C1

551.553.11 (931-13)

NEW ZEALAND METEOROLOGICAL SERVICE

TECHNICAL INFORMATION CIRCULAR NO. 157

TIC 157

THE SEA BREEZE AT HOKITIKA

The following notes on the Sea Breeze at Hokitika during the summers of 1972/73 and 1973/74 were written by Mrs G.H. Thompson. They are circulated for general information.

J.S.Hickman

J.S. Hickman
Director

New Zealand Meteorological Service
P.O. Box 722
WELLINGTON.

21 July 1977

NEW ZEALAND METEOROLOGICAL SERVICE

THE SEA BREEZE AT HOKITIKA

Abstract

This study was done to establish which weather situations are most favourable for a sea breeze to develop at Hokitika and what the characteristics of this sea breeze are. A short account on the nocturnal land breeze is also given.

1. Introduction

Many authors have studied the sea breeze circulation by observational or by theoretical consideration as it is in the ideal case a simple thermally induced circulation. Sea breezes develop during fine summer days along most coasts. The strength of the sea breeze - land breeze system increases with increasing intensity of sunshine, with decreasing cloudiness, and with decreasing intensity of the large scale flow. In middle and high latitudes the intensity of the sunshine is not as great as in the subtropics and tropics because of the smaller angle of elevation of the sun in the former areas, and the large scale flow is usually much stronger as well. Therefore the sea breeze circulation occurs more regularly in the tropics and subtropics. The famous example of the sea breeze at Batavia is shown in Fig. 1. In middle and high latitudes the likelihood that the sea breeze will develop is greater if the gradient wind is in the same direction as the sea breeze. An earlier onset of the sea breeze can be expected in that case as well. If the gradient wind is, however, too strong it might obscure the sea breeze.

In areas where a mountain range is situated close to the coast the nocturnal breeze and the sea breeze are influenced by the mountain wind and the valley wind respectively.

The sea breeze has a larger horizontal and vertical extent than the night-time land breeze. In middle latitudes the sea breeze reaches vertical heights of 200 m - 500 m, and a landward range of 15 km - 50 km is given by some authors (e.g. Defant (1951a), Flohn (1969), Peters (1938)). The respective values for the nocturnal land breeze are generally only one-third of the above-mentioned ones.

Defant (1950) gave the sea breeze circulation some theoretical consideration. His model has a linear solution. It takes into account the vertical turbulent heat exchange, friction and the Coriolis Force. As a coordinate system normal to the coastline is used, this model neglects the thermal differences along the coast. It gives, however, in spite of that, fairly good results for the ordinary sea breeze but not for the frequently occurring sea breeze front. Some results from the model: The wind speed decreases with height to a minimum at a certain level and increases above this level to reach a secondary maximum. The velocity decreases then again to be almost zero at a height of 2000 m. The lower minimum is the height of the change from the sea breeze to the upper counter current. The secondary speed maximum gives the level of the core of the upper counter current. These two heights increase with increasing friction. The effect of the Coriolis Force on the sea breeze is to deflect the airflow to the left of the motion in the southern hemisphere which results in a backing of the wind during the afternoon and evening.

2. The sea breeze circulation at Hokitika

For this study the Pilot Balloon Data and the hourly AERO weather reports of Hokitika Aerodrome were used for the summers 1972/73 and 1973/74. Isogon and isotach charts were drawn for several days when sea breeze conditions existed, but only one example will be given. For that case the time sections of the meridional and zonal components will be shown as well.

Hokitika Aerodrome is located on a plateau 45 m above mean sea level less than 2 km from the coast (Fig. 2). One important feature in the topography of the aerodrome's surroundings is that the land rises to above 300 m - in some parts to 1000 m - within 10 km-20 km in most parts of the landward sector. The proximity of the mountains to the coast causes a large reduction in wind speed from the geostrophic in most onshore flows and a deflection of the wind direction as well (unpublished airport climatology).

The sea breeze at Hokitika normally blows from a 240°-250° direction in the range of 5-15 kt (unpublished airport climatology). The sea breeze at Hokitika does not normally blow in a direction perpendicular to the coast as the wind is deflected by the nearby ranges. The onset times of the sea breeze which are shown in Table 1 vary quite considerably, but on just under half of the selected days it started between 1100 and 1300 NZST.

The nocturnal land breeze is a light E to ESE drift which blows during many nights throughout the year (unpublished airport climatology). The direction of the land breeze is influenced by the orientation of the nearby valleys which mainly run in a northwest-southeast direction from the Southern Alps towards the coast.

