

The effect of atmospheric blocking high and ridges on weather over Maitri, East Antarctica – A case study

E. KULANDAIVELU, S. SRIDHARAN and S. R. RAMANAN

Regional Meteorological Centre, Chennai – 600 006, India

(Received 11 March 2003, Modified 18 August 2004)

सार – अंटार्कटिका में शीत और वसंत ऋतु में वायुमंडलीय अवरोध के कारण भारतीय अंटार्कटिक केन्द्र, मैत्री में एक सप्ताह से अधिक समय तक प्रबल धरातलीय हवाओं और धरातल के तापमान की अनियमितताओं सहित लगातार बर्फानी तूफान अक्सर आते रहते हैं। अगस्त 2000 के अंतिम सप्ताह के ऐसे ही एक मामले और जलाई 1996 के मध्य के एक अन्य मामले के संबंध में अध्ययन किए गए। शीत और वसंत ऋतु के महीनों में अवरोध की गतिविधियाँ अधिक पाई गई हैं। इस अध्ययन की अवधि के दौरान मौसम प्राचलों पर पाए गए अत्याधिक अवरोध के तीव्र प्रभाव के संबंध में भी बताया गया है।

ABSTRACT. The Indian Antarctic station, Maitri is often experiencing continuous blizzard over a week with strong surface winds and surface temperature anomalies due to atmospheric blocking during winter and spring seasons of Antarctica. One such case during the last week of August 2000 and another case in mid-July 1996 are studied. There is more blocking activity in winter and spring months. The influence of blocking high on weather parameters during the study period is also presented.

Key words – Blizzard, Blocking, Geopotential height, Ridge and advection.

1. Introduction

Atmospheric blocking is a well-documented mid-latitude weather phenomenon and has been studied by many authors. Blocking is defined as a continuous occurrence of high geopotential height for a relatively long time in a confined region (Hartmann & Ghan 1980). Tanaka (1998) defines the atmospheric blocking as abnormally persistent, quasi-stationary anticyclone that blocks the mid-latitude jet stream and the onset of blocking is triggered by Rossby wave breaking.

Ordinary low and high-pressure systems associated with traveling synoptic waves have a typical lifetime of a few days. Blocking is abnormal, in that the anticyclone stays for one to two weeks at a fixed geographical location against the strong westerly waves. Its lifetime is slightly longer than that of the synoptic disturbances. Once a block is formed within a jet stream, the mobile synoptic waves superimposed on the westerly are blocked by the abnormally persistent high pressure system. This is why the system is called 'blocking' (Elliott and Smith, 1949 and Rex, 1950a,b).

A blocking anticyclone forms at latitudes higher than where the normal sub-tropical high forms and is frequently accompanied by a cutoff low in low latitudes.

However, in the Southern Hemisphere (S.H), blocking highs tend to have a shorter life time than in the Northern Hemisphere (N.H) and form at somewhat lower latitudes in general (Van Loon, 1956; Taljaard, 1972).

Another characteristic feature widely recognized is that even when a blocking high does break down or move away, there is a marked tendency for another high to form and intensify in the same location (Taljaard, 1972; Wright, 1974). Blocking in a barotropic atmosphere can occur as a result of resonant enhancement of Rossby lee waves forced by two stationary sources of potential vorticity (Kalney and Merkine 1981). Resonant interactions among planetary scale waves may be an important physical mechanism in generating certain atmospheric blocking (Colliucci *et al.*, 1981). A block may be initiated by a deep cyclonic storm development, which locks the flow pattern into a blocking equilibrium, or *vice versa*, when it drives the flow out of a blocking equilibrium (Charney *et al.*, 1981).

Berggren *et al.* (1949) demonstrated that the establishment of a blocking is connected with deepening of a number of synoptic-scale cyclones west of the blocking ridge. Later this eddy forcing mechanism has been explained theoretically by Shutts (1983). During recent years it has also been shown that planetary-scale

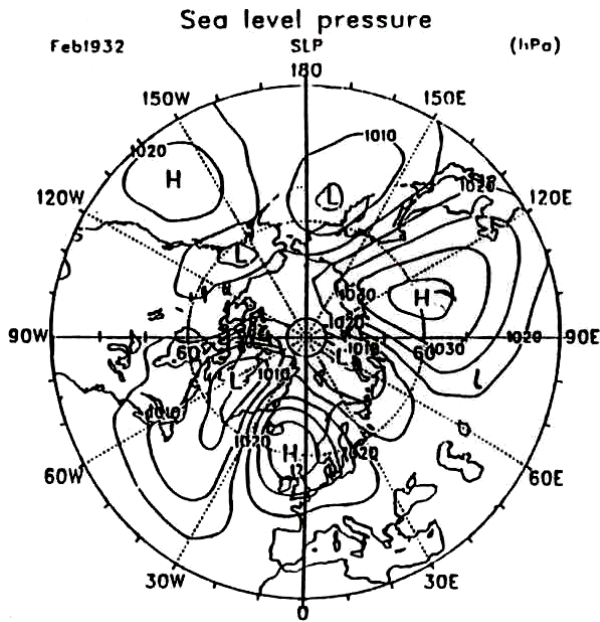


Fig. 1. Location of blocking high in N.H. (Reproduced from Lejenas, 1995; *J. Met. Soc., Japan*, 73, 1, 79-89)

