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TECHNICAL NOTE 228

ANTICYCLONES IN THE AUSTRALIA-NEW ZEALAND REGION

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M.L. Browne

Abstract

Data are presented of the frequency and intensity of anticyclones in the Australia-New Zealand region during the decade 1960-69. In the Australian sector the maximum anticyclone frequency is found south of the continent in summer, but about 10 degrees further north, over the continent itself, in winter. In the New Zealand area the greatest number of anticyclones occur west of the North Island in spring, summer and autumn, especially summer. A large number of anticyclones are located just east of the South Island in all seasons, especially winter. East of the 180th meridian the distribution is comparatively uniform.

Blocking anticyclones occur throughout the region, but they are rather more common east of New Zealand and in the longitude of eastern Australia.

The tracks of anticyclones which develop south-west and south of New Zealand are also discussed.

Introduction

A distinctive characteristic of the general circulation of the atmosphere in the Australia-New Zealand region is the absence of semi-permanent anticyclones, such as exist in the eastern Pacific and Indian Oceans. Daily surface weather charts show a series of anticyclones moving across the area, nearly always in an easterly direction, separated by troughs of low pressure and depressions. Few studies of the behaviour of Southern Hemisphere anticyclones have been made because of the paucity, until recently, of observations over large areas. However, meteorological satellite observations now provide sufficient data to allow analysis to be carried out in areas which formerly had to be left blank.

Green (1942) studied anticyclone tracks between 165°E and 175°W in the decade 1928-37 but the synoptic charts were often incomplete, there being very few observations north of New Zealand, none to the south and few ship reports.

Kidson (1947) presented tables showing the mean latitudinal position of anticyclone centres at different longitudes from 120°E to 170°E. The tables were based on 30 years of observations prior to World War II, when the charts for the most part contained only meagre information.

Karelsky (1961) studied 15-year averages of monthly and seasonal anticyclonicity where "anticyclonicity" is defined as the time, in hours, during which anticyclonic centres occupy a given 5 degree square during a given period. Karelsky (1965) has also published data on anticyclone intensities in the region. Taljaard (1967) and van Loon (1956) have studied the atmospheric circulation of the entire hemisphere.

The objectives of the present study were:

(a) to construct seasonal charts of the frequency of anticyclones in the Australia-New Zealand region,

(b) to study the incidence of blocking anticyclones and

(c) to examine the tracks of anticyclones which develop southwest and south of New Zealand and give rise to cold southerly out-breaks over the country.

Data

0000 GMT sea level weather charts prepared by the National Weather Forecasting Centre, New Zealand Meteorological Service, Wellington, for the period 1960-69 constituted the data source. An anticyclone was defined as such when, at 5 mb intervals, at least one closed isobar could be drawn. The central pressure and the central position, to the nearest one degree latitude and longitude were recorded for all anticyclones occurring in southern latitudes between 110°E and 151°W.

Frequency of Anticyclones

Seasonal charts of the distribution of the 10 years of anticyclones at 0000 GMT are shown in Fig. 1. (Summer has been taken as Dec, Jan and Feb, etc.). The charts were divided into 3° latitude by 5° longitude zones and all anticyclone centres in each area were plotted at the mid-point. Isopleths at intervals of 10 are drawn for each set of data.

Figure 1a for summer months shows that the highest concentration of anticyclone appearances lay south of the Great Australian Bight, (see Appendix for location map) while the few anticyclones over Australia are centred near the south and east coasts. This distribution results from low pressure over the continent associated with high land temperatures. Maximum anticyclone frequency occurs south of the continent and west of Tasmania. A secondary maximum occurs west of the North Island, New Zealand. Forecasting experience indicates that the orographic effects of New Zealand often lead to a new cell of high pressure forming to the east of the South Island. A small maximum thus appears east of the South Island, while relatively few anticyclone centres are located northeast of the North Island.

In autumn, (Fig. 1b) anticyclone centres begin to appear further northwards over Australia, particularly in May, as the seasonal continental land-sea heating contrast reverses. The belt of maximum frequency is in the vicinity of 40°S, but orographic effects of the South Island again distort this pattern.

In winter (Fig. 1c) anticyclones in the Australian region are centred over the relatively cold continent, with maxima over South Australia and southern New South Wales. Distribution over the Tasman Sea is more uniform than in other seasons, but there are concentrations of anticyclone centres east of the South Island of New Zealand and north-east of the North Island.

Figure 1d for spring shows that, although anticyclone centres are still found over the Australian continent, the maximum frequency has moved south of the Great Australian Bight. The belt of maximum frequency extends eastwards to the area west of northern New Zealand and then approximately along latitude 33°S as far as 160°W. Anticyclones passing to the north of New Zealand in spring are associated with a high frequency of westerly winds over the country in that season. Karelsky (1961) showed that anticyclonicity considered over long periods was almost proportional to the frequency of occurrence of anticyclones. A comparison of the frequency charts with Karelsky's anticyclonicity charts shows a good measure of agreement where the area of the charts correspond. The coefficient of variation, defined as the ratio of the standard deviation to the mean, expressed as a percentage of the annual number of anticyclones per division in summer and winter is shown in Fig. 2. Values are relatively low in the region of highest concentration of anticyclones, suggesting a greater year to year regularity of anticyclones in these areas than in those parts of the map where the frequency of anticyclones is lower.