There were 30 days with well developed sea breezes during the summers 1972/73 and 1973/74, i.e. 17% of the days. Wexler (1946) gives as frequencies of days with sea breezes during the summer on the coast of Massachusetts (40°- 41°N) 30%-40% and on the Baltic coast of Germany (about 54°N) about 20%. According to the latitude the value for Hokitika would be expected to be similar to the one for Massachusetts. Hokitika's exposure to the west explains at least partly the relatively low percentage; for the sea breeze is often obscured by the large scale flow.

The most favourable weather situations for a sea breeze development at Hokitika were (Fig. 3a-c):

(1) High pressure area over the Tasman Sea and a shallow trough along the west coast of the South Island.

(2) High pressure areas to the E or the SE of the South Island and over the Tasman Sea and a weak low pressure area along the West Coast or over a greater part of the South Island.

(3) High pressure area over New Zealand with a shallow trough of low pressure along the West Coast or a greater part of the South Island.

A shallow trough of low pressure along the West Coast or over larger areas of the South Island seems to be an important feature for the development of the sea breeze. This trough is most often caused by the orography as the flow is frequently from the southeast or east across the South Island in the above-mentioned weather situations. Therefore the sea breeze at Hokitika is often not a simple thermally induced circulation, but other processes are involved. At times, however, other factors besides the lee pressure trough can have an effect on the development of the low pressure along the West Coast: heat low and synoptic scale low. Johnson and O'Brien (1973) mention a thermally induced low pressure area as an important feature for the occurrence of the Oregon sea breeze.

Some authors found a correlation between the upwelling of cold water along a coast and the strength of the sea breeze (e.g. Johnson and O'Brien (1973)). The favourable weather situations for the development of a sea breeze at Hokitika are of a type that occur after a period of southwesterlies. The southwesterly wind blows parallel to the coast and could cause therefore a water circulation which is on the sea surface normal to the coast. This would lead to upwelling of cold water along the shore. A negative sea surface temperature anomaly would increase the temperature gradient between the sea and the land and therefore be favourable for a sea breeze development.

The average vertical height of the onshore lower branch of the sea breeze circulation was found to be about 2000 ft-3000 ft* (Table 2). The top of this flow was marked by a minimum in wind speed. The average height of the top of the sea breeze circulation could not be determined. In several cases the flow caused by the synoptic situation had the same direction as the upper return flow. On some days the wind data above 4000 ft-5000 ft was missing, while on other days there was hardly any directional wind change with height, and it was not possible to identify the top of the sea breeze circulation.

---

* In this section heights are quoted in feet as the original data were recorded in feet.

On many days when a sea breeze developed a secondary maximum of the wind speed occurred at about 1000 ft-2000 ft, and quite often the main maximum was at this level and not at the surface (Table 3). In this case the speeds at 1000 ft-2000 ft were as high as 25 kt. As the observed heights of the balloon flights were higher than the adopted heights, no decrease in the rate of ascent could have taken place. If there had been a decrease in the rate of ascent this would have meant an artificial increase in the wind speed. The larger values of the observed heights suggest to the contrary that the balloon gets an extra uplift after about 2-3 minutes of the flight. This indicates that the valley to the N and NE of the airport, which is reached by the balloon after about 2-3 minutes, is warmer than the plateau on a fine summer's day and therefore causes a more intense thermal activity than the nearby surroundings.

The land breeze at night at Hokitika was very often weak when there was a sea breeze during the day. The surface wind was most likely calm. This seems to be reasonable as in summer 1973/74 38% and 33% of all surface wind observations were reported calm at 2300 NZST and 0500 NZST respectively. The land breeze is much more frequent during winter. This indicates that the effect of the nearby mountains on the nocturnal breeze is considerable. Snow cover and lower temperatures in the mountains than at sea level cause a stronger katabatic wind in winter than in summer.

The day of 9 January 1974 was chosen as a good example for a well-developed sea breeze at Hokitika. The weather situation on that day (Fig. 4) can be described as the situation favourable for sea breeze development shown in Fig. 3a. The shallow trough of low pressure along the West Coast was caused orographically in a southerly to southeasterly flow across the Southern Alps. Heating cannot have had much effect if any at all on the trough development as the temperature at Hokitika remained below 20°C all day despite the small cloud amounts. The sea breeze is, therefore, in this example not a simple thermally induced circulation but other processes must be involved.

The surface wind made a complete 360° turn in 24 hours (Table 4a). In the early morning of 9 January the wind was a light southeasterly land breeze, and it backed in the course of the day to become a southwesterly in the afternoon. During the evening and night further backing of the surface wind occurred until the direction of the nocturnal land breeze was reached again.

