# WINDS IN SOUTHEAST QUEENSLAND AND RAIN IN AUSTRALIA AND THEIR POSSIBLE LONG-TERM RELATIONSHIP WITH SUNSPOT NUMBER

W. T. WARD
*Division of Soils*

and

J. S. RUSSELL
*Division of Tropical Crops and Pastures,*
*Commonwealth Scientific and Industrial Research,*
*Organization, Mill Road, St. Lucia, Queensland 4067, Australia.*

**Abstract.** Wind records at Brisbane indicate past changes in ambient weather systems that appear to be confirmed by observed changes in Australian rainfalls. Both wind and rainfall data support geological field evidence of a climatic change in southeast Queensland in the 1930s.

At Brisbane the numbers of calms observed in January and July declined from 1887 to 1935, and then increased again. This variation was associated with changes in wind patterns, particularly in winter (July) from 1933 to 1937 and afterwards, but also in summer (January) during the 1930s. The changes in circulation were enough to explain the movement of beach and dune sands at that time.

The changes in windiness show a close connection with the 80-year trend in sunspot number: the initial period of below average sunspot number coincided with increasing wind strength and more southeasterly winds. Rainfall trends show similar associations with sunspot trends, but the direction of rainfall change is different in different regions. In southeast Australia changes in rainfall are positively correlated with trends in sunspot number over the last 80 years, while the opposite holds for the far southwest and Cape York Peninsula. On the north coast negative correlations occur in summer, and positive correlations in winter, but in Queensland and western New South Wales the correlations are positive in summer and negative in winter. It is too soon to tell whether the connection between sunspots and weather is accidental or functional.

## Introduction

Studies of climatic change usually proceed from a meteorological or a geological base. The first is concerned with recorded weather observations while the second arises from observations of sediments showing that different climates have succeeded one another in time. These approaches lead naturally to two distinct points of view. Meteorological data are continuous, and show large variations from year to year, so much so that real changes to different climatic regimes are obscured. Indeed, it is difficult to find any persuasive grounds for subdividing the data records. The temperature and rainfall discontinuities which are noticed at times could indicate real changes in the climate, or result from inherent variability. Moreover, a statistical approach is usually adopted in a climatic study because the observations are numerous, and means and trends are determined, even though statistical summaries such as these can conceal actual changes (Kraus, 1956; Gribbin, 1979). From the viewpoint of the climatologist, climatic changes are best seen,

*Climatic Change* 3 (1980) 89–104. 0165–0009/80/0031–0089$01.60.

it is said, "in terms of the movement of the mean climatic state towards one extreme of the existing range of climatic variations" (Pittock, 1975). A significant change in statistical measures should therefore indicate a change in climate, but it is not likely that everyone would agree with this, unless the duration of the change was also defined. Among climatologists, therefore, judgment of climatic change is rather a matter of individual preference than objective assessment (Gibbs *et al.*, 1978).

Geological data support a different view. The geologist has to deal with rock sequences that contain frequent discontinuities. He sees an interglacial deposit, for example, giving way abruptly to a glacial one and his field impression is of rapid change between different and more-or-less enduring conditions. The sediments prove that the climate has changed; only the scale of the change has to be decided.

The different views become evident in formal definitions. Thus a working group (J. M. Mitchell, 1966, chairman) of the W.M.O. Commission for Climatology recommends that "a particular *statistical form* of change" be associated with terms such as "climatic change" and "climatic fluctuation" and states that these terms should be applied to the whole period in which that form of change prevailed. For a geologist, statistics are unobtainable and rainfall or temperature must be estimated. Different parts of a sediment sequence are separated on the relative amount of temperature change, and critical points of change are sought. As a working rule Suggate (1965) suggests that the beginnings of rapid coolings should be distinguished, but his proposals are not like those recommended by the W.M.O. Commissioners, for he argues that deposits representing warming and warmth should be separated from those of cooling and cold.