Taljaard (1967) has shown the distribution of anticyclone centres in summer and winter during the period of the I.G.Y. (July 1957 to December 1958). His summer diagram shows a maximum in the Australasian region south of the Great Australian Bight. Another smaller maximum north of New Zealand between North Cape and 31°S does not agree with the results of this study, nor with Karelsky's maps of anticyclonicity. The winter diagram agrees well except for a maximum area between Queensland and New Caledonia, found neither in this study nor in Karelsky's results. Taljaard, himself, draws attention to "the remarkable differences in the atmospheric circulation and tracks of systems which can occur in corresponding periods of different years". He also says that conditions were decidedly abnormal during the winter of 1957 in the South African region and it seems likely that other parts of the hemisphere were affected at the same time. The relatively high standard deviations of annual anticyclone frequency found in this study indicates that a period of 18 months is too short a time for a statistical study of such erratic entities as anticyclones.

The seasonal median latitude of anticyclone concentration for each 10 degrees of longitude is shown in Table 1. The data for autumn are separated into those for March-April and May in the Australian sector, where in May anticyclones are located several degrees further north than in the two previous months.

	110-119E	120-129E	130-139E	140-149E	150-159E	160-169E	170-179E	180-171W	170-161W	160-151W
Summer	38	37	39	42	40	38	40	41	40	39
Mar-Apr	(38	38	38	39)	39	38	41	41	39	40
May	(36	32	32	34)						
Winter	34	30	30	34	37	39	40	37	36	35
Spring	36	35	35	36	37	36	34	37	36	37

Table 1. Seasonal median latitudes of anticyclone centres within each 10 degrees of longitude

The total number of anticyclones within each 5 degrees of longitude is shown for each season in Fig. 3. The total number of anticyclones counted on the 0000 GMT charts was approximately the same in each season, the number in the season with the most anticyclones being only 4 percent higher than that with the least.

In all seasons there are few anticyclones centred between 110°E and 120°E. However, a ridge of high pressure frequently extends eastwards across this region from a large anticyclone over the Indian Ocean. New anticyclonic cells commonly develop in this ridge with a maximum in the vicinity of 130°E - 134°E in all seasons. At other longitudes the distribution in summer and winter is quite dissimilar.

In summer, anticyclones rarely move onto the warm land. Instead, as they approach Tasmania and New Zealand, the centres tend to decelerate, while at the same time a ridge of high pressure extends eastwards. A new anticyclone cell subsequently forms east of the land and moves eastwards, while the original centre remains slow-moving and usually loses intensity. One maxima of anticyclone occurrence, in summer, is over the central Tasman Sea and a second lies east of New Zealand. Minima occur near Tasmania and in the vicinity of New Zealand.

In winter anticyclones are common over eastern Australia where they remain slow-moving for days.

In autumn the distribution is similar to that for spring and in both seasons longitudes of maximum and minimum occurrence correspond approximately to those of summer.

Intense Anticyclones

Anticyclones with central pressure ≥ 1025 mb and ≥ 1030 mb have seasonal frequency patterns similar to those shown in Fig. 1.

The latitude of occurrence of intense anticyclones is compared with that of all anticyclones, in the three sectors Australia, the Tasman Sea and east of New Zealand, in Fig. 4.

In summer, in the Australia sector, the latitude of highest frequency of occurrence of intense anticyclones is the same as that for all anticyclones. However, the summer latitude is about 9 degrees further south than the winter one (Fig. 4a). In the Tasman Sea sector the maximum frequency of intense anticyclones is located further south than for all anticyclones but east of New Zealand the maximum occurs in the same latitude. In summer, the proportion of anticyclones which have central pressure ≥ 1025 mb is much lower than in winter, while the proportion of those with central pressure ≥ 1030 mb is very small. Anticyclones of 1030 mb are rare over the Tasman Sea in summer.

However, in winter, over Australia, anticyclones with high central pressure are most frequent about 6 degrees poleward of the latitude of highest frequency of all anticyclones (Fig. 4b). In the other two sectors, in winter, anticyclones with high central pressure also tend to lie poleward of other anticyclones but differences are less pronounced than in the Australia sector.

The proportion of anticyclones, in autumn, with central pressures ≥ 1030 mb is close to that for winter, while in spring the proportion is about mid-way between that for winter and summer.

Blocking Anticyclones

Although the incidence of slow-moving anticyclones persisting for a period of a week or more is not as frequent in the Southern as in the Northern Hemisphere, the phenomenon is far from uncommon. Often these blocking anticyclones are accompanied by cut-off cold depressions in lower latitudes which may produce widespread rain. The early recognition of blocking patterns is important in weather forecasting as they have a profound effect on the movement of other pressure systems.

In the period 1965-69 the average speed of the 70 anticyclones which could be traced from between 110°E and 130°E to beyond 160°W, i.e. across at least 70 degrees of longitude, was 8.3 degrees of longitude per day, the standard deviation being 2.4. A blocking anticyclone was regarded as one in which the eastwards speed was less than half of the average, that is, 4 degrees of longitude per day, over a period of at least three days. The seasonal distribution of blocking anticyclones of various duration is shown in Tables 2 and 3. Blocking is slightly more common in winter than in the other seasons.