The vertical profiles of wind direction and wind speed (Fig. 5a, b) show that the depth of the onshore branch of the sea breeze circulation increased during the afternoon. The level of minimum wind speed as well as the level at which the wind direction changed to a southeasterly, the upper counter current, rose during the afternoon. The maximum depth of the onshore flow was reached with 3000 ft at 1700 to 1800 NZST.

The velocity maximum of the sea breeze occurred at or near the surface.

The time sections of the meridional and the zonal flow (Fig. 6a,b) confirm the statements made above.

3. Conclusions

The predominant large scale flow over the South Island is from the westerly quarter. Therefore the sea breeze at Hokitika is often obscured by the gradient wind, and the percentage of summer days with a detectable sea breeze is relatively small. Another marked factor is the influence of the orography of Hokitika's surroundings on the direction of the sea breeze and of the nocturnal breeze.

Three main weather situations favourable for sea breeze development at Hokitika were found. They all had one feature in common: a shallow low pressure trough along the West Coast of the South Island. This trough was the resultant of one or more effects, the most important of which was the orographically induced lee pressure trough. This means that other processes must be involved in the sea breeze development besides the horizontal temperature gradient.

Acknowledgement

I am grateful to Mr A.A. Neale for his helpful comments.

References and Bibliography

Bluthgen, J., 1966: Allgemeine Klimageographie, pp. 269-273. Berlin: Walter de Gryter & Co.

Clarke, R.H., 1955: Some observations and comments on the sea breeze. Austr. Meteor. Mag. 11: 47-68.

Defant, F., 1950: Theorie der Land - und See winde. Arch. Met. Geophys. Bioklimat. Ser. A, 2: 404-425.

Defant, F., 1951a: Local winds in Compendium of Meteorology, pp. 655-672. Boston: Amer. Meteor. Soc.

Defant, F., 1951b: Windstau und Auftrieb an ozeanischen Kusten. Arch. Met. Geophys. Bioklimat. Ser. A, 2: 296-308.

Edinger, J.G., 1960: The influence of Terrain and Thermal Stratification on Flow across the California Coastline, Final Report. Univ. California, Dept. Met.

Flohn, H., 1969: World Survey of Climatology, 2: 140-154. Amsterdam, London, New York: Elsevier Publishing Company

Johnson, A. and J.J. O'Brien, 1973: A Study of an Oregon Sea Breeze Event. J. Appl. Meteor. 12: 1267-1283.

Peters, S.P., 1938: Sea Breezes at Worthy Down, Winchester. Met. Office Prof. Notes, 6, No. 86.

Wexler, R., 1946: Theory and observations of land and sea breezes. Bull. Amer. Meteor. Soc. 27: 272-287.

TABLE 1. Onset time of the sea breeze at Hokitika. Actual number of occurrences during summer 1972/73 and 1973/74.

0800	0900	1000	1100	1200	1300	1400	1500	1600	NZST
1	2	1	4	6	6	4	4	2	

TABLE 2. Depth of the onshore branch of the sea breeze circulation at Hokitika. Actual number of occurrences during summer 1972/73 and 1973/74.

0 - 999 ft	0
1000 - 1999 ft	6
2000 - 2999 ft	15
3000 - 3999 ft	9

TABLE 3. Level of the speed maximum of the onshore branch of the sea breeze circulation at Hokitika. Actual number of occurrences during summer 1972/73 and 1973/74.

0 - 499 ft	11
500 - 999 ft	1
1000 - 1499 ft	13
1500 - 1999 ft	5

TABLE 4a. SURFACE WIND DIRECTION (TENS OF DEGREES) AND SPEED (KT), HOKITIKA 9 and 10 JANUARY 1974 AT SPECIFIED HOURS NZST

0400	0500	0600	0700	0800	0900	1000	1100	1200	NZST
14 07	11 02	08 03	09 07	06 10	02 06	33 10	28 10	28 10	

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	NZST
26 10	26 10	24 08	27 10	24 10	24 08	21 06	17 03	14 08	07 02	06 07	08 07	

0100	0200	0300	0400	0500	0600	NZST
06 06	05 07	06 07	05 05	00 00	05 06	

TABLE 4b. SURFACE WIND IN COMPONENTS (KT), HOKITIKA 9 and 10 JANUARY 1974 AT SPECIFIED HOURS NZST

	0400	0500	0600	0700	0800	0900	1000	1100	1200	NZST
N-S Component	-5	-1	1	0	5	6	9	2	2	
W-E Component	-4	-2	-3	-7	-9	-2	5	10	10	