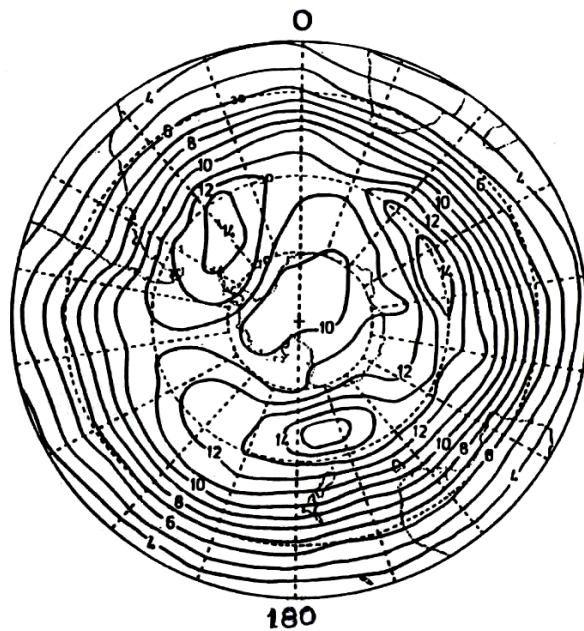


Fig. 2. Location of blocking high in S.H. departures from the mean of 500 hPa geopotential height for May 1972 – Jan 1978. (Reproduced from Trenberth, 1981b. *J. Atmos. Sci.* 38, 2585-2605).

waves influence atmospheric blocking (Lejenas and Madden, 1989). Using barotropic channel model, Egger (1978) showed that blocking could result from the nonlinear interaction of forced stationary waves with

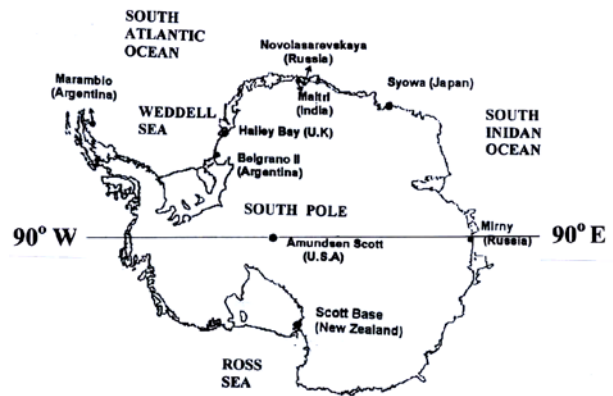


Fig. 3. Location of Maitri in Antarctica

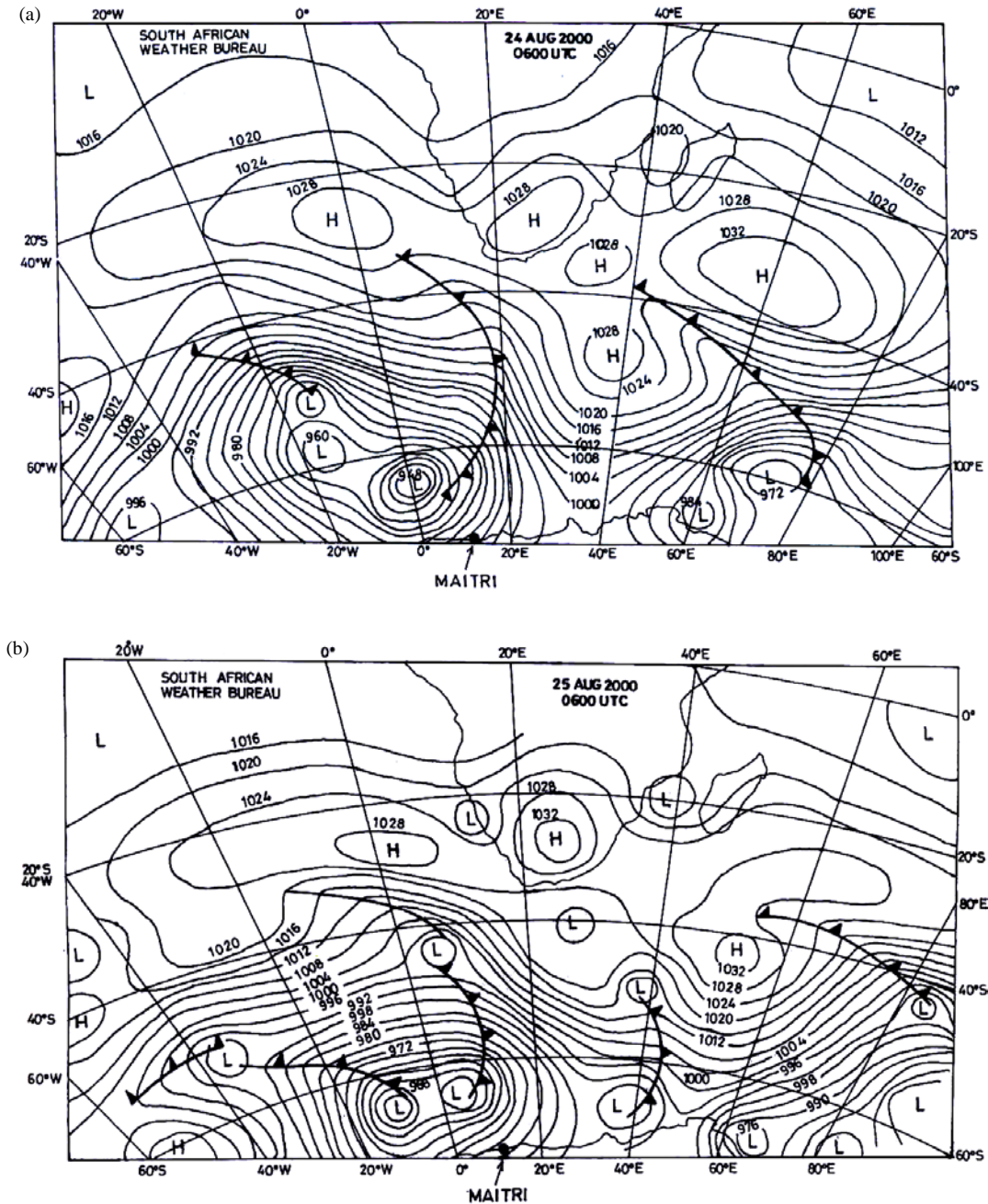
slowly moving free waves. Using equation of motion Hasanean and Hafez (2003) explained how the main westerly air current splits into two branches leading to the formation of blocking high.