	Duration (days)									Total 3-17	Total 6-17
	3	4	5	6	7	8	9	10	11-17		
Summer	22	18	10	8	8	3	1	1	2	73	23
Autumn	20	20	10	8	4	2	2	2	1	69	19
Winter	22	16	9	14	1	4	3	2	2	73	26
Spring	27	12	11	9	8	2	1	1	1	72	22

Table 2. Number of blocking anticyclones of duration ≥ 3 days

	A	B	C
Summer	95	23	24%
Autumn	108	19	18%
Winter	92	26	28%
Spring	102	22	22%

Table 3. Percentage of anticyclones of duration ≥ 6 days classified as "blocking".

Column A : Total anticyclones of duration ≥ 6 days
Column B : No. of blocking anticyclones
Column C : Column B expressed as percentage of A.

The range of longitude passed through by each anticyclone which remained slow-moving for at least six days was plotted. It was found that blocking occurred in all longitudes between 120°E and 151°W and in all seasons. There were, however, preferred locations for blocking, which varied from season to season. In summer there were more blocking anticyclones between 170°W and 161°W than in any other 10 degree longitude range. In autumn and winter most blocking occurred between 135°E and 148°E, while in spring blocking anticyclones were most common between 166°E and 176°E.

Van Loon (1956) has reported on blocking action in the Southern Hemisphere. He found that blocking situations which persist for at least six days happen almost only in three well-defined parts of the Hemisphere, viz, eastern Australasia-Western Pacific Ocean, the Scotia Sea and in the region between Marion and Crozet Islands in the Indian Ocean. These positions are all to the east or southeast of a continent and he assumed that the distribution of blocking is connected with the easy access of warm air which, when advected over the migratory anticyclones, might stabilize them in a position favourable for the further flow of warm air.

In order to make a comparison with van Loon's data it is necessary to consider only those blocking anticyclones meeting his criteria. He defined a blocking anticyclone as one in which the displacement must be less than 25 degrees of longitude at 45°S, during the total period of blocking, which must last for at least six days. This criterion is similar to that adopted in this investigation in the case of blocking of six or more days' duration. In order to avoid confusion with stationary anticyclones in this belt van Loon also required that the centre of the blocking anticyclones must be at least 10 degrees south of the normal position of the sub-tropical high pressure belt as given by Vowinckel (1955).

Vowinckel's data for the location of the semi-permanent sub-tropical anticyclone over the eastern South Pacific Ocean is in good agreement with the charts of the U.S. Navy Marine Climatic Atlas of the World (1959). The monthly surface pressure charts show a ridge of high pressure extending westwards from the anticyclone, the axis of the ridge varying from approximately 32°S in summer to 25°S in winter.

In the five years of van Loon's observations from July 1950 to June 1955, he found 55 cases of blocking in the Southern Hemisphere, 26 of them in the Pacific. By using the same criteria, 49 cases were found in the 10 years of this investigation, so that the annual rate of occurrence was similar.

The total number of blocking anticyclones of six or more days' duration between 110°E and 151°W during the years 1960-69 is shown in Fig. 5.

Figure 5 also shows the number of anticyclones with centres 10 degrees polewards of the sub-tropical high pressure belt. The difference in number is small in the east, where the belt of high pressure extending from the semi-permanent anticyclone might be expected to exert some effect.

Van Loon found that 70 percent of initial blocking in the Pacific Ocean occurred at 175°E and 180° and about 15 percent at 160°E, (the location of blocking anticyclones was taken to the nearest 5°). In the later stages of blocking he found that the locations were further east. His conclusions are not in good agreement with those of this study (Fig. 5 lower curve) which indicate that a considerable number of blocking anticyclones can occur at all longitudes from 130°E to 155°W and that maximum occurrences are near 170°W and between 140° and 150°E. Van Loon's analysis of days of blocking each month was also found to differ from a similar analysis made of the data used in this study, Fig. 6.

High-Latitude Anticyclones

Anticyclones which develop southwest or south of New Zealand are often responsible for prolonged cold southerly spells over the country. Very occasionally, they move into this area from the southwest, but more often they form in a ridge of high pressure extending towards the Macquarie-Campbell Islands area from the northwest. Forecasting experience indicates that such anticyclones usually intensify if a 1000-500 mb confluent thermal trough lies near the anticyclone centre. Central pressures may exceed 1030 mb on occasion.

The distribution of anticyclones south of 48°S on the National Weather Forecasting Centre charts, which extend as far south as Antarctica, is shown in Table 4.

Longitude range	110-129E	130-149E	150-169E	170E-171W	170-151W
No. of anticyclones	3	17	107	126	64
Percentage of total in longitude range	0.4	1.1	6.5	9.3	5.0

Table 4. Longitudinal distribution of anticyclones centred south of 48°S.

Analyses are not attempted over the antarctic continent as much of it is at considerable altitude. High-latitude anticyclones are rare west of 150°E and most common between 170°E and 171°W, where they amount to 9.3 percent of all anticyclones in this longitude range. They occur more often in autumn and winter than in the other seasons.

The tracks of all summer and spring anticyclones which were initially located south of 48°S and west of 170°W are shown in Fig. 7. Anticyclones which appear on only one 0000 GMT chart are shown by a cross. The tracks of the summer anticyclones were mainly towards the east-north-east and could be enclosed in a fairly narrow envelope (Fig. 7 a). Those for March and April were similar to those for summer but in the remainder of the year, from May to November, tracks were quite irregular.

Conclusions

In the vicinity of Australia in summer anticyclones are most frequently centred over the Great Australian Bight, whilst in winter they are most frequently centred over the continent. During spring and autumn more anticyclones are centred over the ocean than over the land.

