9. THE KATABATIC WIND AT MAWSON IN JUNE 1970

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In a discussion about extremely strong winds encountered in some areas of the Antarctic continental coastline, Loewe (1972) gave a concise account of the coastal katabatic wind phenomenon. He noted, however, Mather and Miller's (1967) conclusion that the reasons for the very high wind speeds have not yet been found.

For the synoptic meteorologist the problem is essentially one of deciding the degree to which the reported surface wind at an Antarctic continental station can be regarded as representative of the broad-scale flow pattern in the area, or, expressed another way, endeavouring to establish the degree to which the katabatic wind phenomenon in the Antarctic is independent of the prevailing pressure gradients. No satisfactory conclusions have been reached. Prior to the advent of the cloud observing satellite, it was impracticable to locate cyclone centres over the ocean with adequate accuracy to permit a meaningful study being made of the observed surface wind at a coastal station in relation to the broader-scale pressure field. Hence, even though a strong down-slope surface wind might be observed at a given station, the reason for this could not be given.

The Basic Data Set for June 1970 has been used for a synoptic examination of the low level wind behaviour because this is a mid-winter month and therefore should be representative of conditions over a significant part of the year, and also because of the extensive application of satellite data, including satellite cloud photographs.

It must be admitted that the interpretation of the cloud photographs over the high southern latitudes in winter is not easy, and in any case the photographs only enable the probable positions of the cloud vortexes to be determined with greater confidence. No quantitative assessment of the depth of the cyclones can be made. The chart sequence has been re-examined, and whilst minor modifications could perhaps be suggested, no major changes in positioning cyclone centres have been considered necessary. This study is confined to Mawson (67^{o} 36'S, 62^{o} 53'E) because of the ready availability of supplementary data, and also because the katabatic wind phenomenon is a particularly well-marked feature there.

In an attempt to establish some synoptic features of the Antarctic katabatic wind, Phillpot (1968) examined wind shears between the surface and the 850 mb (1 km approximately) level. He defined the "effective pure katabatic wind" as the shear between a zero 850 mb wind and the surface wind *ie*, the "effective pure katabatic" is the particular boundary layer wind experienced under zero pressure gradient conditions in the free air.

This concept is now extended to examine the vertical wind shear behaviour in the surface boundary layer. As mentioned, the 850 mb level falls near the 1 km level and it is assumed that conditions at this height are reasonably representative of the free air, or at least are above the surface katabatic-affected layer. If $\tilde{V}_S$ is the surface wind vector and $\tilde{V}_{850}$ the 850 mb wind vector, the difference ($\tilde{V}_S$-$\tilde{V}_{850}$) is the boundary layer wind.

At Mawson the run of the coastline is from 230^{o} to 050^{o} (Fig 9.1) and the ice slope is from 140^{o}E (Mather, 1960) hence the boundary layer winds falling clearly seaward may be regarded as katabatic winds, whilst those falling on the continental side may be regarded as non-katabatic winds

For each upper wind flight made at Mawson in June 1970, the surface wind vector ($\tilde{V}_S$), the 850 mb wind vector ($\tilde{V}_{850}$) and the boundary layer wind $\tilde{V}_S$-$\tilde{V}_{850}$ are shown in Table 9.1. The boundary layer winds have also been plotted on a polar coordinate diagram (Fig 9.2). Of the 86 upper wind flights made during the month, the boundary layer winds in 56 cases (65%) could be classed as katabatic winds, 18 (21%)

Table 9.1 The reported winds at the surface level (V_S), at the 850 mb level (V_{850}), and the vector difference (V_S-V_{850}), at 0000, 0500 and 1200 GMT daily in June 1970 at Mawson. Speeds in ms^{-1}.

Each flight is classified as Katabatic (K) non-katabatic (NK) or doubtful (D) according to whether the shear wind vector ($\tilde{V}_S-\tilde{V}_{850}$) falls seaward of, inland of or close to, the coastline (see text).

Time of flight :	0000 GMT				0500 GMT				1200 GMT			
Date	$\tilde{V}_S$	$\tilde{V}_{850}$	$\tilde{V}_S-\tilde{V}_{850}$	Class	$\tilde{V}_S$	$\tilde{V}_{850}$	$\tilde{V}_S-\tilde{V}_{850}$	Class	$\tilde{V}_S$	$\tilde{V}_{850}$	$\tilde{V}_S-\tilde{V}_{850}$	Class
1	140/14	C	140/14	K	140/13	085/3.5	154/11	K	140/13	090/06	164/10	K
2	140/07	018/01	148/08	K	130/05	080/01	142/04	K	140/06	C	140/06	K
3	160/09	013/02	166/11	K	160/06	079/02	175/06	K	180/10	171/03	184/07	K
4	140/12	080/02	150/11	K	140/13	014/01	144/14	K	160/11	212/04	138/09	K
5	150/10	183/1.5	144/09	K	140/15	121/04	148/11	K	150/11	128/08	188/05	K
6	140/12	108/12	215/07	D	160/11	091/08	202/11	K	160/12	086/06	188/12	K
7	220/05	097/07	253/10	NK	160/13	099/11	212/12	D	140/14	098/06	165/10	K
8	140/10	114/08	188/05	K	150/09	110/06	195/06	K	160/17	104/3.5	171/15	K
9	160/12	139/03	167/09	K	140/11	084/10	202/08	K	140/13	078/12	194/13	K
10	150/11	066/3.5	168/11	K	140/14	110/11	192/07	K	140/12	058/06	167/13	K
11	-	-	-	-	160/07	C	160/07	K	160/11	283/01	156/12	K
12	170/08	212/05	138/06	K	230/01	138/06	308/06	NK	240/01	099/10	275/10	NK
13	180/05	101/08	246/09	NK	C	119/06	299/06	NK	150/10	225/04	125/10	K
14	190/10	110/05	218/10	D	C	139/13	319/13	NK	270/09	152/14	309/20	NK
15	170/14	104/04	189/13	K	-	-	-	-	120/09	103/11	233/03	NK
16	160/10	088/03	176/09	K	170/07	122/2.5	189/06	K	160/12	252/03	145/13	K
17	130/12	120/06	140/06	K	150/12	137/08	174/05	K	150/12	121/06	175/07	K
18	210/03	127/16	296/16	NK	140/07	102/13	253/09	NK	C	116/13	296/13	NK
19	120/04	100/11	269/07	NK	C	113/11	293/11	NK	190/05	151/06	280/04	NK
20	170/08	139/09	249/04	NK	-	-	-	-	170/10	171/01	170/09	K
21	270/01	151/05	294/05	NK	C	204/05	024/05	NK	220/03	199/05	349/02	NK
22	130/24	063/12	161/22	K	130/29	077/26	187/25	K	130/23	158/3.5	125/18	K
23	-	-	-	-	150/10	229/02	138/10	K	160/06	190/03	132/04	K
24	170/11	178/04	166/07	K	140/15	080/07	168/13	K	130/18	066/14	180/14	K
25	130/18	089/21	212/14	D	130/12	087/17	221/11	D	140/09	082/05	176/08	K
26	140/11	129/02	143/09	K	140/09	158/05	119/04	K	140/05	083/06	212/05	D
27	140/15	084/08	173/13	K	130/13	094/10	181/08	K	120/15	086/26	234/16	D
28	130/25	098/30	222/16	D	130/25	094/28	212/17	D	130/26	079/20	180/21	K
29	140/24	092/21	196/18	K	140/21	088/11	173/17	K	130/18	087/17	194/13	K
30	120/16	087/28	235/17	D	120/17	088/25	228/14	D	130/20	089/30	228/20	D