	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	NZST
N-S Component	-2	-2	-4	0	-5	-4	-5	-3	-6	1	4	1	
W-E Component	10	10	7	10	9	7	3	-1	-5	-2	-6	-7	

	0100	0200	0300	0400	0500	0600	NZST
N-S Component	3	4	4	3	0	4	
W-E Component	-5	-5	-6	-4	0	-5	

TABLE 5 a UPPER WIND DIRECTION AND SPEED (kt), HOKITIKA, 9 AND 10 JANUARY 1974

	NZST	Height (ft) 500	1000	1500	2000	2500	3000	4000	5000	6000	7000	8000	9000
9.1.74	0500	165 05	210 08	220 12	230 14	240 16	245 18	235 13	225 11	200 08	195 08	185 08	185 11
	1100	285 08	270 05	225 04	185 06	175 06	175 07	160 08	155 08	160 10	160 14	155 19	195 16
	1700	240 09	240 09	235 09	225 06	215 05	205 04	155 05	140 09	145 09	160 09	165 14	
	2300	070 12	085 10	100 10	115 14	130 16	140 18	170 12	185 08	200 08	205 10	205 13	205 15
10.1.74	0500	105 07	135 07	145 08	140 10	145 10	160 11	225 09	230 15	225 20	220 19	185 10	160 12

5 b UPPER WIND IN COMPONENTS (kt), HOKITIKA, 9 AND 10 JANUARY 1974

	NZST	Height (ft)	500	1000	1500	2000	2500	3000	4000	5000	6000	7000	8000	9000
9.1.74	0500	N-S comp	-5	-7	-9	-9	-8	-8	-7	-8	-8	-8	-8	-11
		W-E comp	-1	4	8	11	14	16	11	8	3	2	1	1
	1100		2	0	-3	-6	-6	-7	-8	-7	-9	-13	-17	-15
			8	5	3	1	-1	-1	-3	-3	-3	-5	- 8	4
	1700		-5	-5	-5	-4	-4	-4	-5	-7	-7	-8	-14	
			8	8	7	4	3	2	-2	-6	-5	-3	-4	
	2300		4	1	-2	-6	-10	-14	-12	-8	-8	-9	-12	-14
			-11	-10	-10	-13	-12	-12	-2	1	3	4	5	6
10.1.74	0500		-2	-5	-7	-8	-8	-10	-6	-10	-14	-15	-10	-11
			-7	-5	-5	-6	-6	-4	6	11	14	12	1	-4

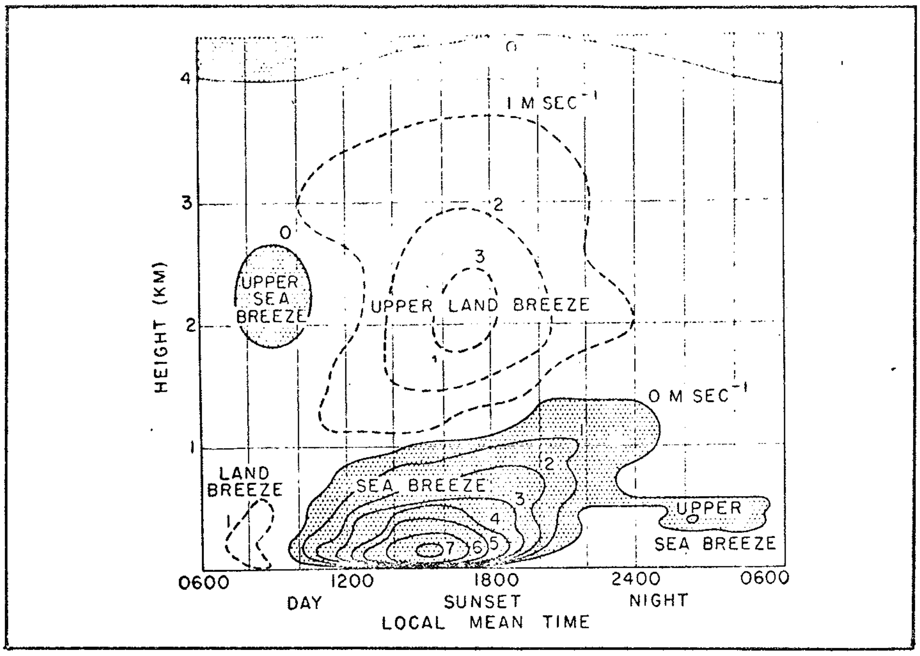

Fig. 1. Velocity isopleths for the land and sea breeze in Batavia (after van Bemmelen, reproduced in Compendium of Meteorology).