In spring, summer and autumn, in the New Zealand area, anticyclones occur most frequently west of the North Island. In winter, the highest concentration of anticyclones is to the east of the South Island.

There is a considerable year-to-year variation in anticyclone frequency over southern latitudes between 110°E and 151°W. In the years 1960-69 blocking anticyclones were distributed in a fairly uniform manner between 130°E and 155°W and were not confined to the narrower range of longitudes reported by van Loon.

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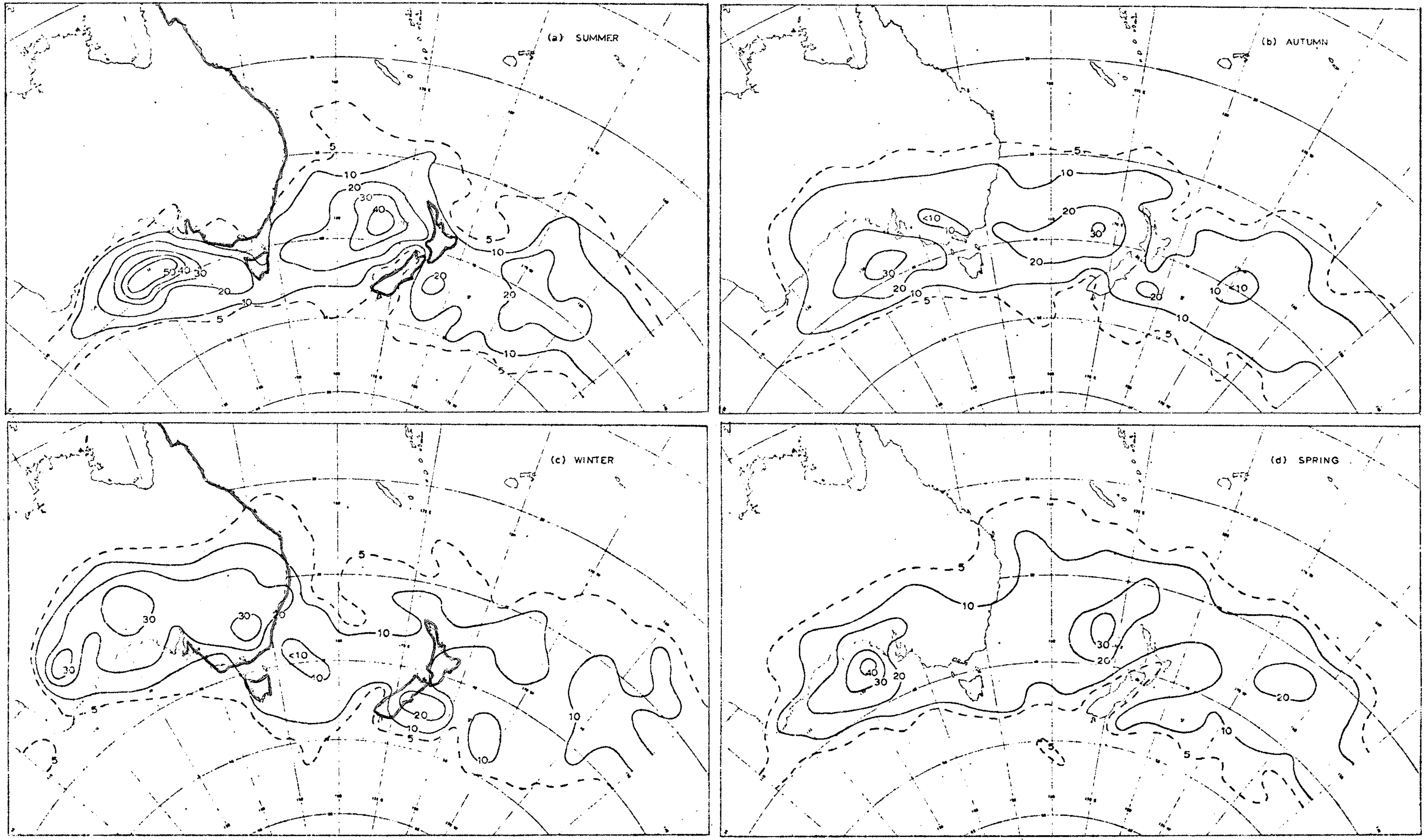


Fig. 1. Frequency of anticyclones in (a) summer, (b) autumn, (c) winter, (d) spring; 1960-69, in sectors 3 degrees latitude, 5 degrees longitude.