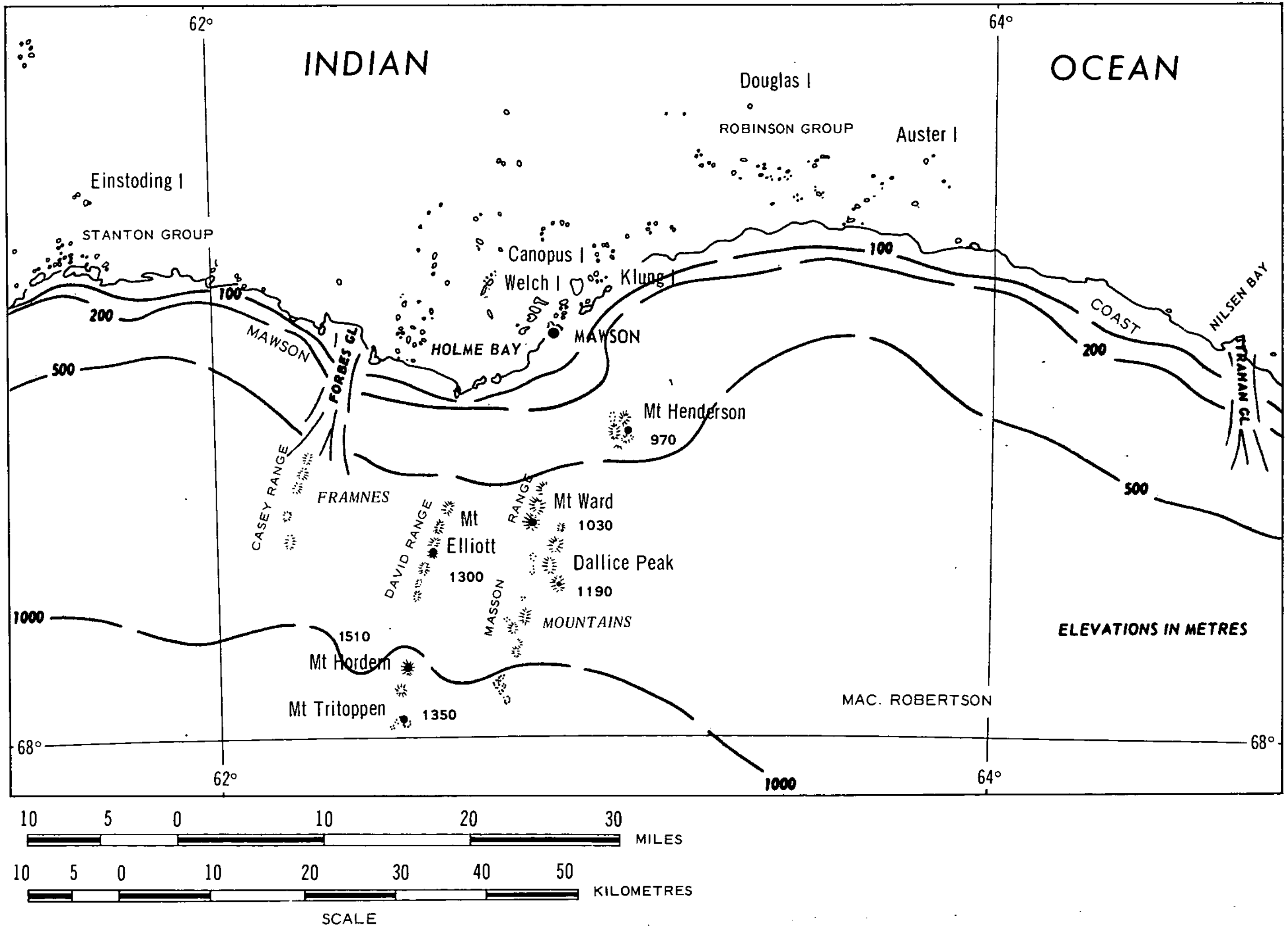


Fig 9.1 The coastal sector of Antarctica in the vicinity of Mawson.

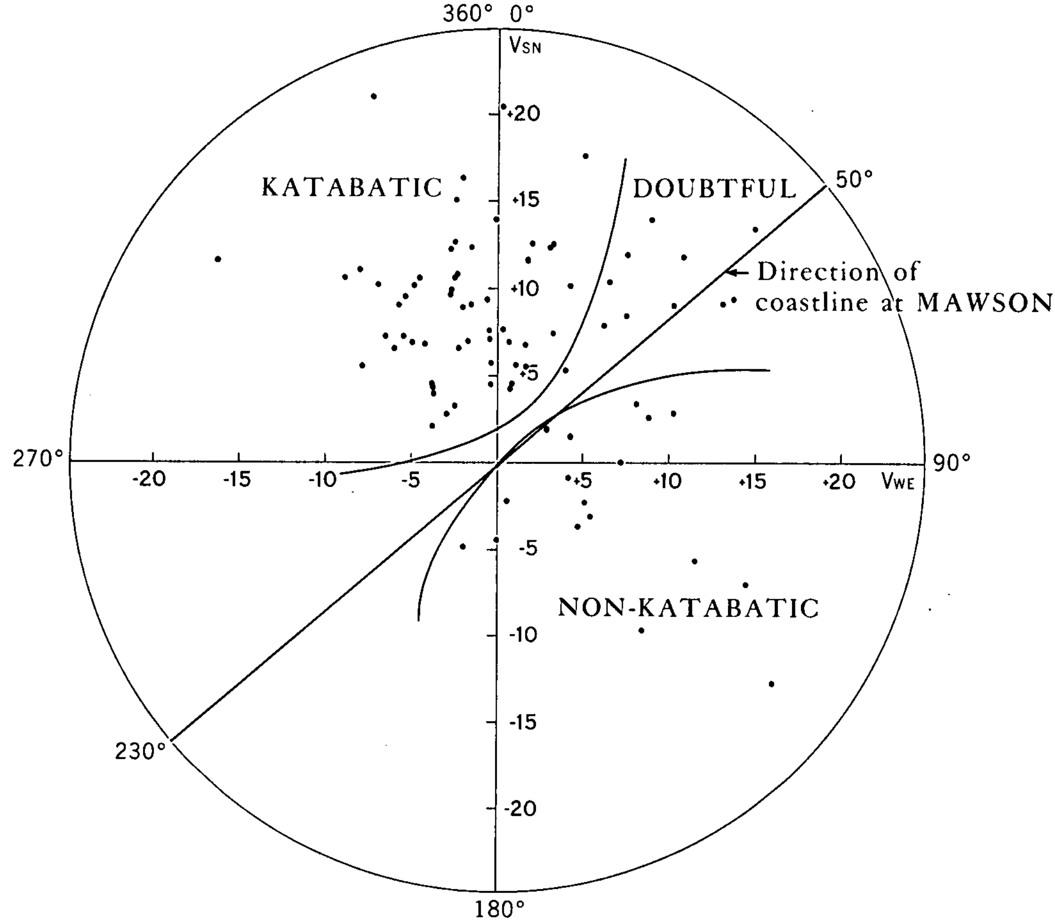


Fig 9.2 The distribution of the end points of the wind vectors ($\tilde{V}_S - \tilde{V}_{850}$) derived from the upper wind flights made at Mawson in June 1970. The end points of the shear (boundary layer) winds falling seaward are considered to be katabatic, those inland non-katabatic and those near the coast doubtful. Units: m sec^{-1}.

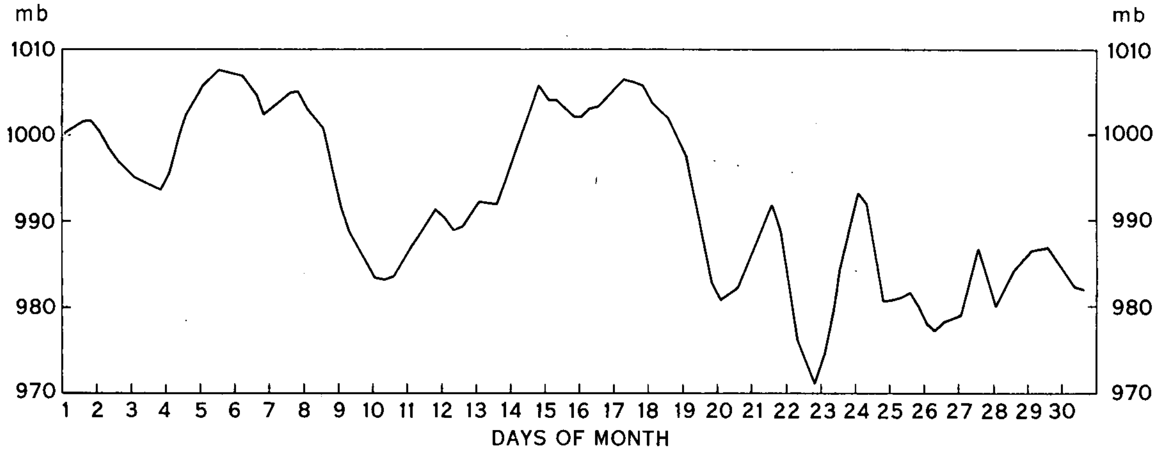


Fig 9.3 The variation in surface pressure at Mawson in June 1970.

could be classed as non-katabatic, and in the remaining 12 cases (14%) the shears fell close to the coastline and have therefore been classed as doubtful. Each flight in Table 9.1 has been identified accordingly.

An analysis of the directional distribution of the boundary layer winds for the katabatic category flights (Table 9.2) shows a fairly even distribution over quite a wide range between 140^{o} and 190^{o}. The vector resultant of the 56 flights in this category is $167^{o}/9.7\ ms^{-1}$, which may be regarded as the average katabatic wind at Mawson during this month, and compares (particularly well in magnitude) with an earlier assessment (Phillpot, 1968) of the "effective pure katabatic" wind at Mawson in winter of $153^{o}/10.4\ ms^{-1}$.

Table 9.2 The directional distribution of the boundary layer winds classified as katabatic winds at Mawson in June 1970

	Boundary layer wind direction (degrees)									
Time of upper air ascent and number of flights	110 to 119	120 to 129	130 to 139	140 to 149	150 to 159	160 to 169	170 to 179	180 to 189	190 to 199	200 to 209
0000 GMT (17 flights)	-	-	1	5	1	5	2	2	1	-
0500 GMT (18 flights)	1	-	1	3	1	2	3	3	2	2
1200 GMT (21 flights)	-	2	2	2	1	3	4	5	2	-
Total (56 flights)	1	2	4	10	3	10	9	10	5	2

An analysis of the directional distribution of the *surface winds* for the flights in each of these categories (Table 9.3) shows that in the katabatic category the predominant surface wind direction is clearly between 130^{o} and 170^{o}, but for the non-katabatic and doubtful categories together, the surface wind directions are more variable. Overall it appears reasonable to say from this boundary layer wind test, that surface winds at Mawson from directions between 140^{o} and 160^{o}E almost certainly include a katabatic boundary layer wind component, whilst those from 130^{o} and 170^{o} *may* do so.

A summary of the observed features of the katabatic wind has been given by Phillpot (1968). One of these is that "strong synoptic pressure gradients tend to inhibit the intensity of the katabatic flow in advance of a depression, and strengthen it in the rear". The variation of surface pressure through June 1970 at Mawson is shown in Fig 9.3, the surface pressure fields in the area at 0000 and 1200 GMT daily are shown in Fig 9.4, and the behaviour of the boundary layer wind has been examined in relation to these features to test the consistency of this reported characteristic.

The assessment for each synoptic hour is given in Table 9.4. Although experience showed the test to be somewhat subjective, the result, namely that consistency was found on 23 occasions, reasonable consistency on 7, somewhat inconsistent results on 14 and inconsistency on 14 occasions, shows that observations in June 1970 cannot be regarded as supporting the statement given above.