2. Climatology of blocking

Early investigators (Berggren *et al.*, 1949; Elliott and Smith, 1949; Rex, 1950a, b) established the synoptic behavior and climatology of blocking. According to Rex (1950a), blocking exists when the basic westerly current at upper level splits into two branches, with each branch transporting appreciable mass. The double-jet system must extend over atleast 45 degrees of longitude. A sharp transition from zonal type flow upstream to meridional flow downstream must be observed across the current split and this pattern must persist for atleast ten days. Rex (1950b) noted that blocking occurs most frequently over the northeastern portions of Atlantic and Pacific Ocean (Fig. 1), normally persists for 12 – 16 days, and is relatively stable in position. The climatological mean position of the block is just downstream from the normal positional of the major mid-latitude jet streams. A pronounced warming occurs in the northern part of the blocked zone with cooling in the southern part in the N.H.

Trenberth and Mo (1985) have pointed out that the primary location for blocking in the S.H. is in the New Zealand sector and blocking occurs through a local enhancement of the climatological split in the mean westerlies on a spatial scale of 60 degree longitude. Other maxima occur southeast of South America and over southern Indian Ocean. Marques and Rao (2001) found a second region of frequent blocking over the southeast Pacific in S.H.

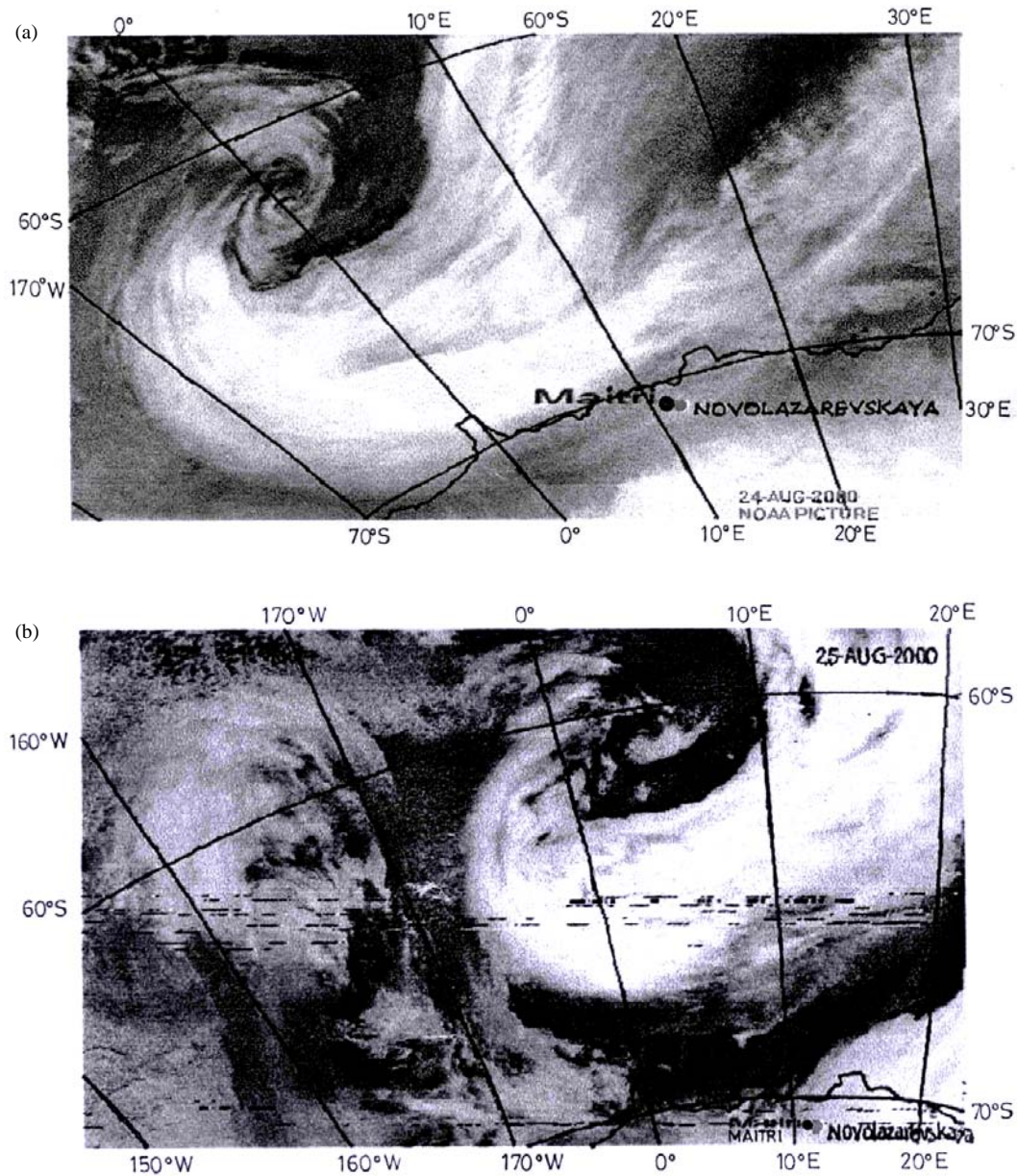
Blocking episodes were identified as persistent highs having central pressure exceeding normal value of mean sea level (MSL) pressure by more than 20 hPa. In most