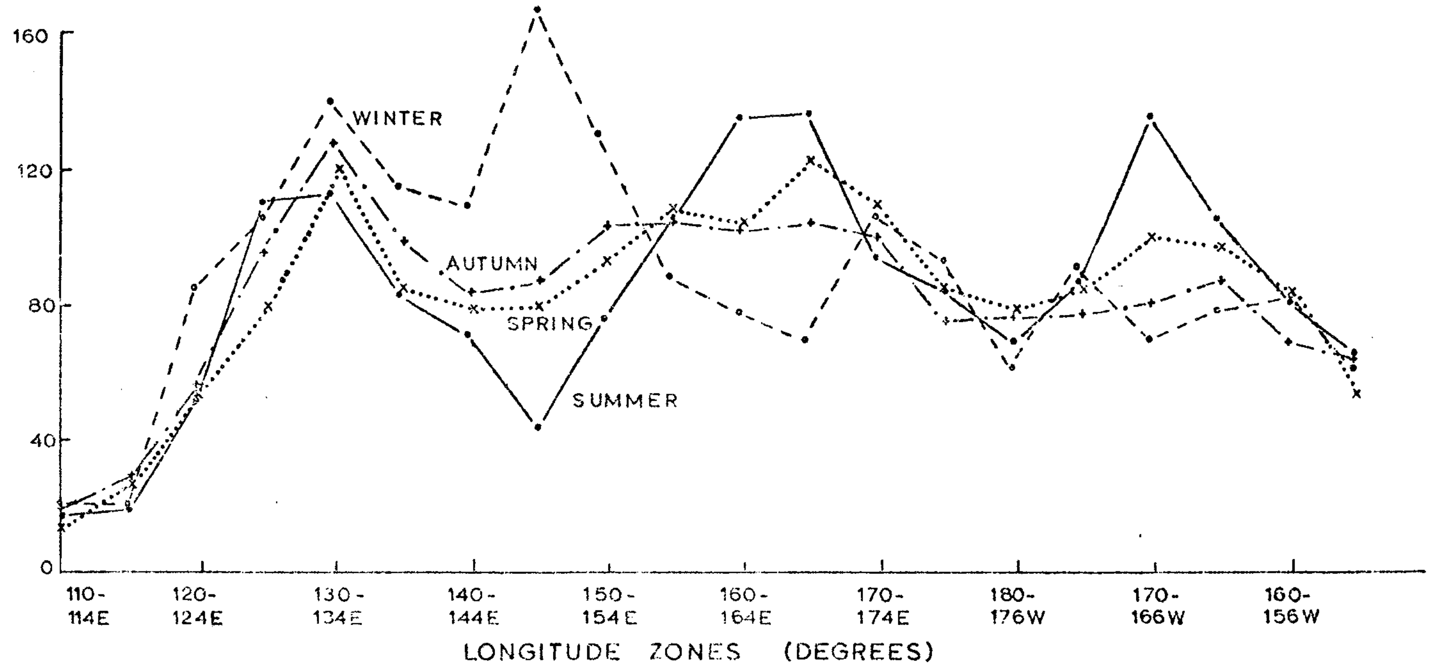


Fig. 3. Numbers of anticyclones, in each season in 5 degree longitude zones.

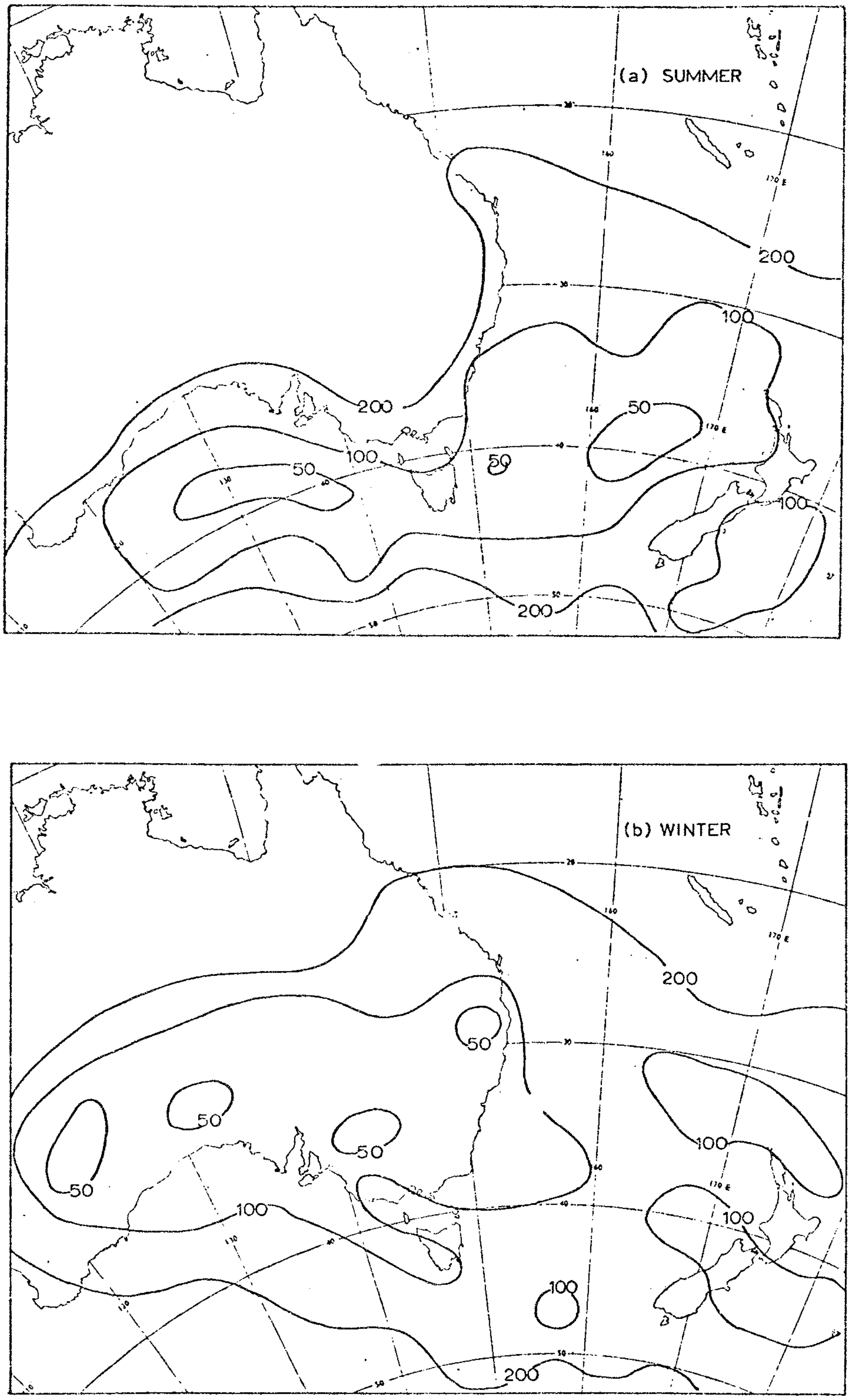


Fig. 2. Coefficient of variation (a) Summer (b) Winter.