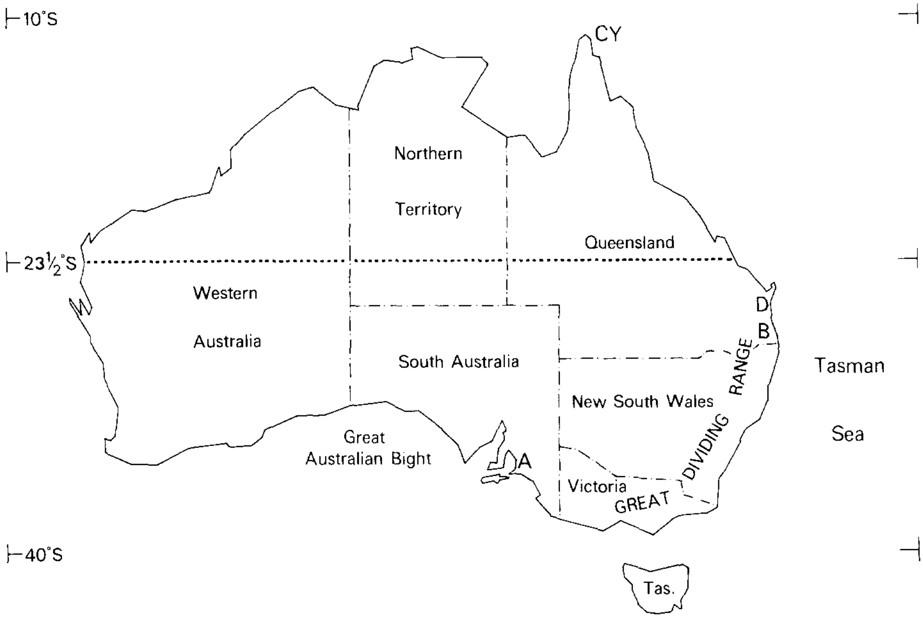

Fig. 1. Location map. B, Brisbane; D, Double Island Point; A, Adelaide; CY, Cape York; Tas., Tasmania.

The fact is that geologists and climatologists see things differently. The differences in their points of view have not been particularly obvious or consequential, till now, for there are few geological studies of historic periods for which meteorological data are available, and few climatological studies of geological data. However, the interest of geologists in very recent events is increasing, and their observations give a new perspective to the interpretation of the meteorological record.

An example of a recent geological change of climatological interest is found in southeast Queensland (Figure 1). In this area, large massed sand dunes have formed at times of low sea level and, by implication, in glacial ages. Smaller masses of blown sand appear to be associated with episodes of slightly lowered sea level in postglacial time (? Little Ice Ages). The latest episode of sand movement occurred in the 1930s, or more correctly at some time between 1927 and 1942, for there was no contemporary record of the exact time. Maps drawn in 1927 show the land prior to drifting, however, and aerial photos show that movement was complete in 1942. Except for scale, this episode differs in no way from its predecessors, and a geological argument to identify it as a time of significantly different climate could be justifiably proposed. To help define the prevailing conditions we have studied the wind records for Brisbane and rainfalls for Australia. These studies are reported in Part I, below. In the course of the work a coincidence of windiness with sunspot activity was noticed, and possible relations with rainfall were explored. The results of these studies are given in Part II.

## Part I: Changes in Wind and Rainfall

### *I.1. Sand Movement and Winds in Southeast Queensland*

In Australia generally the 1930s are remembered as years of drought and dust-storms, especially in the southeast. These conditions have not been seen as a consequence of a change in the winds but have been attributed to cultivation of drought-prone lands not suited to agriculture (Williams, 1978) and to over-grazing by sheep and rabbits (Ratcliffe, 1936, 1937, 1938). On Queensland's coast sand movement onshore was accompanied by long-shore drift on the beaches, however. This movement of beach sand is obviously not due to cultivation or drought, or to the depredations of grazing animals, and in consequence a change in the winds between 1927 and 1942 is clearly indicated.