Table 9.3 Mawson June, 1970. The directional distribution of the surface winds associated with
(a) the 56 boundary layer winds classified as katabatic, and
(b) the 30 boundary layer winds classified as non-katabatic and doubtful

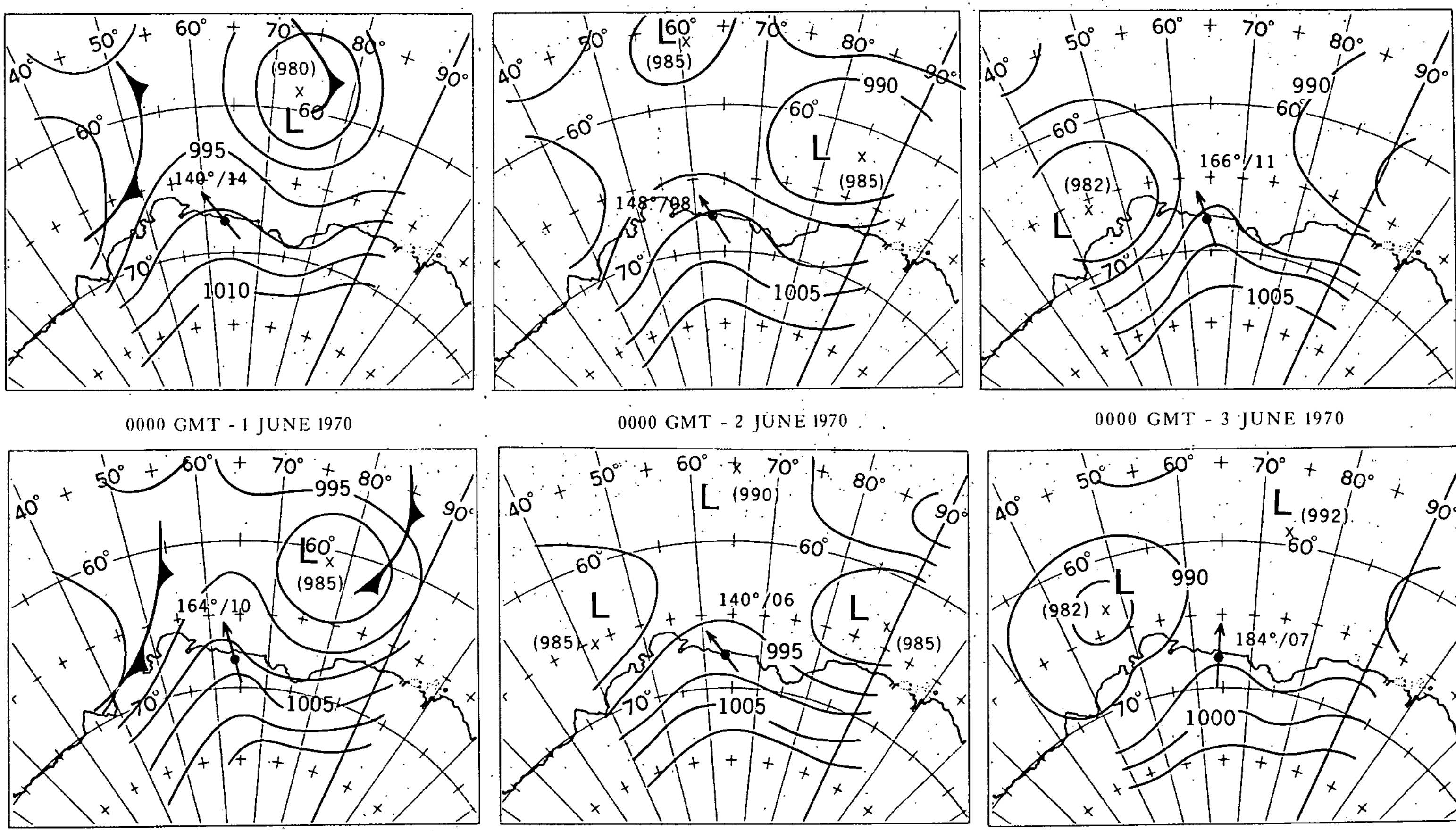
Time of upper wind ascent and number of flights in each category	Direction of wind at surface level (degrees) 120	130	140	150	160	170	180	Other
0000 GMT								
(a) 17 flights	-	2	7	2	3	3	-	
(b) 11 flights	2	2	1	-	-	2	1	210°, 220°, 270°
0500 GMT								
(a) 18 flights	-	3	8	3	3	1	-	
(b) 10 flights	1	2	1	-	1	-	-	230°, Calm (4)
1200 GMT								
(a) 21 flights	-	4	6	3	6	1	1	
(b) 9 flights	2	1	1	-	-	-	-	190°, 220°, 240°, 270°, Calm
Total								
(a) 56 flights	-	9	21	8	12	5	1	
(b) 30 flights	5	5	3	-	1	2	1	13 (includes 5 Calms)

It might be noted that Table 9.1 shows a tendency for both katabatic and and non-katabatic winds to persist for relatively long periods. The *predominant* boundary layer wind behaviour in the month can be summarised:

- katabatic between 0000 GMT/1 and 0000 GMT/12 June
- non-katabatic " 0500 " /12 and 1200 " /15 "
- katabatic " 0000 " /16 and 1200 " /17 "
- non-katabatic " 0000 " /18 and 1200 " /21 "
- katabatic " 0000 " /22 and 1200 " /24 "
- katabatic and doubtful after 0000 GMT/25 June.

The vector resultant 850 mb wind (Table 9.1) in the katabatic category cases is 097°/4.8 ms^{-1}, in the non-katabatic category 126°/7.9 ms^{-1} and in the doubtful cases 092°/19.7 ms^{-1}. These rather support another of the statements made about the katabatic wind behaviour (Phillpot, 1968) namely "strong katabatic flow is sometimes associated with light pressure gradients in the free air", and explains why, as shown above, katabatic wind conditions may be experienced for relatively long periods, since light pressure gradients sometimes do persist.

Additional tests were made with the Mawson observations. The boundary layer wind conditions were examined against the surface temperature behaviour (Fig 9.5) but no clear relationship could be found. Marked temperature variation through the first twelve days, with a general downward trend to the monthly minimum late on 11 June, was associated with predominantly katabatic winds, but during 12 and 13 June,



0000 GMT - 1 JUNE 1970

0000 GMT - 2 JUNE 1970

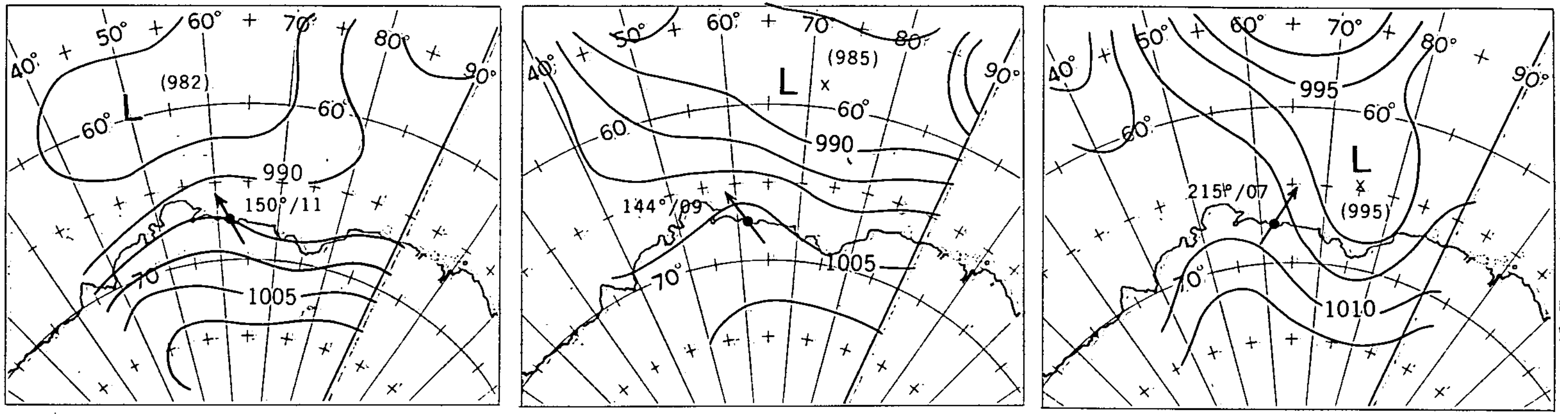
0000 GMT - 3 JUNE 1970

1200 GMT - 1 JUNE 1970

1200 GMT - 2 JUNE 1970

1200 GMT - 3 JUNE 1970

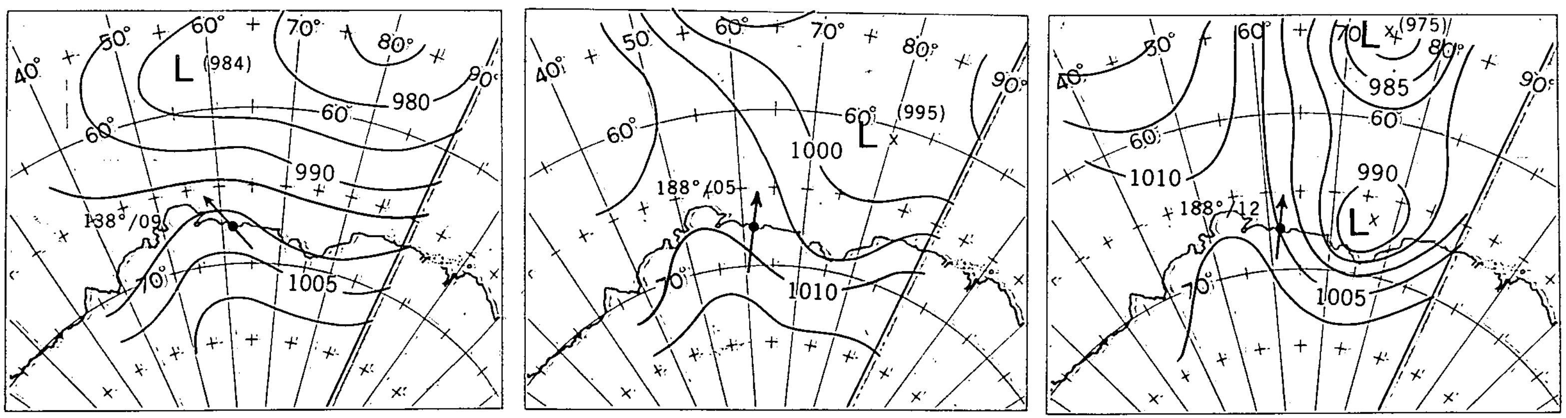
Fig 9.4 MSL pressure analyses in the area around Mawson at 0000 and 1200 GMT daily through June 1970. The boundary layer wind (i.e. $\tilde{V}_S - \tilde{V}_{850}$) at Mawson is shown at each synoptic hour (speed: m sec^{-1}).