Figs. 4(a&b). Surface weather chart on (a) 24 August 2000 and (b) 25 August 2000 during blocking high

studies of characteristics of atmospheric blocking 500 hPa geopotential height data have been used. Outside of the Indian Ocean, the geopotential height variance is a maximum where blocking high alternate with cyclones, whereas the transient kinetic energy has a maximum much further north in association with disturbances over all three southern oceans and cutoff cold-centered lows

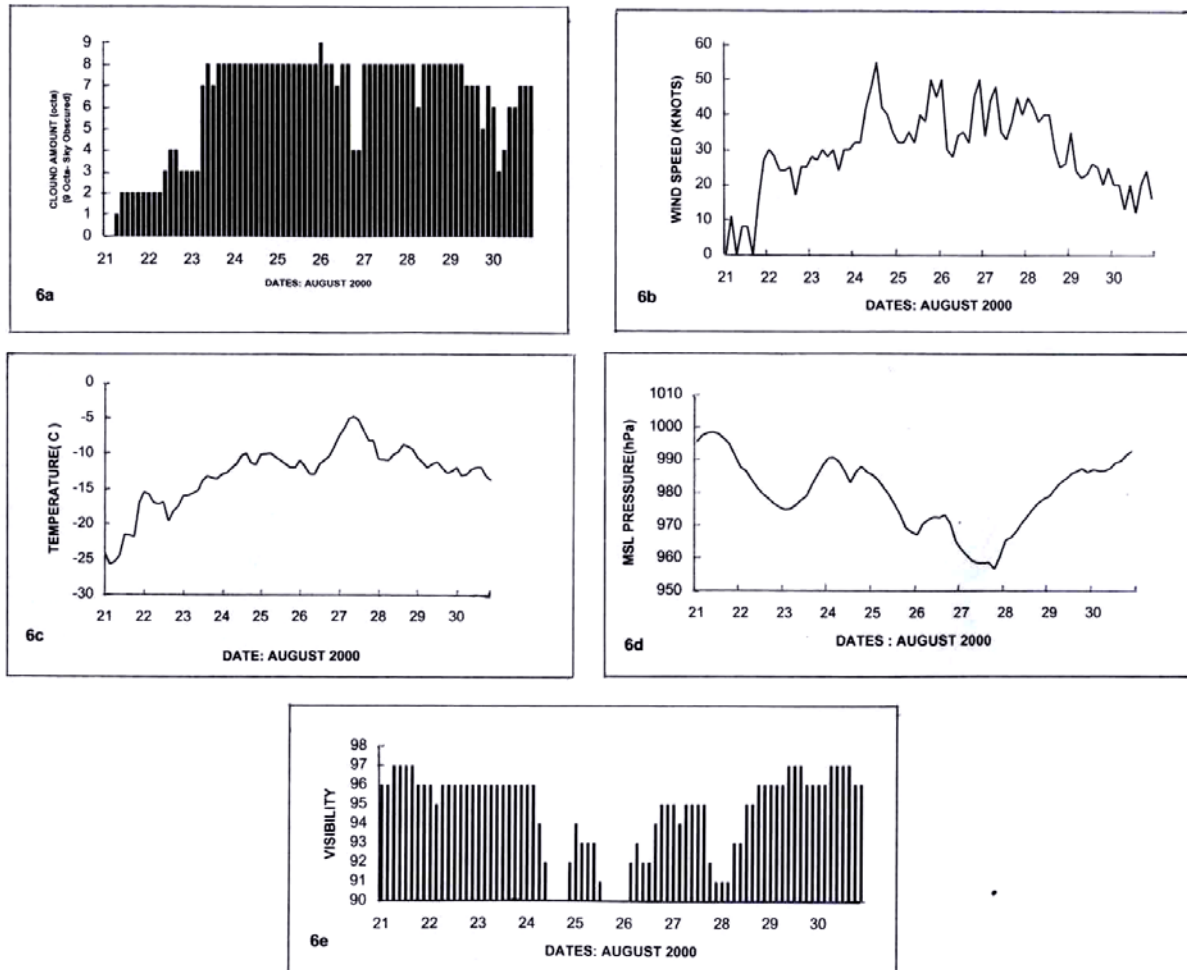
(Trenberth, 1981b). Broadly, such studies based on investigation of persistent positive 500 hPa geopotential height anomalies (Fig. 2) and studies focusing on characteristic features of 500 hPa flow field during a blocking. The study done by Lejenas (1995) shows the frequency of blocking in winter is higher than that of in summer in both hemispheres.