Our study of the wind records for Brisbane was made to examine the timing and nature of the wind changes. Continuous wind records began in Brisbane in 1887. Wind speed (Beaufort scale) and direction (16 points) at 0900, 1500 and 2100 h have been recorded daily, except for the period from July 1903 to January 1910, when the 2100 h observation was not made. Most of the data remain in manuscript form and to make the work practicable the wind study was confined to the months of January and July. One measure of windiness is the number of observed calms per month. Although January is windier, the records for both January and July are surprisingly alike in respect to the numbers of observed calms (Figure 2). In the long term the numbers of calms decrease from 20 to 30 per month in the 1890s to less than five in the 1930s, and then increase again, so as to

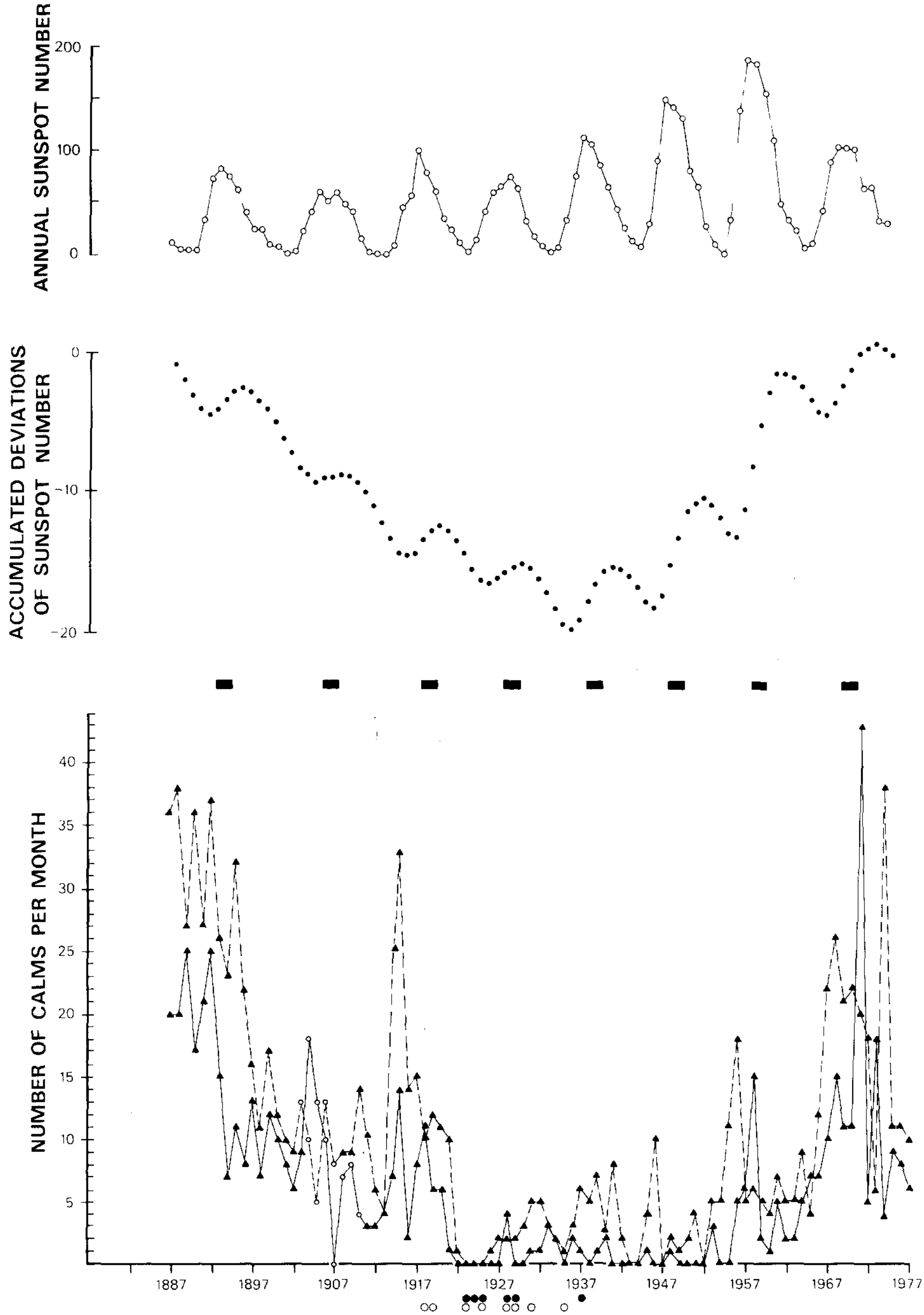

Fig. 2. (Top). Plot of sunspot number for the period of this study, 1887–1974. (Middle). Accumulated deviations of annual sunspot numbers from the 1887–1974 mean. Short bars mark years of sunspot maxima. (Bottom). Numbers of calms in January (full line) and July (broken line) observed in Brisbane at 0900, 1500 and 2100 h, 1887–1977. Filled circles indicate years when dust hazes were reported in January; open circles show dust hazes in July. Values from July 1903 to January 1910 were estimated from observations at 0900 and 1500 h.

reach values in the 1970s like those of the late 19th century. These long-term changes in the occurrence of calm air are too large and too systematic to be attributed to variation amongst observers. Moreover, they follow the same trends as several indices of zonal circulation reported by Lamb (1972) and are therefore likely to reflect the same world-wide phenomenon. This inference seems to be supported by the occurrence of a parallel shift in the North Pacific trade winds (Beals, 1927; Wentworth, 1949) and development of dust-bowl conditions in the American southwest at the same time as sand-blowing in Australia. In southeast Queensland the long-term trend does not appear to be related to any change in the mean position of the subtropical belt of high pressure, which dominates the local climatic regime, for the centre of the anticyclone track where it passes through eastern Australia has shown no displacement since 1940 (Pittock, 1973, 1978). In all this time there was a continuing move in Brisbane towards calmer weather.