0000 GMT - 4 JUNE 1970

0000 GMT - 5 JUNE 1970

0000 GMT - 6 JUNE 1970

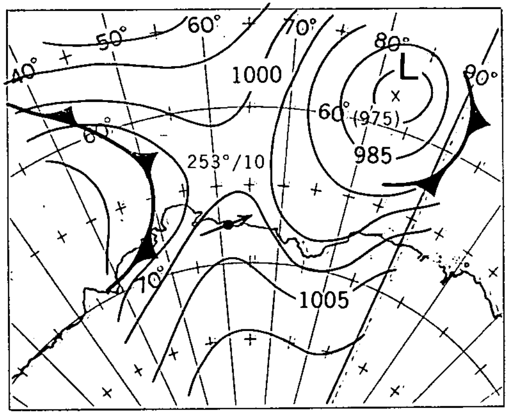


1200 GMT - 4 JUNE 1970

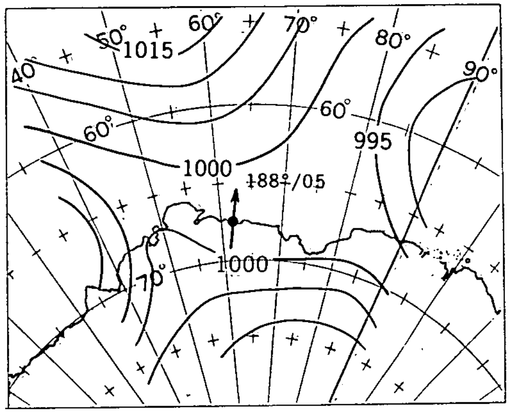
1200 GMT - 5 JUNE 1970

1200 GMT - 6 JUNE 1970

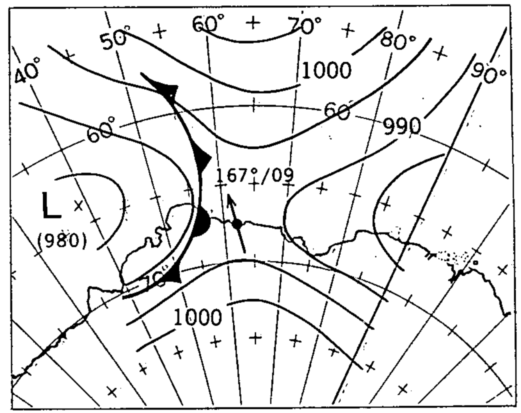
Fig 9.4 (continued)



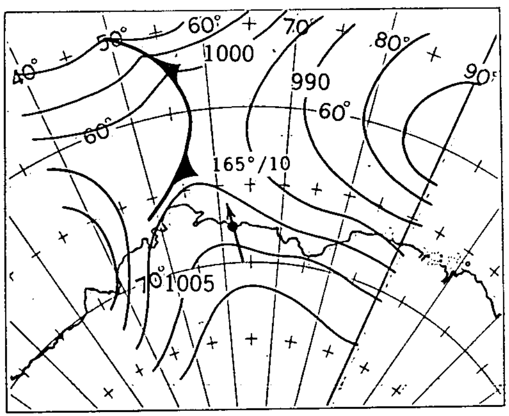
0000 GMT - 7 JUNE 1970



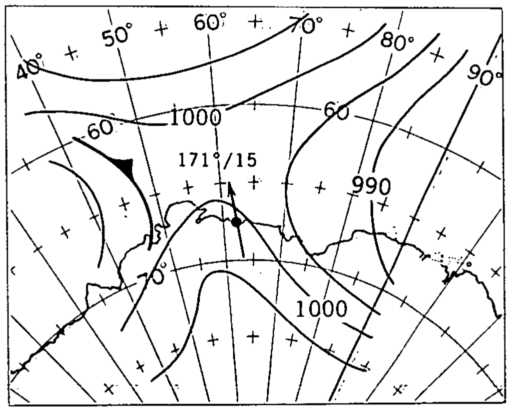
0000 GMT - 8 JUNE 1970



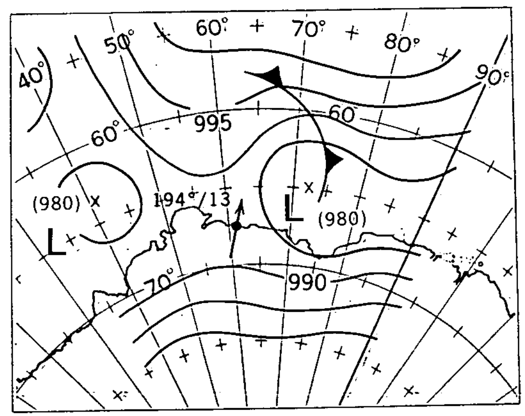
0000 GMT - 9 JUNE 1970



1200 GMT - 7 JUNE 1970



1200 GMT - 8 JUNE 1970



1200 GMT - 9 JUNE 1970

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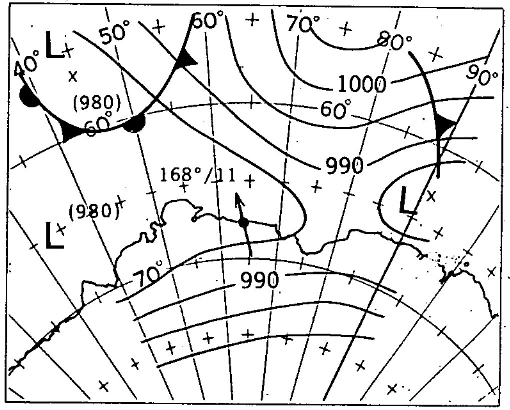
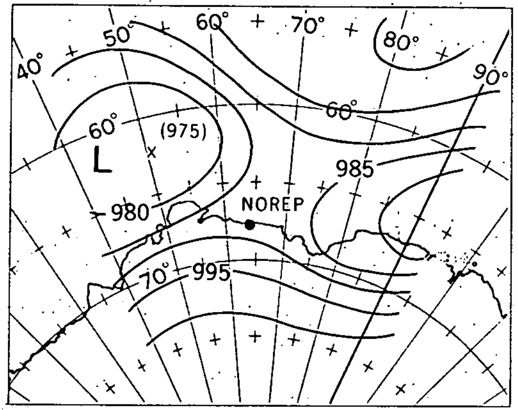
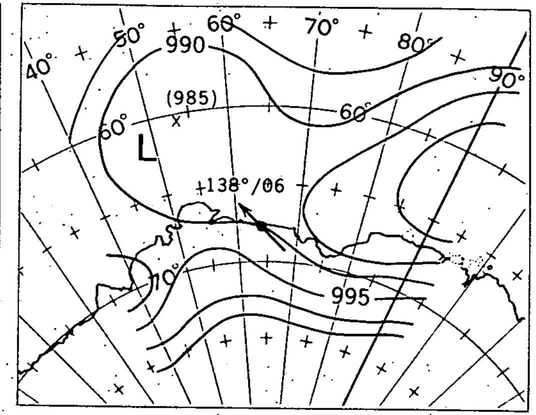


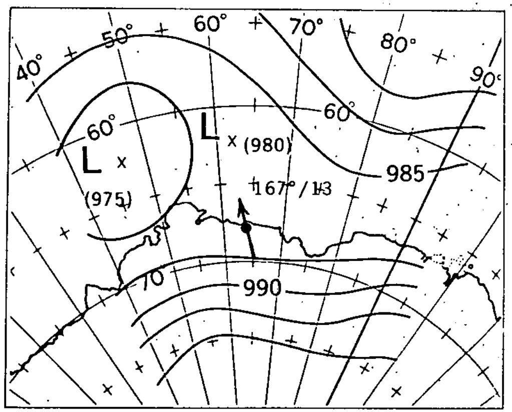
0000 GMT 10 JUNE 1970



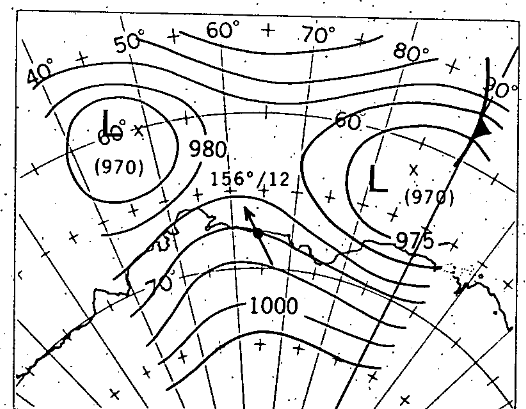
0000 GMT - 11 JUNE 1970



0000 GMT - 12 JUNE 1970



1200 GMT - 10 JUNE 1970



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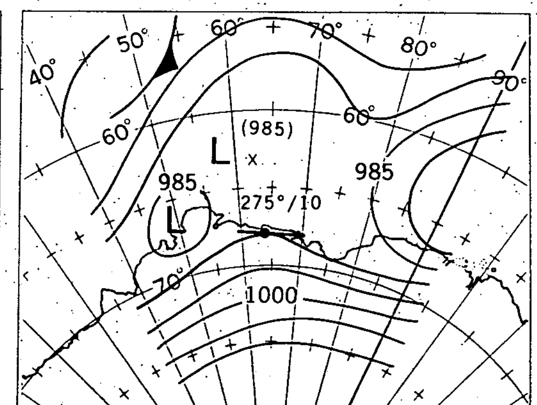