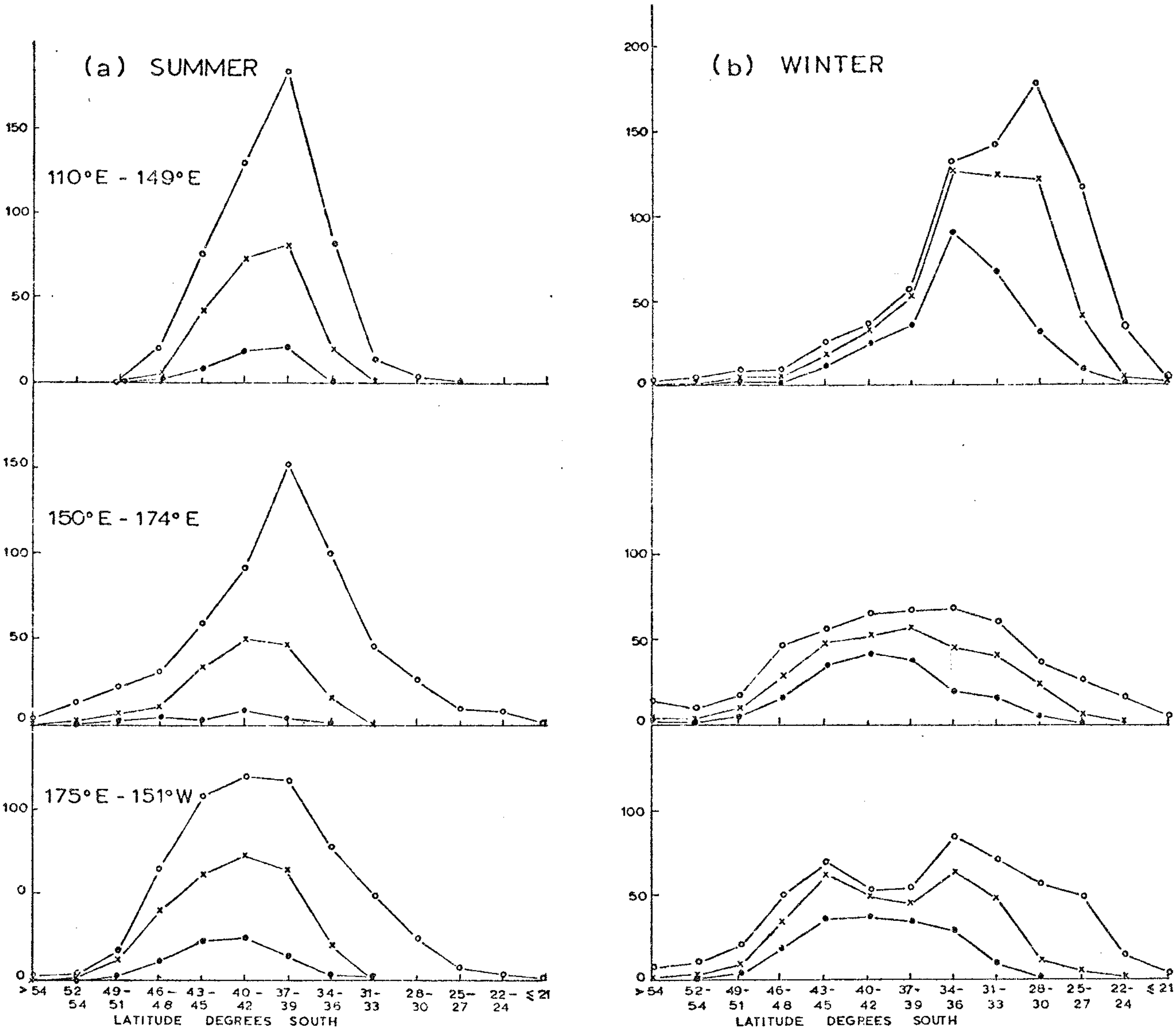


Fig. 4. Frequencies of anticyclones each 3 degree latitude zone in various longitude zones. Upper curve, all anticyclones; middle curve, those with central pressure ≥ 1025 mb; lower curve, those with central pressure ≥ 1030 mb, (a) Summer (b) Winter.