Figs. 5(a&b). NOAA Satellite picture during blizzard on (a) 24 August 2000 and (b) 25 August 2000

Indian Antarctic Scientific Research Station Maitri ($70^{\circ} 45' 39''$ S, $11^{\circ} 44' 48''$ E) (Fig. 3) in east Antarctica was established in 1989 and meteorological observations are being taken since January 1990. Meteorological data show that Maitri generally experienced bad weather whenever there was a low-pressure system moving towards east in the vicinity of the station. Blizzard with strong surface wind and very poor visibility put hardship to the scientists in carrying out their work outside. The

blizzard some times continued 2 – 5 days in the presence of atmospheric blocking high and ridges located about 40° E during winter and spring seasons. The surface air temperature shot up abnormally high about 10 degree Celsius or more, One such case of situation that occurred at Maitri during 22 – 29 August 2000, and another occasion during 17 – 27 August 1996 have been studied. The eddies and lows moving around close to the icy continent blocked by a ridge which extended from the



Figs. 6(a-e). Variations of meteorological parameters, viz., (a) Cloud amount, (b) Wind speed, (c) Surface air temperature, (d) MSL pressure and (e) Visibility at Maitri during 21-30 August 2000

mid-latitude blocking high in Indian Ocean region has been analysed. The wind was very strong and the surface temperature shot up by 20 degree Celsius.