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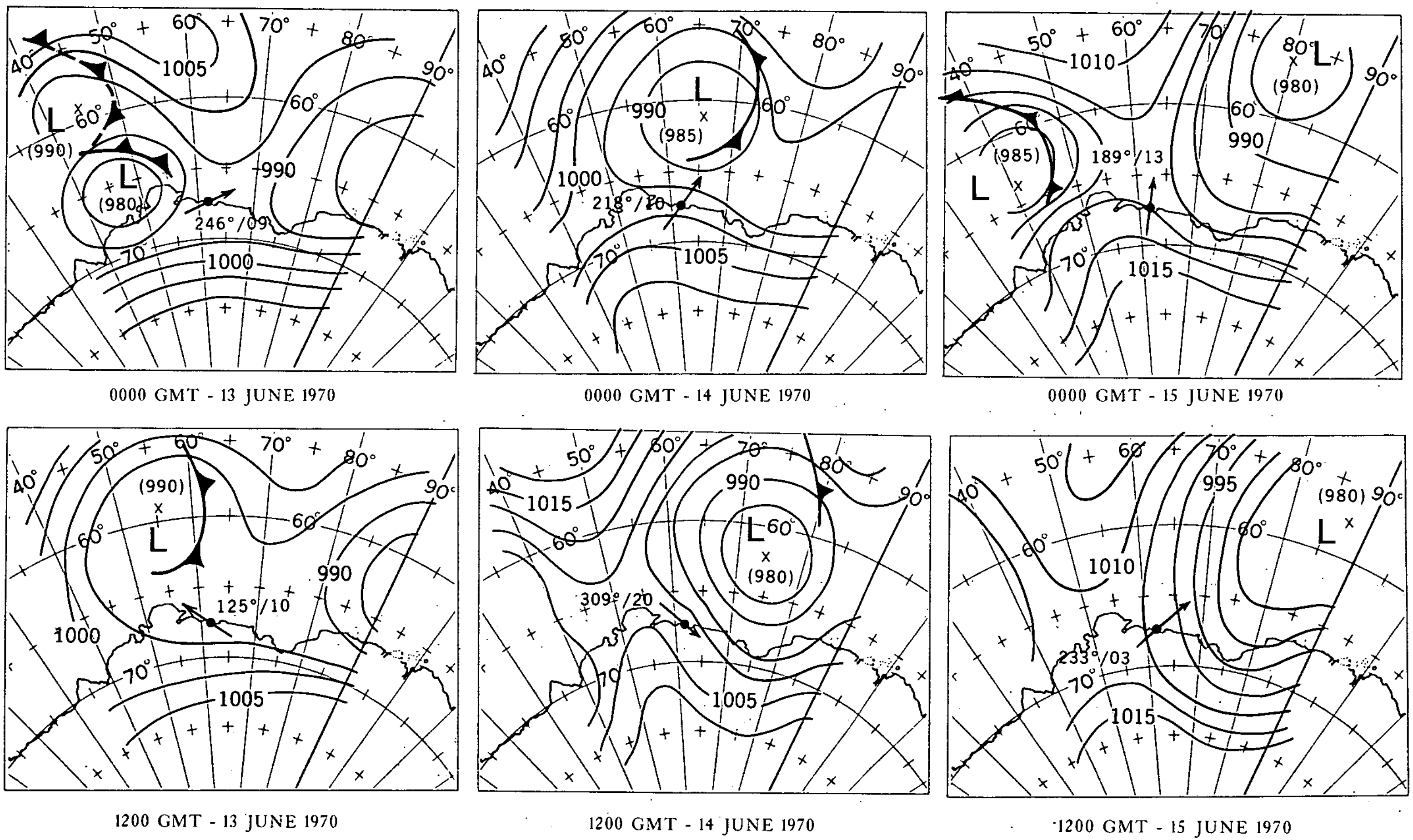

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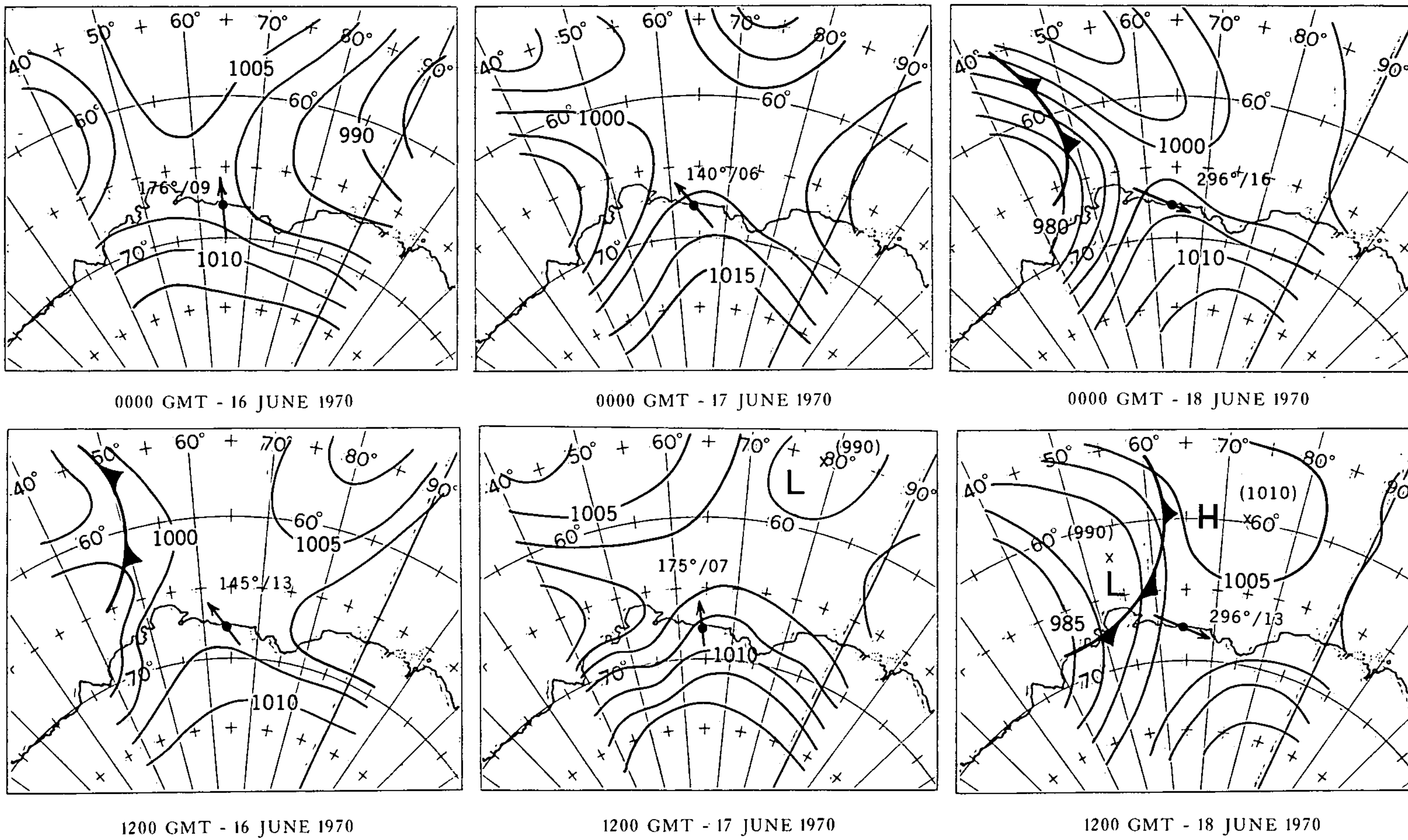

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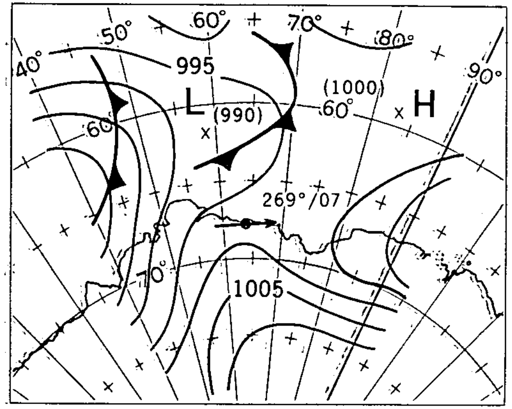
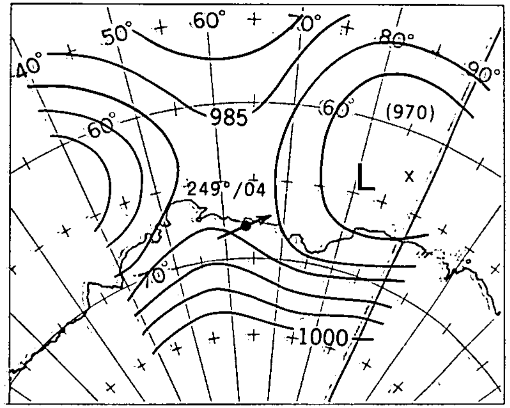
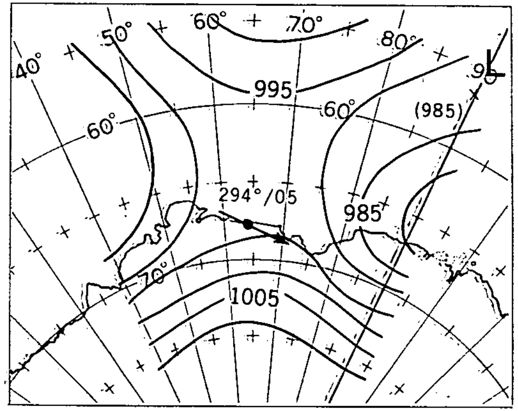


