wind direction (from ESE to SSE) and wind strength (from 10 knots to 25 knots). Also due to the pure katabatic flow, the surface atmosphere fell (from –3° C to –8° C) and an inversion occurred in the lower level of the temperature on 1st March at 0000 UTC (Fig. 2).

(*ii*) *Winter period (1 – 10 June 1990)*

The weather sequence during the period 1 June to 10 June 1990 is one of the best example to illustrate the pure katabatic flow and extra-ordinary katabatic flow. Being polar winter solar radiation is completely cut-off in this period and earth's surface cools considerably due to continuous loss of heat through long wave radiation. This

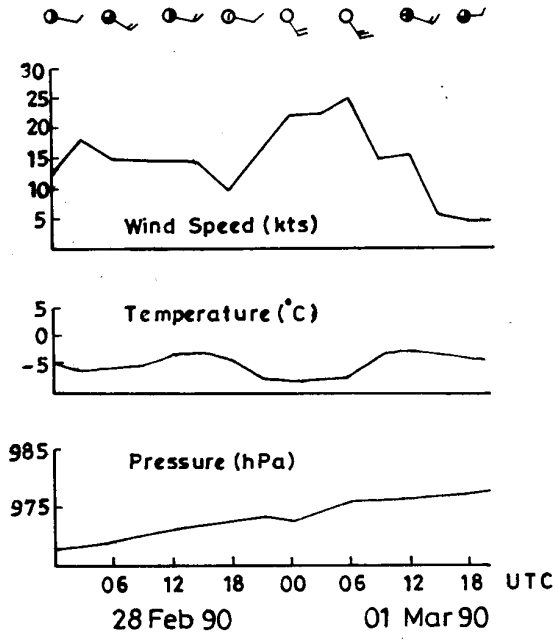
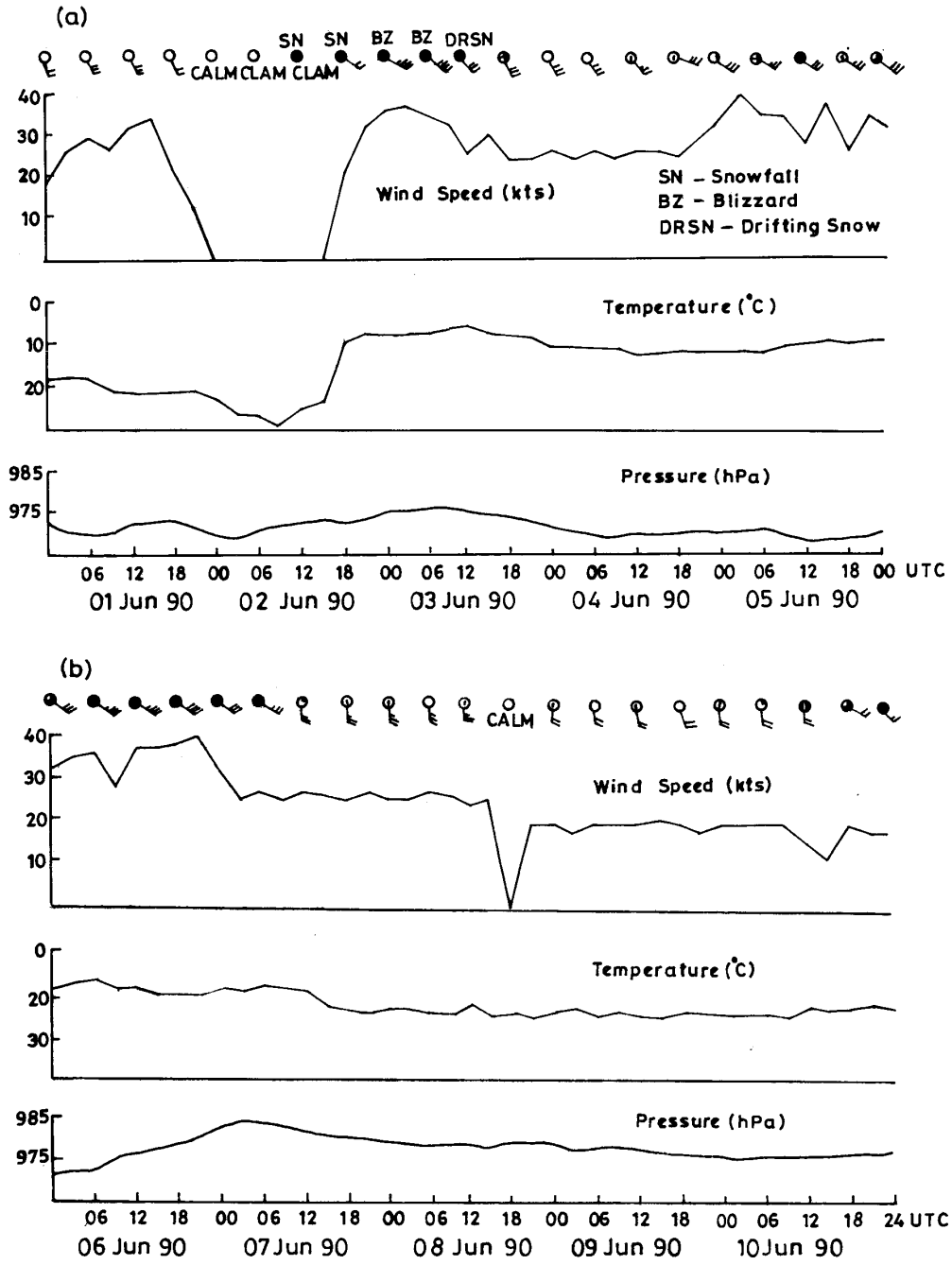