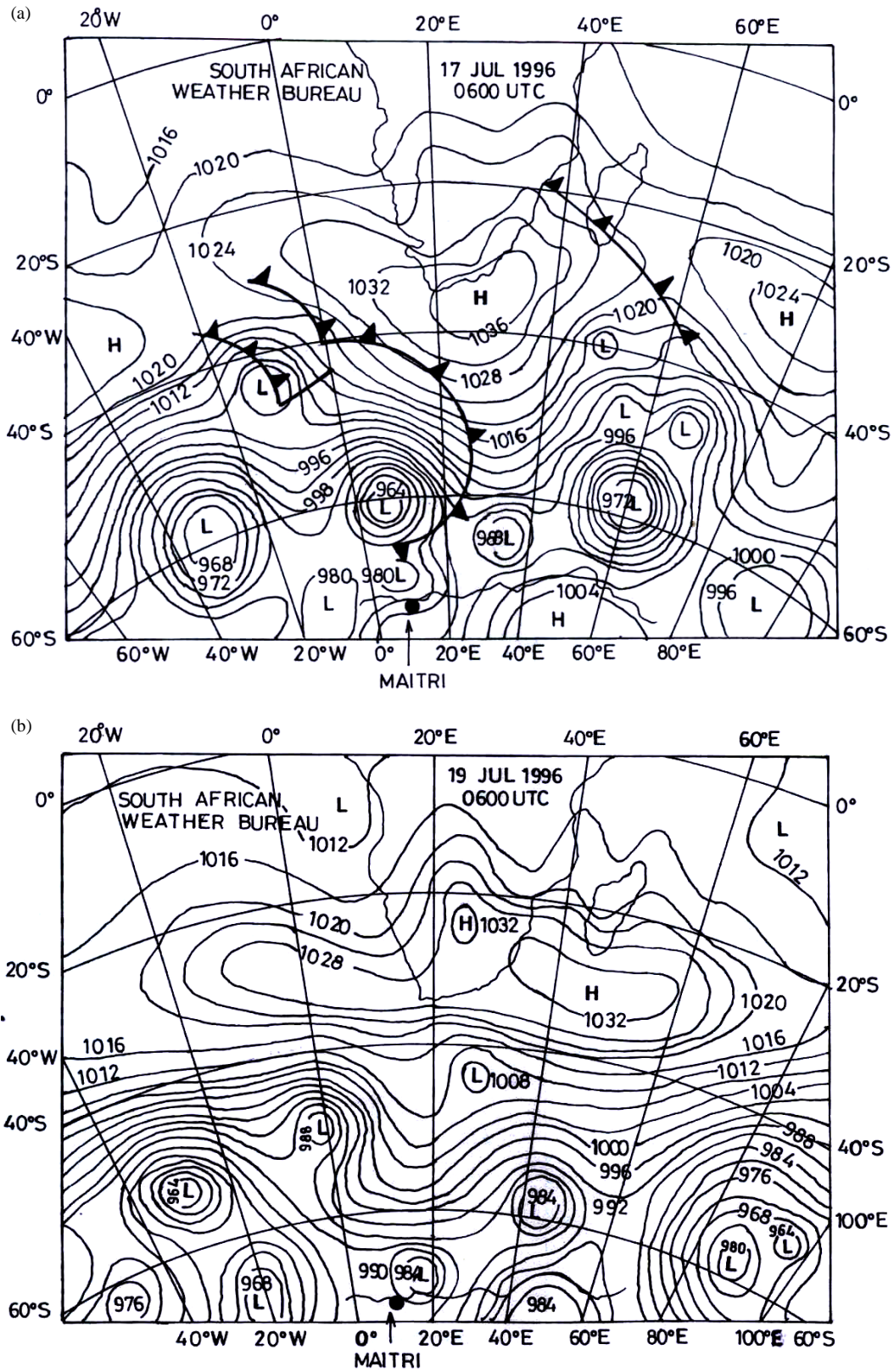
3. Data

Three hourly synoptic observations of Maitri, sea level analysed chart received from South African Weather Bureau, Cape Town and cloud imageries of NOAA satellite are considered for the study.

4. Synoptic conditions during blocking high period 22 – 29 August 2000

Surface level analysed chart on 24 and 25 August 2000 are shown in Figs. 4 (a&b). On 24 August, the 'high' with central pressure 1032 hPa over Indian Ocean at about

35° S, 60° E and another high with 1028 hPa at about 50° S, 40° E were present. The ridge from the high extended from 50° S to 70° S. One more high with 1028 hPa was also present in the Atlantic Ocean. Three eddies associated with extra-tropical systems were also present. One front extending from 40° S, 40° E to 60° S, 80° E in the Indian Ocean, the second one from 35° S, 5° E to 65° S, 7° E having usual frontal curvature were present. The third one is small and far away from the icy continent. A strong low-pressure with central pressure 948 hPa was present at 64° S, 0° E. With this synoptic condition, the cloud imagery of NOAA-12 on 24 & 25 August is shown in Figs. 5(a&b). The imagery shows the system has moved little towards east in the same latitude. This confirms the ridge has moved towards east. However, the mid-latitude sub-tropical high was in the same original position. This high was in the same position for about 10 days till the end of August 2000.



Figs. 7(a&b). Surface weather chart on (a) 17 July 1996 and (b) 19 July 1996 during blocking high

5. Variation of various Meteorological parameters during 21 – 30 August 2000

Using 3 hourly synoptic observation data, variations of (a) Sky condition (b) Wind Speed (c) Surface air temperature (d) MSL pressure and (e) Visibility during 21 to 30 August 2000 are presented in the Figs. 6 (a-e).

5.1. Sky condition

The histogram Fig. 6(a) shows the sky was almost overcast from 1500 UTC of 23 August to 0600 UTC of 29 August 2000 except few hours. The sky was covered mainly by medium cloud altostratus. This is due to eddy moving towards east, which was blocked by the ridge, and hence the cloudiness prolonged for a long period instead of one or two days.

5.2. Wind speed

During winter at Maitri, the wind blows normally from ESE/E'ly direction. Whenever there is an extra-tropical system in the vicinity of East Antarctica, the direction of wind changes to SE from E/ESE. The wind during the blocking period is shown in Fig. 6 (b). On 22nd the wind was more than 20 kts. When the low pressure was close to the station the wind became very strong and touched maximum speed of 55 kts with maximum gustiness of 78 kts. The strong wind continued till 29th. Due to this strong wind, blizzard prevailed for four days between 24 and 27 August 2000.

5.3. Surface air temperature

Abnormally high surface temperature in the interior of Antarctica was usually associated with strong inland advection of warm, moist air. Warm advection is an important factor of the Antarctic heat budget. Poleward transport of sensible and latent heat is the major process, which counters the radiative loss of heat in winter (Schwerdtfeger, 1970). High temperature was associated with intrusions of warm air, which penetrated the continent from the Atlantic and Indian Ocean sectors. The incursion of warm air gave rise to high temperature at East Antarctica (Mark, 1981). The rise of surface air temperature during the blocking period is shown in Fig. 6(c). The surface temperature was less than -25°C on 21st slowly shot upto more than -5°C on 27th due to continuous advection of warm moist air from the lower latitudes to East Antarctica coast. The nature also released its latent heat while condensation in the form of snowfall in the continent.