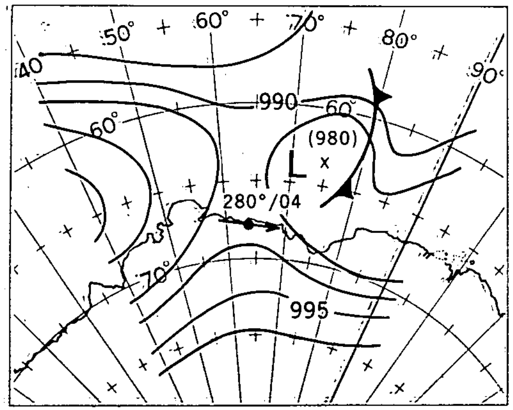
0000 GMT - 19 JUNE 1970



0000 GMT - 20 JUNE 1970



0000 GMT - 21 JUNE 1970



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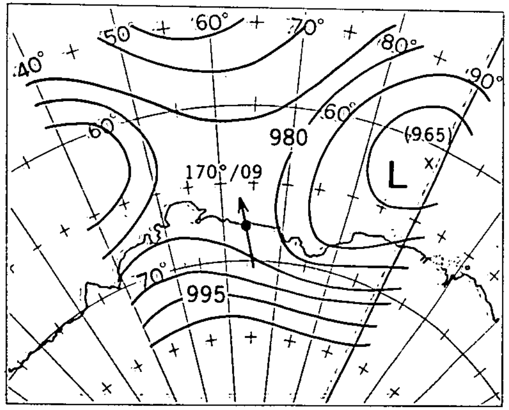

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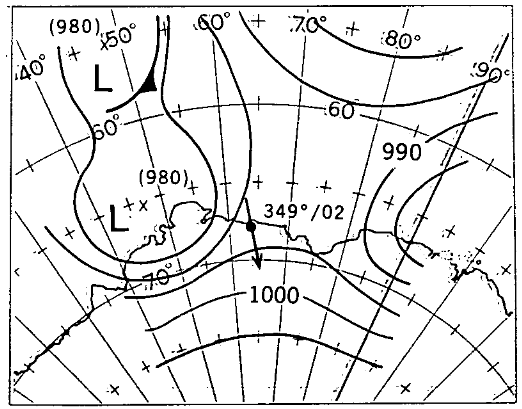

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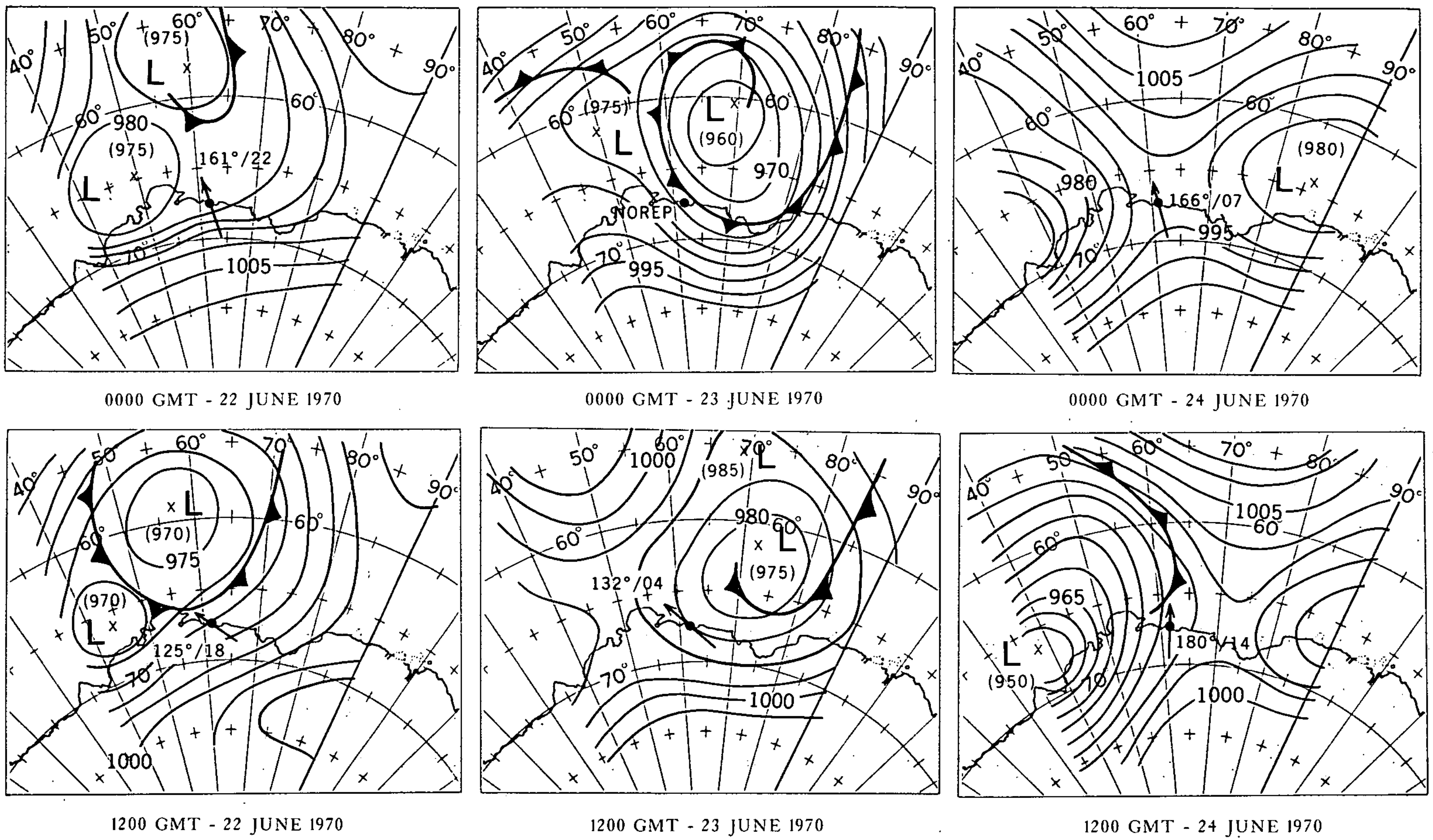

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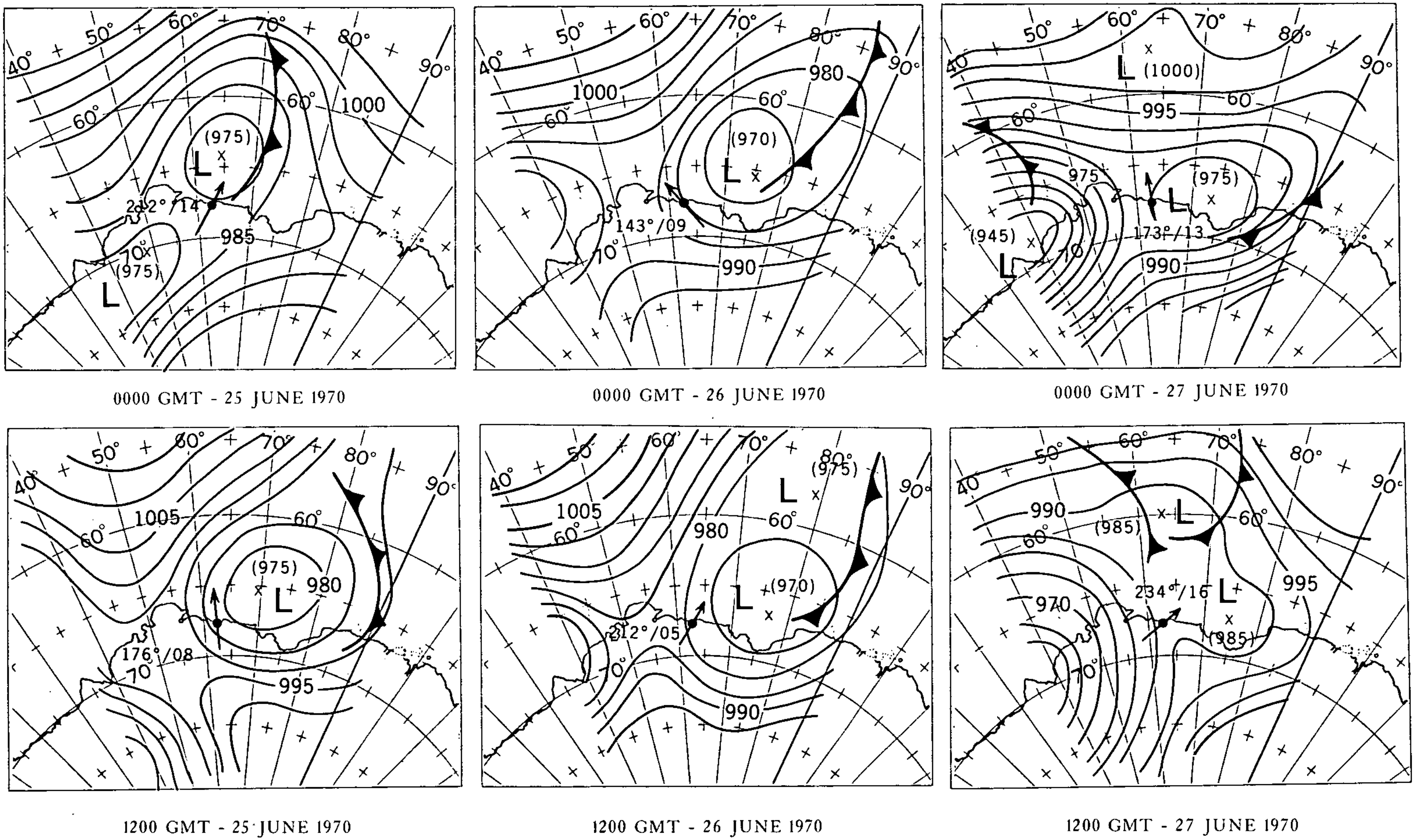