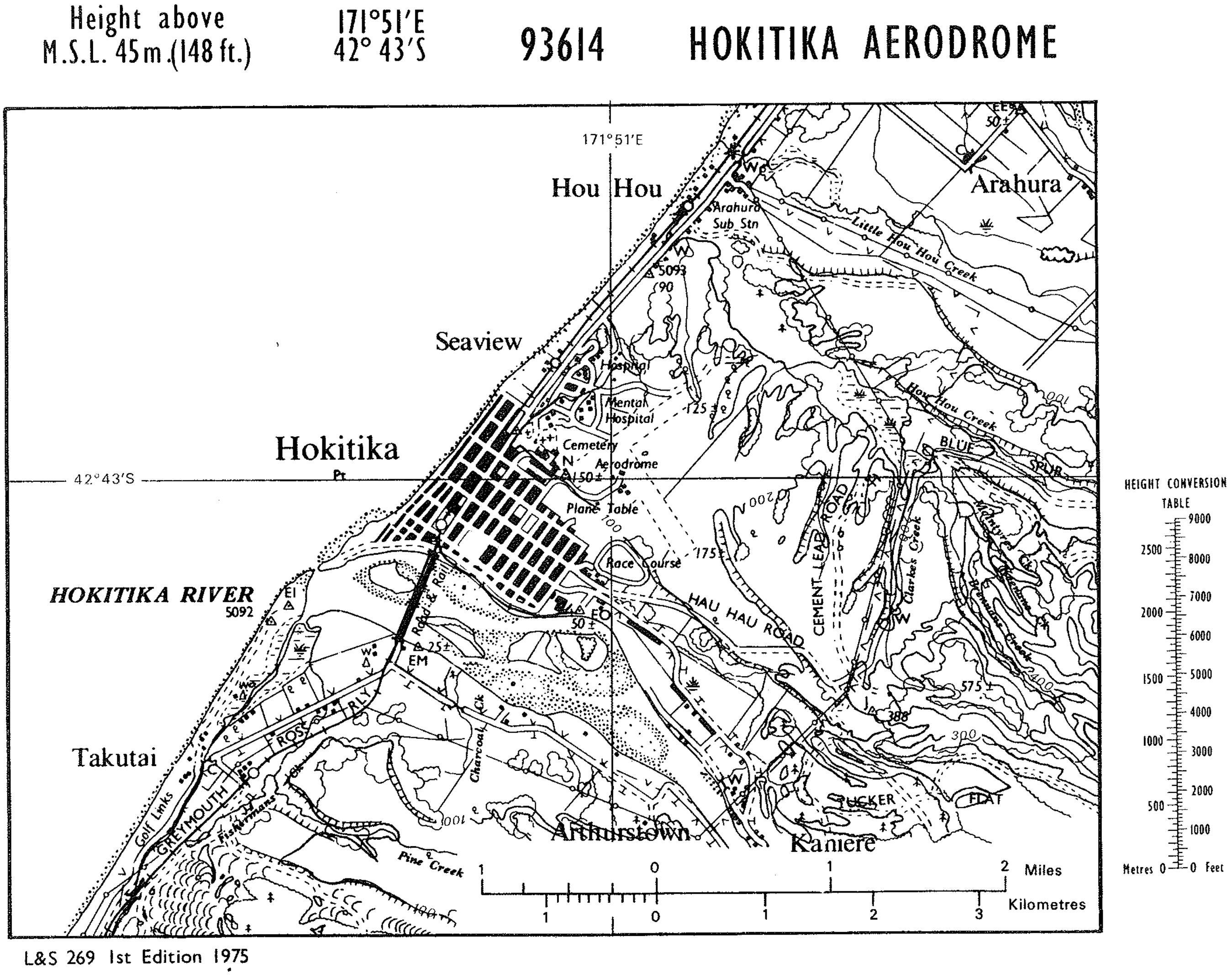

Fig. 2. Location map.