5.4. MSL pressure

The MSL pressure of Maitri during the blocking period is presented in Fig. 6 (d). The movement of low pressure systems and eddies slowed down due to the presence of ridge at 40°E . The isobars were very close and the pressure gradient was abnormally high.

5.5. Visibility

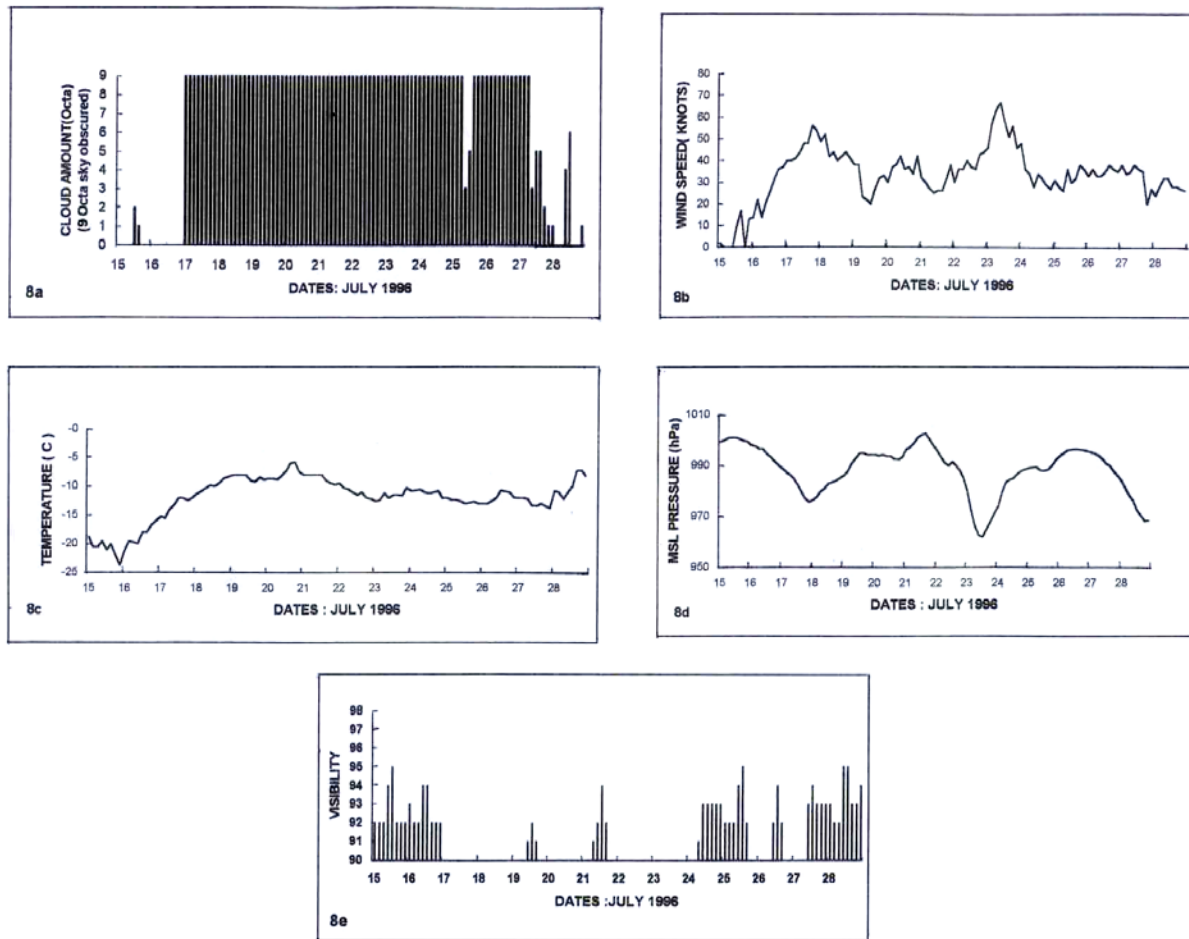
The visibility is an important meteorological parameter at Antarctica. A sudden surge of wind more than 25 kts can cause poor visibility less than 1000 m. This is mainly due to the availability of loose snow in the coastal areas and carried by strong winds horizontally. When the low pressure system passes close to the station the coastal areas receive the precipitation as snowfall. The strong surface wind lifts the snowfall from one area to another and reduces the visibility. During strong blizzard on 24 – 26 August 2000, the visibility reduced to zero [Fig. 6(e)]. During the other times the visibility is good except on 28th, when it reduced to 1000 m due to drifting snow (lifting of snow below eye level).

6. Synoptic conditions during blocking period 15 – 28 July 1996

Analysed surface weather charts received on 17 and 19 July 1996 are shown in Figs. 7(a&b). On 17 July there were three sub-tropical highs present; one in the south Atlantic Ocean and two in the south Indian Ocean. The prominent high with 1036 hPa was located at 35°S , 25°E and the associated ridge extended from this high to 60°S . Another high in the Indian Ocean with 1024 hPa was at 30°S , 80°E . Three extra-tropical low pressure systems were also present along 60°S around the East Antarctica. Four more eddies were also associated with these low pressure systems close to the coast. Continental high of 1004 hPa was present around 75°S , 50°E . The high moved east and positioned between 40°E and 60°E around 30°S on 19 July and persisted for more than a week till the end of the month. The associated ridge from the centre of the high extended towards south upto 60°S . Because of this ridge Maitri experienced a prolonged bad weather with strong winds and poor visibility during 17-27 July.