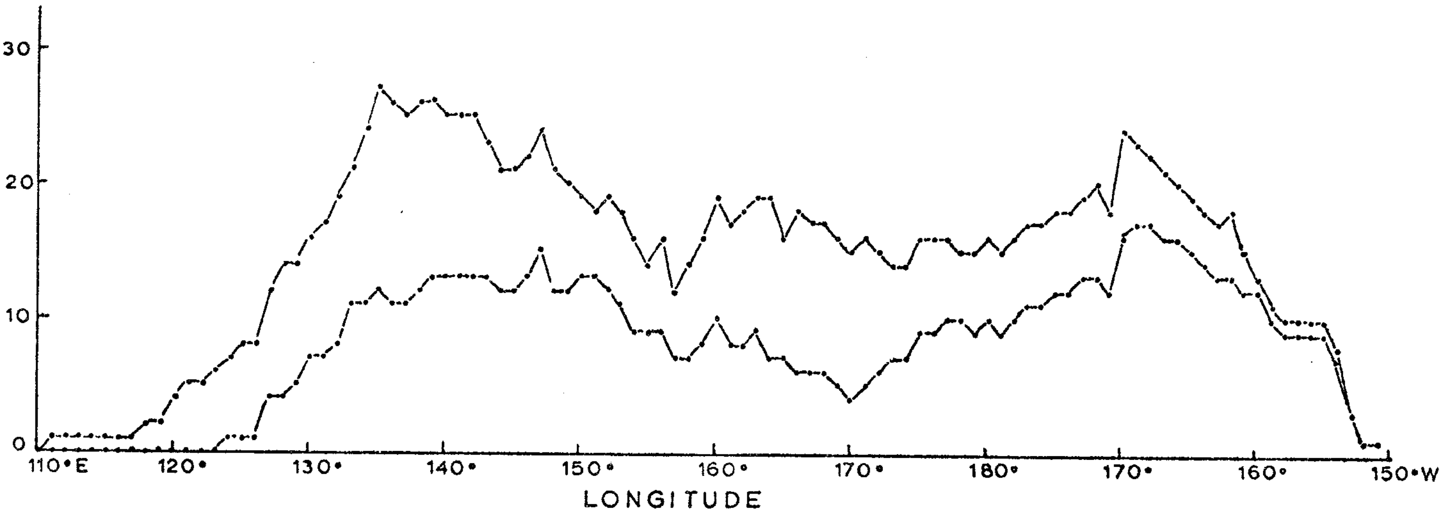


Fig. 5. Upper curve: number of blocking anticyclones stationary over or passing each meridian. Lower curve: Those with centres ≥ 10 degrees south of sub-tropical high pressure belt.

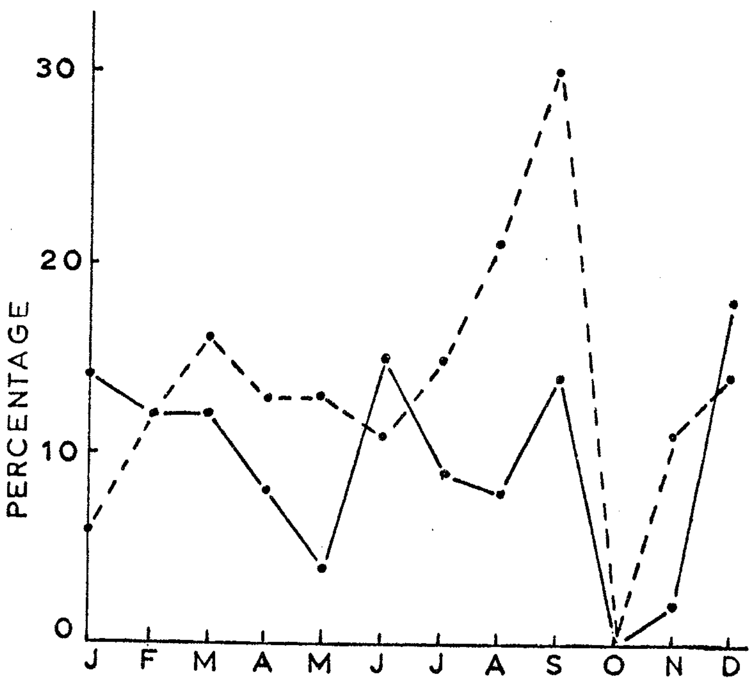
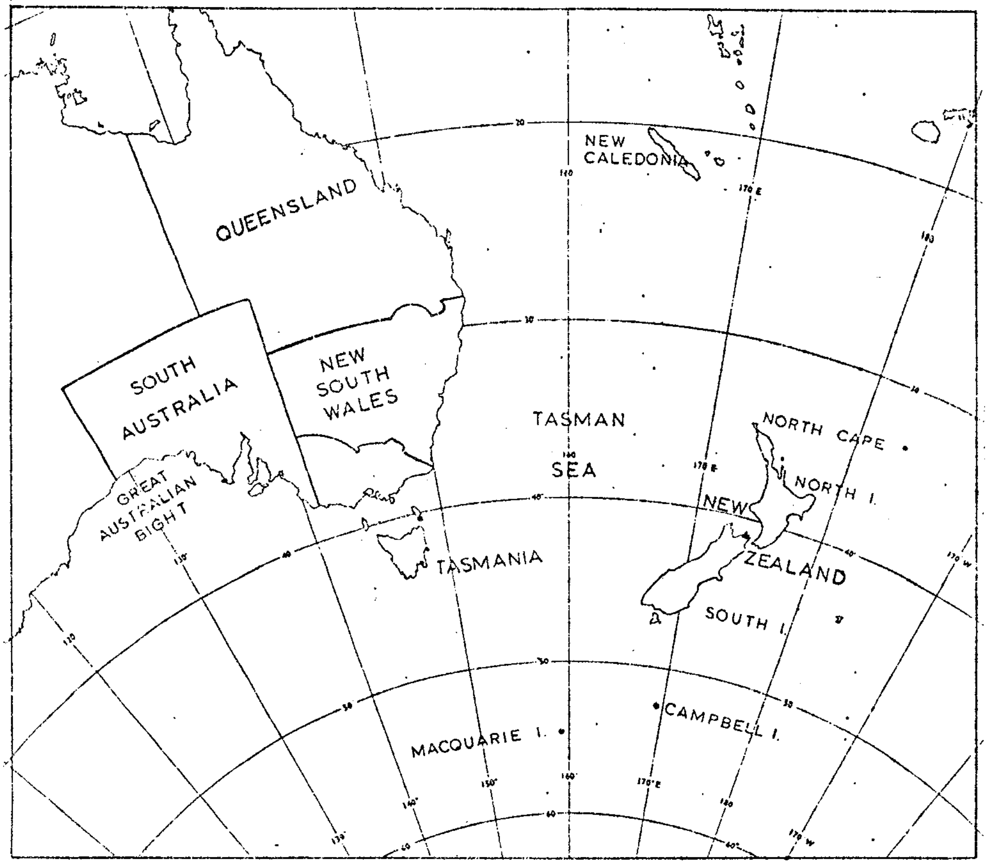