The period of greatest windiness, judged by the small numbers of recorded calms, extended from the early 1920s to the late 1930s, when dust hazes derived from inland areas were frequently recorded in Brisbane (Figure 2). A vigorous air circulation is suggested and this is confirmed by the observed wind speeds, Figure 3. The numbers of calms in January and July show similar trends in the short-term, as in the long-term. This would suggest that much of the short-term variation in the occurrence of calms is not random.

Variations in daily wind direction were examined over the period 1888–1977 by summing data for consecutive 5-year intervals and reducing to 8 compass points (Figure 4). Wind directions in January are dominated by winds from the northeast and southeast. The frequency of northwesterly, westerly, and southwesterly winds increased after 1930, but there is no apparent change in the January wind pattern between 1927 and 1943 which might explain sand movement from the southeast then. The wind data for July show a considerable variation in the frequency of south and easterly winds, however, and this, together with the increased wind speeds, could well have been enough to produce the observed sand drifting.

The period from 1933–37 ended with a marked change in the July wind pattern. Before 1933 winds from the west to south had been equally prominent. Since 1937 the numbers of southerlies have declined by half, while the southwesterlies have increased in proportion. The stability of the two wind patterns for July is worth noting: the change which occurred in the middle '30s has persisted until now although there have been some irregularities in numbers of southwesterly winds in the last few years. The changed pattern appears to represent a real change in the wind at Brisbane, for there was no alteration in instrument exposure during the 1930s. Moreover, if that had happened the January record would have shown a discontinuity in the southeasterly sector like that seen in the July record.