Fig. 3. Variation of wind speed, air temperature, station level pressure and sky conditions at Maitri during 28 February - 1 March 1990



Figs. 4(a&b). Variation of wind speed, air temperature, station level pressure and sky conditions at Maitri during (a) 1-5 June 1990 and (b) 6-10 June 1990

helps in the setting of pure katabatic flow during late evening and night time. The weather pattern changes with the passage of extra-tropical frontal systems in the middle latitudes which bring warm air and increased cloudiness over the station alongwith precipitation in the form of snow. Also wind pattern changes during this disturbed weather period. Figs. 4(a&b) shows the sequence of weather alongwith the wind speed, dry bulb temperature and surface pressure during 1-10 June 1990 at Maitri. Initially [Fig. 4(a)] the sky was clear and the surface

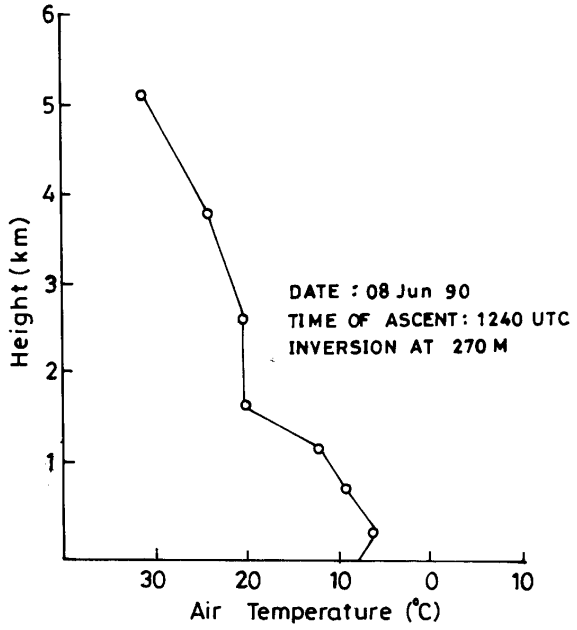


Fig. 5. Temperature profile showing good ground inversion on 8 June 1990 at Maitri

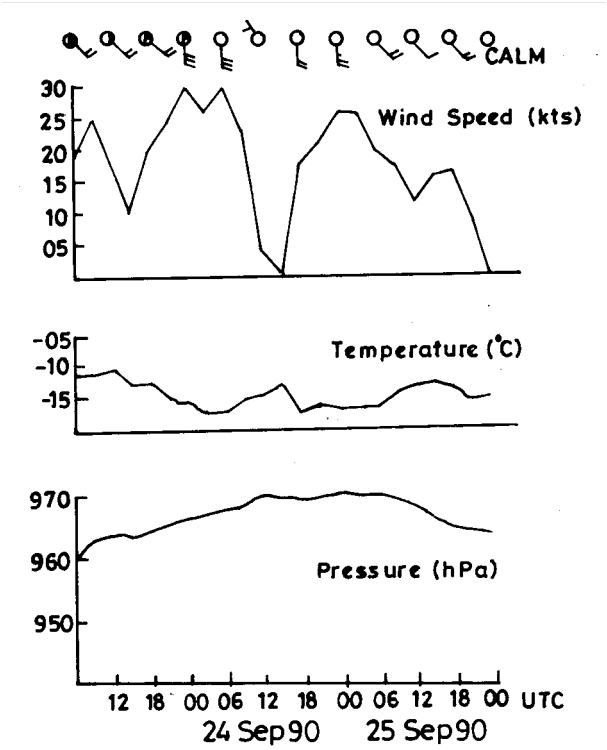


Fig. 6. Variation of wind speed, air temperature, station level pressure and sky conditions at Maitri during 23-25 September 1990

winds were from SSE with strength 20-30 knots indicating that pure katabatic flow was prevailing over the station. Due to this the surface temperature fell to –29° C from –18° C.

From the afternoon of 2 June there was a rapid change in the weather pattern over the station due to the extra-tropical frontal system in the middle latitudes. The sky became overcast and snowfall started. The wind speed increased to 20 knots from calm and direction became ESE to SE. Subsequently the wind speed further increased to 35 knots and the station reported blizzard. Due to the incursion of warm moist air from the lower latitudes the surface temperature rose to –6° C from –29° C. These features showed extra-ordinary katabatic wind was flowing over the station.