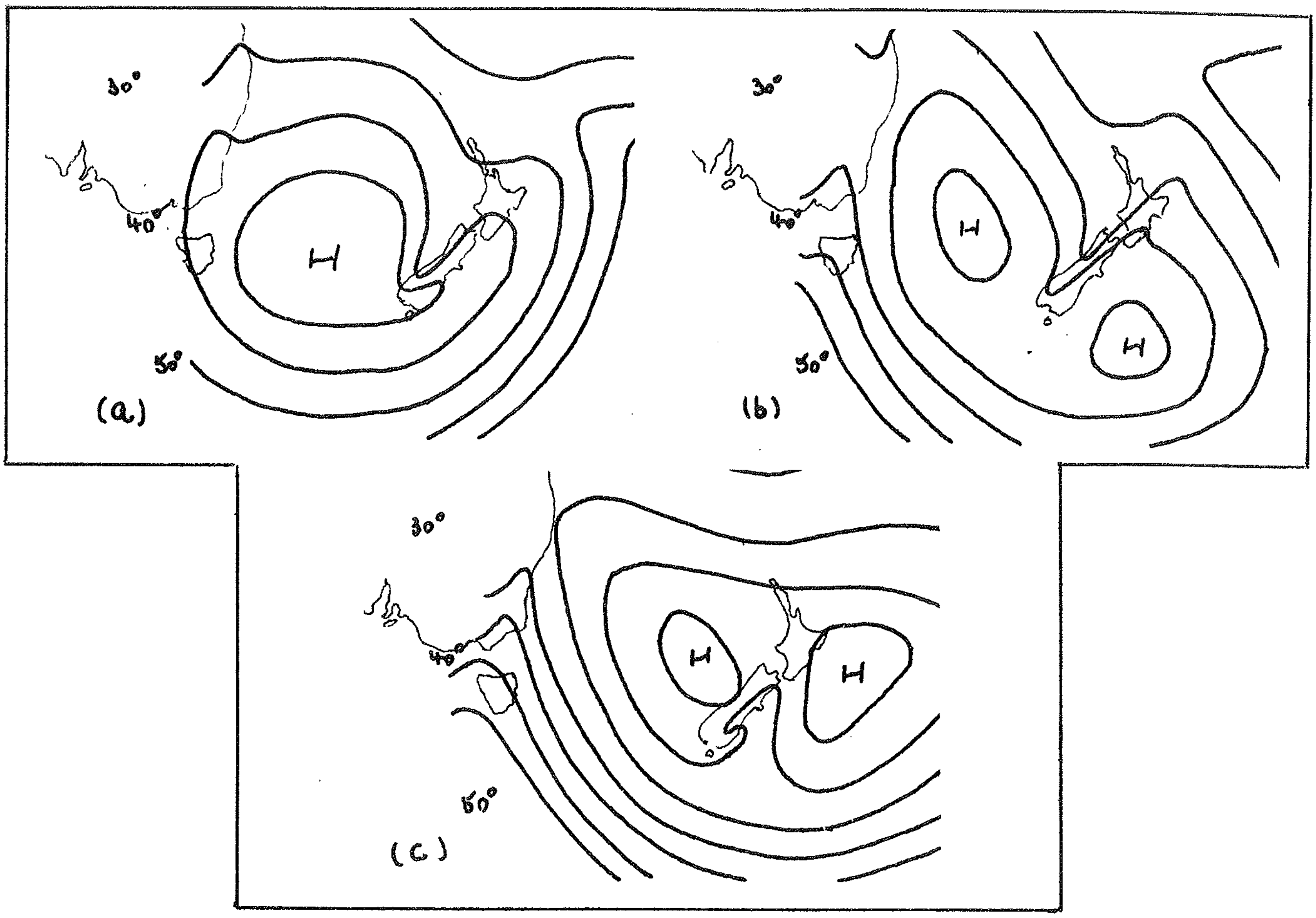

Fig. 3. Schematic illustrations of pressure distributions favourable for a sea breeze development at Hokitika (5 mb intervals).