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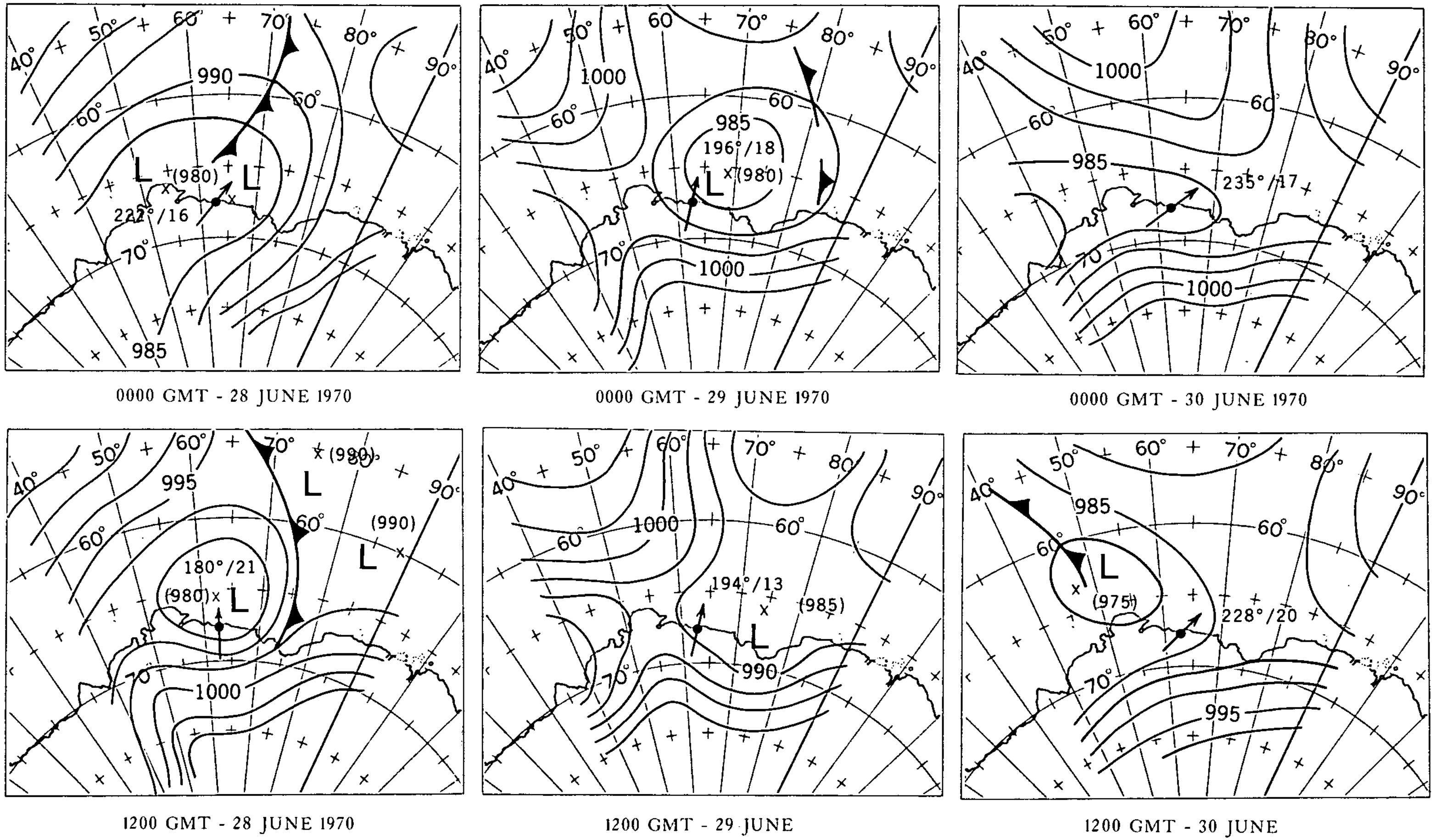

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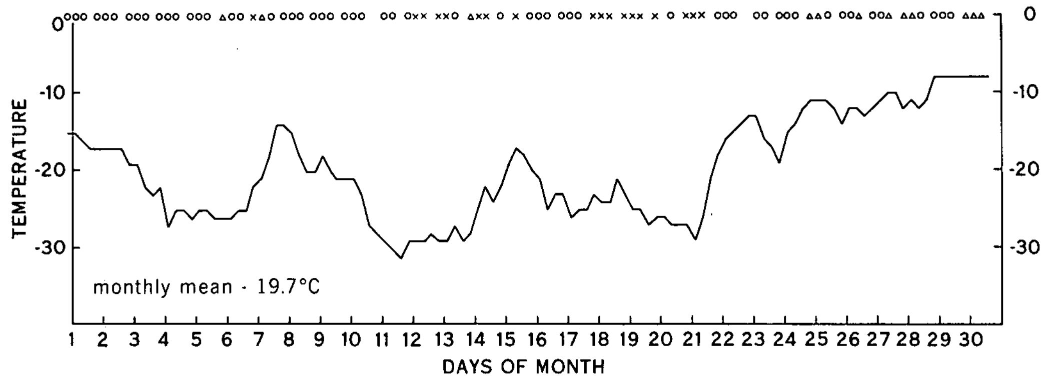

Fig 9.5 The variation in screen dry bulb temperature (°C) at Mawson in June 1970. The classification of each upper wind ascent i.e. whether the boundary layer winds were katabatic (O), non katabatic (X) or doubtful (Δ) is also shown.

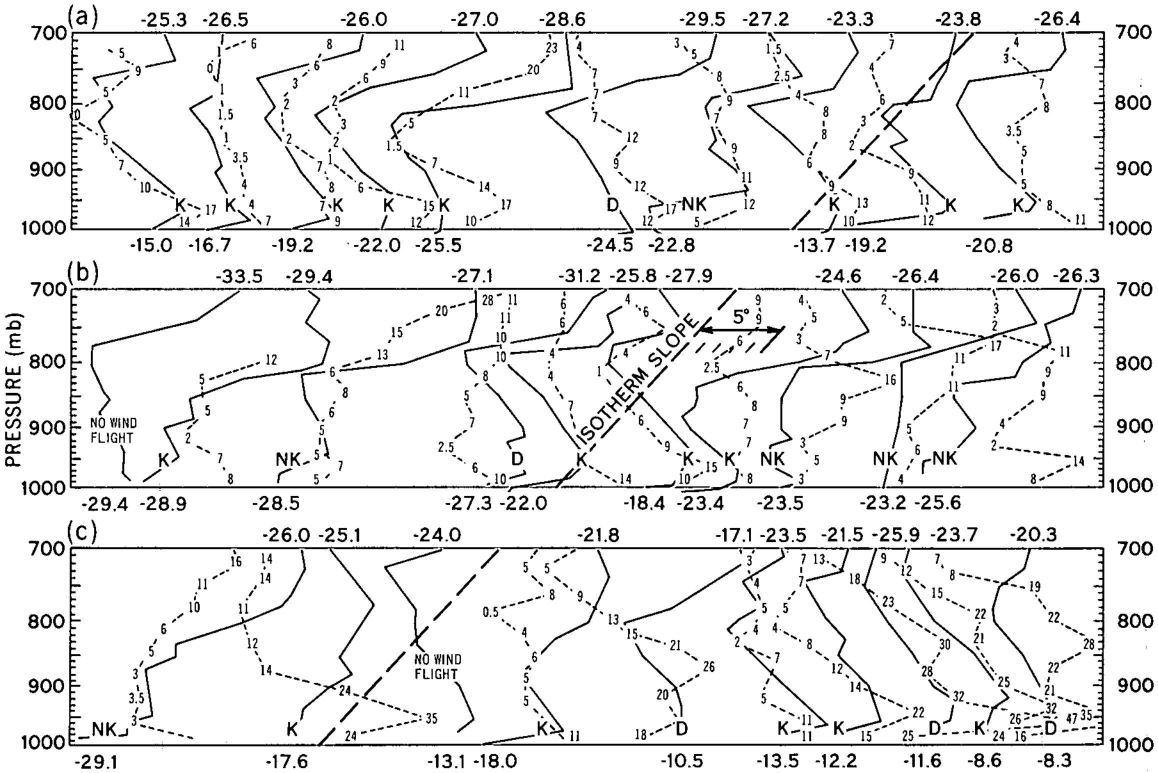

Fig 9.6 The temperature profile for each radiosonde flight (made daily at 0000 GMT) and the associated wind speed profile, between the surface and 700 mb at Mawson in June 1970 (a) days 1-10 (b) days 11-20 (c) days 21-30. The surface and 700 mb temperatures (°C) are shown for each radiosonde flight, and wind speeds ($m\ sec^{-1}$) entered at the reported heights on the wind profiles.

The letters K, NK, D show the classification (katabatic, non-katabatic or doubtful) of each wind flight according to the wind shear criterion.

when surface temperature was still very low, non-katabatic winds were observed, as was the case also on 18 and 19 June. After 22 June the most prolonged warm period in the month was characterised by many occurrences of katabatic winds. The mean surface temperature for 18 non-katabatic wind cases was in fact 6°C lower than for the 56 katabatic wind cases.