Fig. 6. Percentage of days blocked per month:
dashed line: Van Loon
solid line : 1960-69

Appendix



Locality map showing place names mentioned in the text.

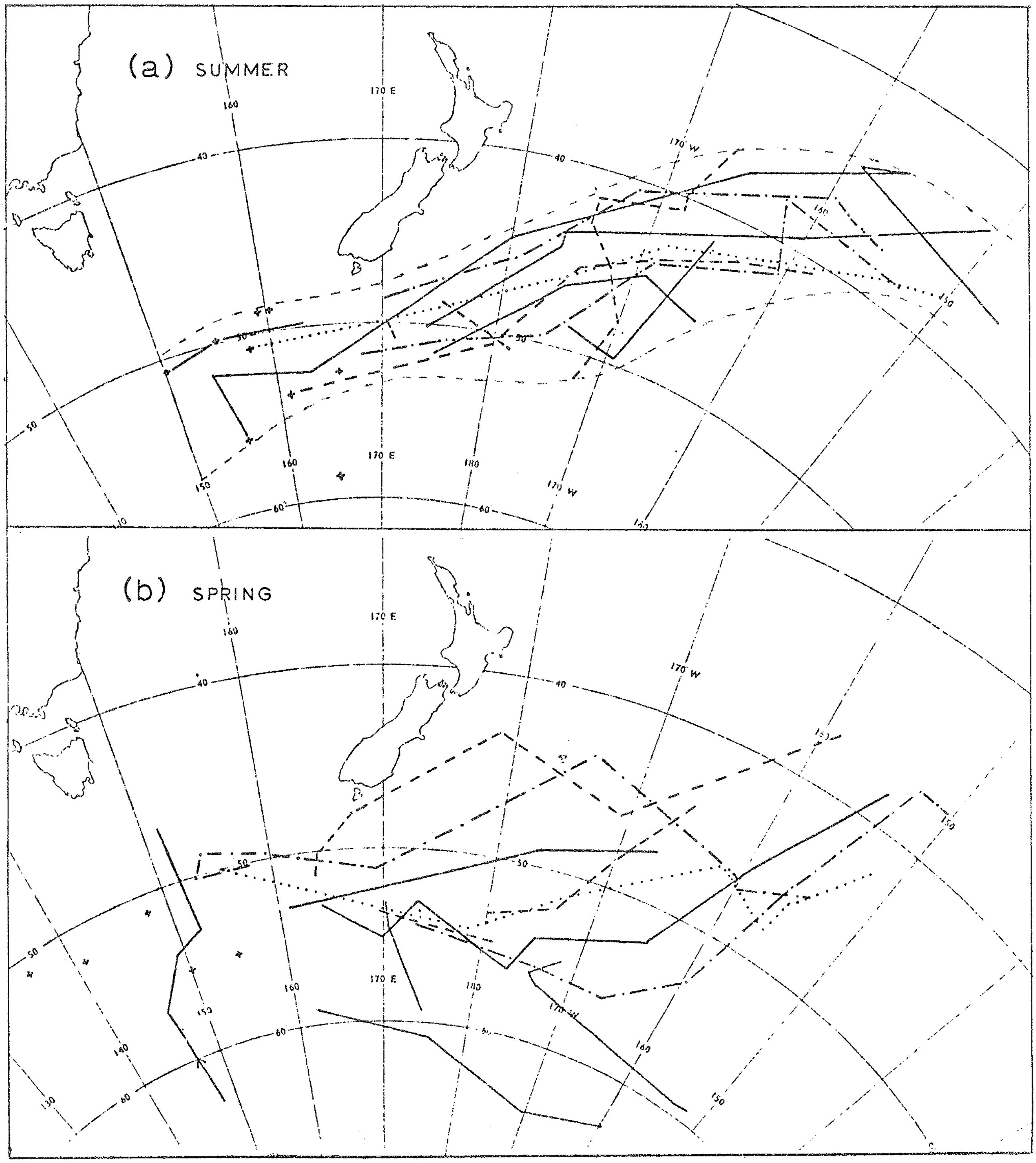


Fig. 7. Tracks of anticyclones south of 48°S and west of 170°W (a) Summer (b) Spring.