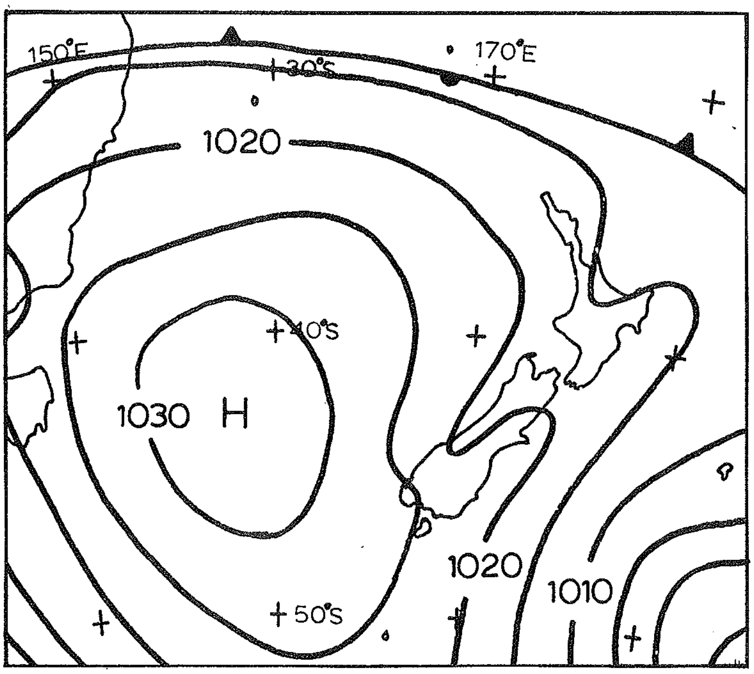

Fig. 4. Surface chart, 0000 GMT 9 January 1974

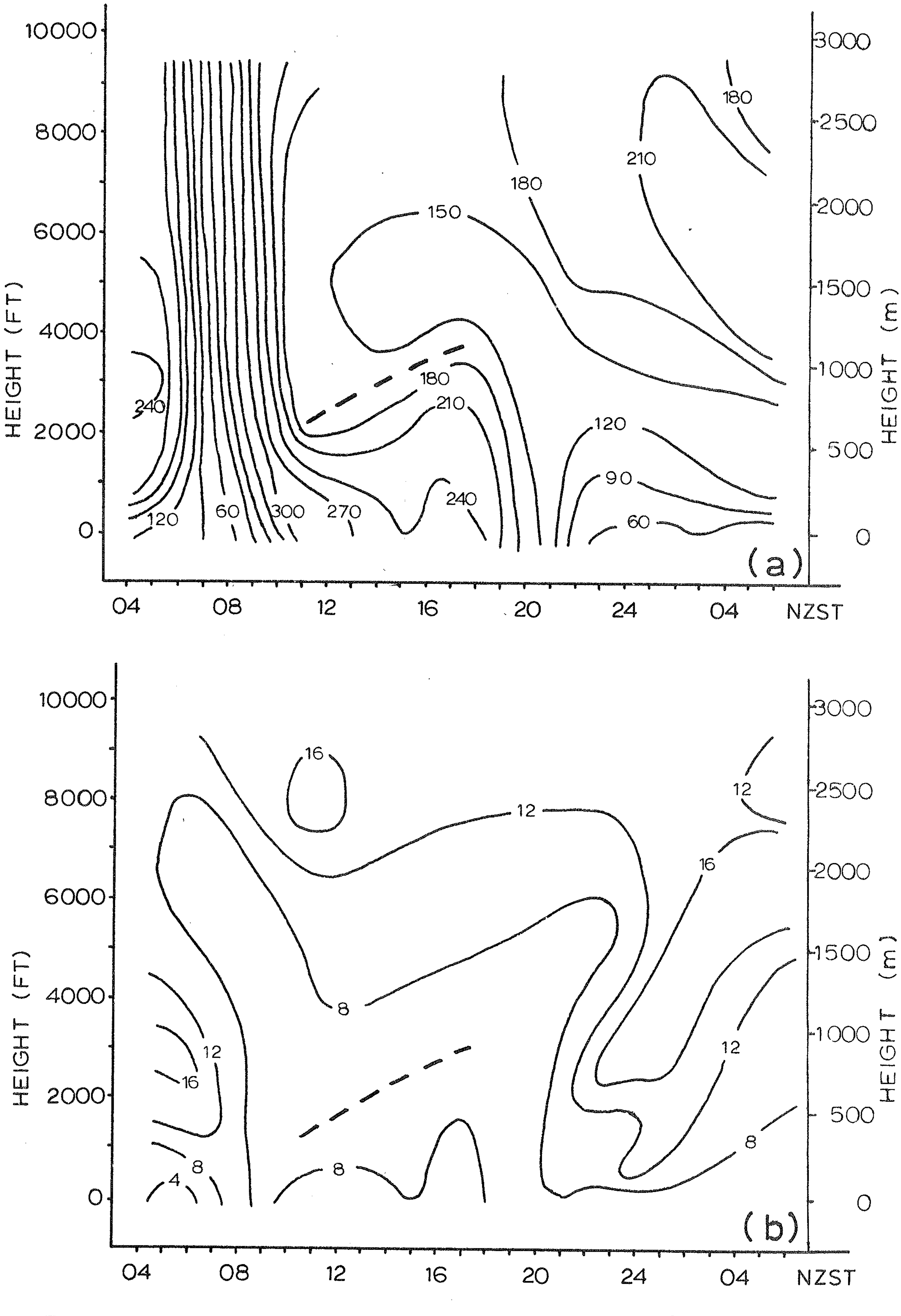

Fig. 5. Time section of isogons in degrees in 30° intervals (a) and of isotachs in 4 kt intervals (b), at Hokitika, 9-10 January 1974.