7. Variations of various meteorological parameters during 15 – 28 July 1996

Using 3 hourly synoptic observation data of Maitri, variations of (a) Sky condition (b) Wind speed (c) Surface air temperature (d) MSL pressure and (e) Visibility during 15 - 28 July 1996 are presented in Figs. 8(a-e).



Figs. 8(a-e). Variations of meteorological parameters, viz., (a) Cloud amount, (b) Wind speed, (c) Surface air temperature, (d) MSL pressure and (e) Visibility at Maitri during 15-28 July 1996

7.1. Sky condition

The histogram Fig. 8 (a) shows that on 15 and 16 July except for a few hours clear condition prevailed. From 17 to 27 July the entire sky was obscured may be due to blizzard raised by very strong surface winds during the movement of eddies towards east close to the continent which was blocked by the ridge and hence the bad weather continued for a longer period.

7.2 Wind speed

The wind speed during the blocking period is shown in Fig. 8(b). The wind direction at Maitri varied mainly between ESE to SE directions. However on 28th the wind was from SSE due to katabatic flow from the icy continent. There are two peaks in the wind speed curve one on 17th with maximum speed of 56 kts and another on 23rd with maximum speed of 67 kts. The winds were very strong due to the passage of two synoptic systems blocked

by the formation of ridge about 45° E from primary high at 40° S. The blizzard was continued till 1300 UTC on 27th. On the evening of 27th the wind changed from SE to southerly direction and the sky cleared by dry cold katabatic flow from the continent and hence the visibility improved over 1000 m.

7.3. Surface air temperature

The rise of surface air temperature during the blocking period is shown in Fig. 8(c). During peak polar winter season in July, the surface air temperature at Maitri normally is well below -25°C . With the passage of synoptic system around the continent, the strong winds brought the warm moist air from the lower latitude towards coastal region of East Antarctica, the surface temperature increased from -24°C on 15 July to -6°C on 20 July and later the temperature was between -10°C and -13°C .

TABLE 1

Frequency of Blizzard at Maitri during 1996 and 2000

Month	1996		2000	
	No. of days	Frequency	No. of days	Frequency
January	1	1	0	0
February	0	0	0	0
March	4	4	2	3
April	7	4	4	4
May	13	9	3	2
June	9	7	2	2
July	15	6	2	2
August	4	2	9	3
September	10	9	2	1
October	3	2	3	2
November	2	2	4	3
December	4	2	0	0

7.4. MSL pressure

The MSL pressure curve Fig. 8(d) during the blocking period at Maitri shows the passage of two low pressure systems successively in the vicinity of the station. The first system resulted in the lowest MSL pressure of 975.1 hPa on 17th and the second system brought the pressure further down to 965.2 hPa on 23 July. The movement of low pressure systems and eddies slowed down due to the presence of ridge at 45° E.

7.5. Visibility

During the strong blizzard period 17 – 27 July 1996, the visibility was very poor and reduced to less than 50m and occasionally to zero mainly due to lifting of loose dry snow by very strong surface winds. The Fig. 8(e) shows improvement of visibility on 24th mainly due to non-availability of loose snow. However with the commencement of blizzard again on 25 July the visibility was very poor again till mid-day of 27th. The visibility became normal on 28th mainly by katabatic flow from southern high plateau.

8. Blizzard

Antarctica is the home of blizzard. Generally blizzard is associated with strong surface wind with snowfall. Sometimes it may occur during strong surface wind lifting the loose dry snow available in the continent and transporting from one place to another. At Maitri the

blizzard usually occurs when a low-pressure system crosses the vicinity of the station associated with strong surface wind. The frequency of blizzard during 1996 and 2000 is listed in Table 1. Most of the time it was within two days. Only once each in July 1996 and August 2000 the blizzard persisted for more than a week. This is because of blocking high around 40° E, which decreased the movement of low pressure eddies towards east in the Indian Ocean area. Most of the blocking high at 40° E gives a lot of bad weather like blizzard and warms the inland stations by advection of warm moist air from lower latitudes. Blizzards are more in winter and spring months than in summer. No blizzard was experienced in summer months of January, February and December in 2000.

9. Conclusion

Blocking high at 40° E in the south Indian Ocean region affects the normal weather condition at Maitri, East Antarctica coast. The blocking high generates blizzard with strong surface wind over the East Antarctica coast over a good number of days. The surface temperature shoots up gradually till the ridge disappeared or moved eastward. The study confirmed that the bad weather experienced continuously for more than five days at Maitri, East Antarctica is mainly due to the low pressure system moving eastwards close to the continent in association with blocking high formed between 40° E and 60° E in the south Indian Ocean in the Southern Hemisphere.

Acknowledgements

The authors are grateful to the referee for the valuable suggestion for improving the quality of the paper.

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