From 1500 UTC of 3 June [Fig. 4(a)] the wind direction changed to SSE from SE as the extra-tropical frontal system moved away towards higher latitudes. Also the wind strength decreased and was of the order of 25 knots. The sky became practically clear and due to the southerly wind the temperature gradually fell to –12° C from –6° C. These features show that pure katabatic flow was prevailing over the station.

From 0000 UTC of 5 June to 0900 UTC of 7 June [Fig. 4(b)] the wind direction again changed to ESE – SE and wind strength increased to the order of 35-40 knots due to the presence of another extra-tropical frontal system in the middle latitudes. The sky was generally overcast and the surface temperature rose to –7° C from –12° C. This sequence of weather pattern showed that the station was having extra-ordinary katabatic flow.

From 1200 UTC of 7 June to 0600 UTC of 10 June [Fig. 4(b)] the wind direction has become southerly and the speed decreased to 20-25 knots. The sky was practically clear and the surface temperature fell to –15° C from –8° C. The upper air sounding (Georg Forster) on 8 June 1990 (Fig. 5) showed the presence of good ground inversion upto 270 m due to the flow of cold katabatic flow from the higher icy plateau to the north.

(*iii*) *Transition period – Spring (23-25 September 1990)*

From 0600 UTC of 23 September winds were SE'ly with speeds 15-20 knots till 0000 UTC of 24 September (Fig. 6). The sky was partly cloudy which became clear by 0600 UTC of 24 September. Wind strength increased and remained between 20-30 knots till 0600 UTC of

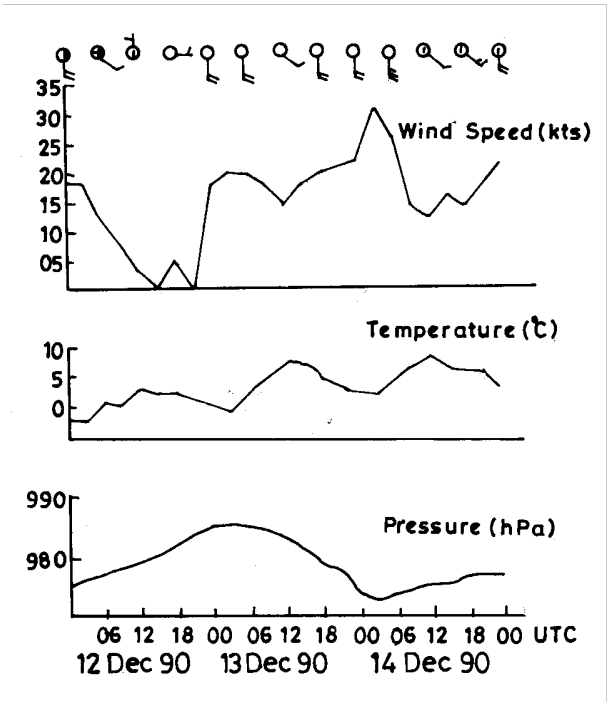


Fig. 7. Variation of wind speed, air temperature, station level pressure and sky conditions at Maitri during 12-14 December 1990

25 September (except for a few hours around 1200 UTC of 24th) and the direction was southerly. The temperature gradually fell from –11° C to –17° C. These features showed that the station was experiencing pure katabatic flow in this period.

(*iv*) *Summer period (12-14 December 1990)*

During summer, the icy continent receives about 22-24 hours of sunshine and so ground cooling is very little. Hence strong southerly wind could be observed in short intervals and Fig. 7 shows such a case in December 1990. Two spells of pure katabatic flow (*i*) during 0000 - 0600 UTC of 13 December 1990 and (*ii*) during 1800 UTC of 13th – 0600 UTC of 14th December 1990 can be observed from the figure. The associated fall in surface temperature is small as ground cooling is little due to prolonged solar radiation in this season.

5. Conclusion

Using the 13 months data of surface obsevations and self recording instruments collected during 9th Indian Antarctic Expedition the following preliminary conclusions may be drawn regarding the katabatic flow at Maitri, east Antarctica.

(*i*) Pure katabatic winds are observed in all the months with higher frequency in winter than summer and transition seasons.

(*ii*) The strength of the pure katabatic wind is stronger in winter than other seasons. Also in winter the duration of katabatic flow is longer.

(*iii*) Generally, the extra-ordinary katabatic flow is stronger compared to pure katabatic flow.

(*iv*) Pure katabatic winds being colder bring down the surface temperature considerably whereas extra-ordinary katabatic flow is warm and moist as it is in association with the extra-tropical frontal systems in middle latitudes.

(*v*) During winter, the likely occurrence of bad weather at Maitri can be inferred from the change in the katabatic flow pattern. The wind regime changes from pure katabatic flow to extra-ordinary katabatic flow with the approach of a transient frontal system in the middle latitudes. This causes warm moist air advection over the station and cloudy skies and usually results in snowfall and blizzard.

More years of observations are to be examined to confirm the above preliminary findings.

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