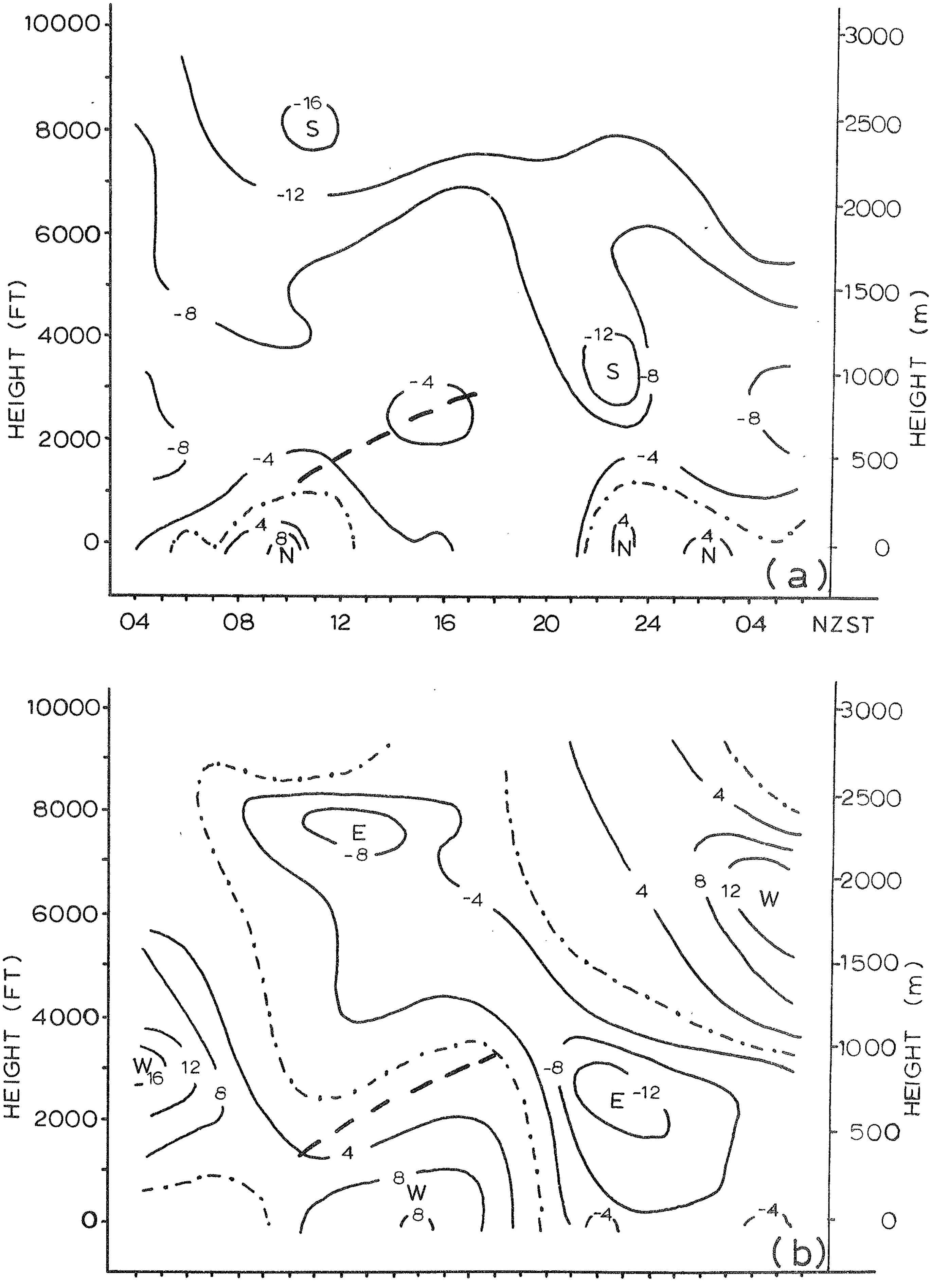

Fig. 6. Time section of meridional (a) and zonal flow (b) in 4 kt intervals, at Hokitika, 9–10 January 1974.