Table 9.4 The behaviour of the boundary layer wind and the surface pressure at Mawson in association with the surface pressure field in the area around Mawson, at 0000 and 1200 GMT on each day in June 1970

Col 1: Time/date (GMT)

Col 2: Classification of the boundary layer wind (*ie*, whether katabatic (K), non-katabatic (NK) or doubtful (D),) and its strength:

0-3 ms^{-1}, much below average - MBA

4-7 " , below average - BA

8-12 " , average - A

13-16 " , above average - AA

≥ 17 " , much above average - MAA

Col 3: Surface pressure behaviour at Mawson:

Fall - F

Slight fall - Sl. F

Steady - St

Slight rise - Sl. R

Rise - R

Col 4: Overall consistency between the boundary layer wind and the surface pressure behaviour

- Consistent - C
- Reasonably consistent - RC
- Somewhat inconsistent - SIC
- Inconsistent - IC

1	2	3	4	1	2	3	4
00/1	K AA	R	C	00/16	K A	St-Sl.R	C
12/1	K A	Sl.R-St	C	12/16	K AA	Sl.R	SIC
00/2	K A	F	C	00/17	K BA	Sl.R	SIC
12/2	K BA	F	C	12/17	K BA	Sl.F	SIC
00/3	K A	F	IC	00/18	NK AA	F	C
12/3	K BA	F	RC	12/18	NK AA	F	C
00/4	K A	Sl.F-R	C	00/19	NK BA	F	C
12/4	K A	R	C	12/19	NK BA	F	C
00/5	K A	R	C	00/20	NK BA	F-Sl.R	C
12/5	K BA	R-Sl.F	SIC	12/20	K A	R	C
00/6	D BA	Sl.F	IC	00/21	NK BA	R	SIC

1	2	3	4	1	2	3	4
12/6	K A	F	C	12/21	NK MBA	R-F	RC
00/7	NK A	F-R	IC	00/22	K MAA	F	IC
12/7	KA A	S1.R	C	12.22	K MAA	F	IC
00/8	K BA	F	RC	00/23	-	-	-
12/8	K AA	F	IC	12/23	K BA	R	IC
00/9	K A	F	SIC	00/24	K BA	R-F	RC
12/9	K AA	F	C	12/24	K AA	F	IC
00/10	K A	F-St	RC	00/25	D AA	F-S1.R	RC
12/10	K AA	St-R	SIC	12/25	K A	S1.R-F	SIC
00/11	-	-	-	00/26	K A	F	SIC
12/11	K A	R	C	12/26	D BA	S1.R	SIC
00/12	K BA	R-F	SIC	00/27	K AA	R	C
12/12	NK A	S1.R-R	SIC	12/27	D AA	R-F	IC
00/13	NK A	R-S1.F	C	00/28	D AA	F-R	IC
12/13	K A	S1.F-R	C	12/28	K MAA	R	RC
00/14	D A	R	SIC	00/29	K MAA	R-S1.R	C
12/14	NK MAA	R	IC	12/29	K AA	S1.R-F	C
00/15	K AA	R-F	SIC	00/30	D MAA	F	IC
12/15	NK MBA	F	IC	12/30	D MAA	F	IC

Temperature soundings were made only once per day (at 0000 GMT) through the month, and each profile is shown for the 1000-700 mb layer in Fig 9.6. The associated wind speed profile is also shown, and marked K, NK or D according to whether the flight was assessed from the boundary layer wind criterion (Table 9.1) as katabatic, non-katabatic, or doubtful.

The results are not particularly conclusive although there does appear to be a tendency for surface temperature inversions to occur in association with katabatic wind conditions, (21 June is a notable exception), and this is revealed in the mean temperature and wind profiles for the three categories (Fig 9.7). The differences between the mean profiles for the katabatic and non-katabatic cases are:

(a) a mean surface temperature inversion in the former category, an isothermal layer in the second;

(b) although the wind speed increases a little up to 300 m in both cases, in the former wind strength decreases and is less than the surface wind strength above 400 m (up to the 3 km level at any rate), whilst in the latter case the minimum wind strength occurs at the surface.

In the doubtful cases the main characteristics are the absence of a temperature inversion and the high wind speeds.

Mean wind profiles were derived for the flights at 0500 and 1200 GMT. They support the results found (in the winds) at 0000 GMT.

In summary of this examination of the katabatic wind phenomenon at Mawson, it appears:

from the sample of 86 wind flights through the month of June 1970, in 56 (65%) of these the boundary layer wind (defined as $\vec{V}_S - \vec{V}_{850}$) was a katabatic wind, in 18 cases (21%) the boundary layer wind was non-katabatic and in 12 cases (14%) the boundary layer wind classification was doubtful

- the katabatic boundary layer winds were distributed fairly evenly over directions ranging from 140^{o} to 190^{o} (through 180^{o}); and the vector resultant of the (56) winds in this category was $167^{o}/9.7\ ms^{-1}$. This can be regarded as the *average* katabatic boundary layer wind at Mawson for this month

- an analysis of the directional distribution of *surface* winds for the flights where the boundary layer wind falls in the katabatic category, indicates that surface winds from directions between 140^{o} and 160^{o}E almost certainly include a katabatic boundary layer wind component whilst those from 130^{o} *and* 170^{o} *may* do so

- an examination of these boundary layer winds in association with the surface pressure fields in the Mawson area, and the surface pressure tendency at Mawson did not support the previous statement "that strong pressure gradients tend to inhibit the intensity of the katabatic flow in advance of a depression and strengthen it in the rear"

- the vector resultant 850 mb winds for the three categories of boundary layer winds, namely

  - katabatic $097^{o}/4.8\ ms^{-1}$
  - non-katabatic $126^{o}/7.9\ ms^{-1}$
  - doubtful $092^{o}/19.7\ ms^{-1}$

  offer some support for the statement that "(strong) katabatic flow is sometimes associated with light pressure gradients in the free air"

- no clear relationship could be found between boundary layer winds and temperatures. When examined against surface temperature, some evidence was found to suggest that surface temperatures tend to be lower in association with non-katabatic boundary layer wind conditions in winter, whilst the temperature soundings show that surface temperature inversions are not confined to katabatic wind cases. However *mean* temperature and wind profiles for the three boundary layer wind categories show that for the katabatic category there is a surface temperature inversion, but an isothermal layer in the non-katabatic category, and for wind the greatest strength occurs in the layer immediately above the surface (katabatic category), whilst the minimum strength is found at the surface (non-katabatic category)

- no explanation can be advanced from this study to throw light on the very persistent high wind speeds experienced at places on the Antarctic continental coastline, as discussed by Loewe (1972).

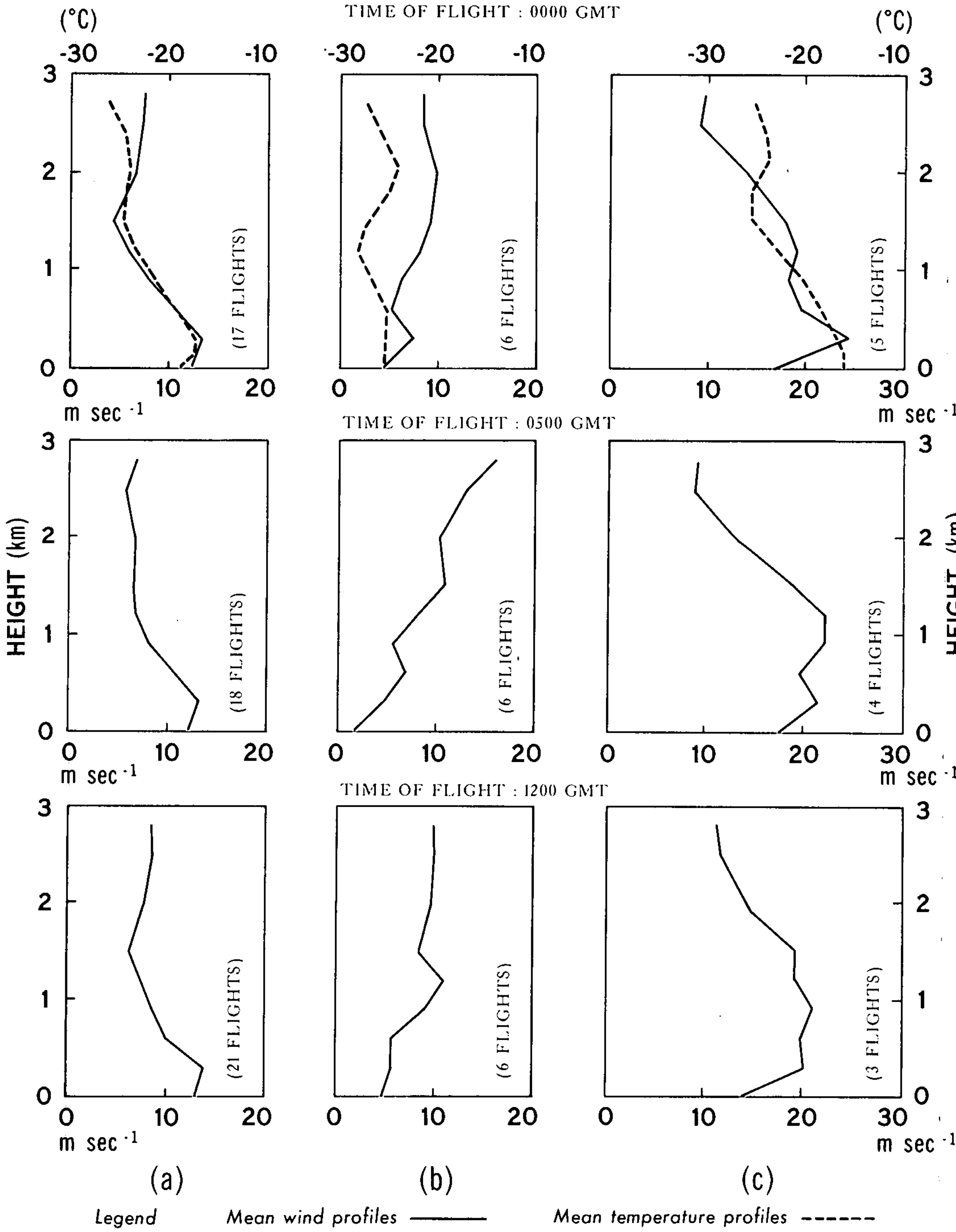

Fig 9.7 Mean wind profiles from the surface to 3 km derived from upper wind ascents made daily at 0000, 0500 and 1200 GMT at Mawson in June 1970 grouped according to flight classification (a) katabatic (b) non-katabatic or (c) doubtful. Mean temperature profiles corresponding to the wind categories derived from radiosonde flights made with the wind ascents at 0000 GMT are also shown.