To check these wind changes records taken at Double Island Point lighthouse 200 km to the north were also examined. At this exposed station calm air is rare but southeasterly winds were more frequent in the mid 1930s and at that time there was also an overall increase in wind strength. There have been less northerlies and more easterlies at Double Island Point since 1935. The wind change seen in the southerly and southeasterly sectors at Brisbane in July is less prominent at Double Island Point, but before 1930 there were

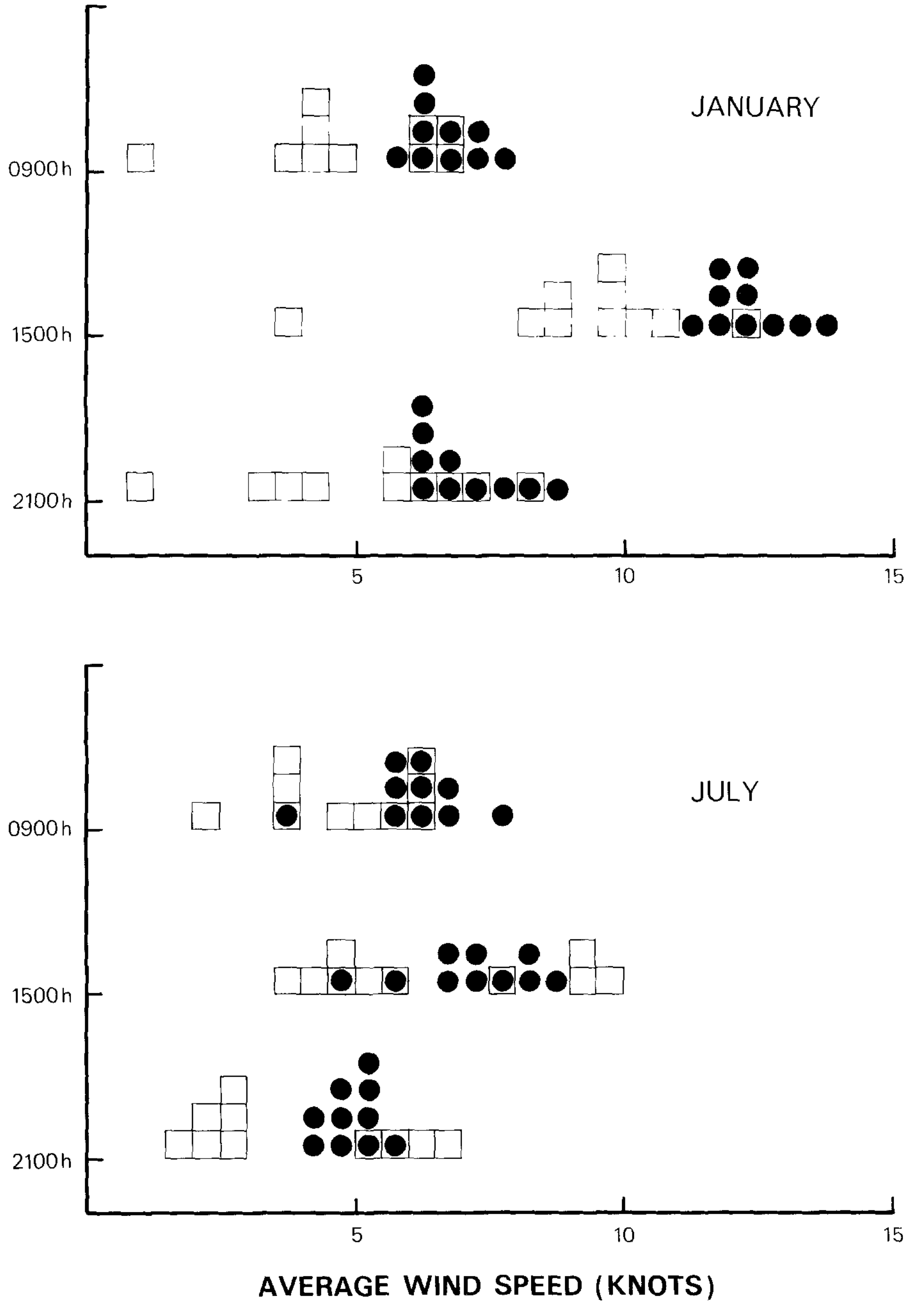

Fig. 3. Average wind speed each January and July at Brisbane for 1930–39 (circles) and 1960–69 (squares).

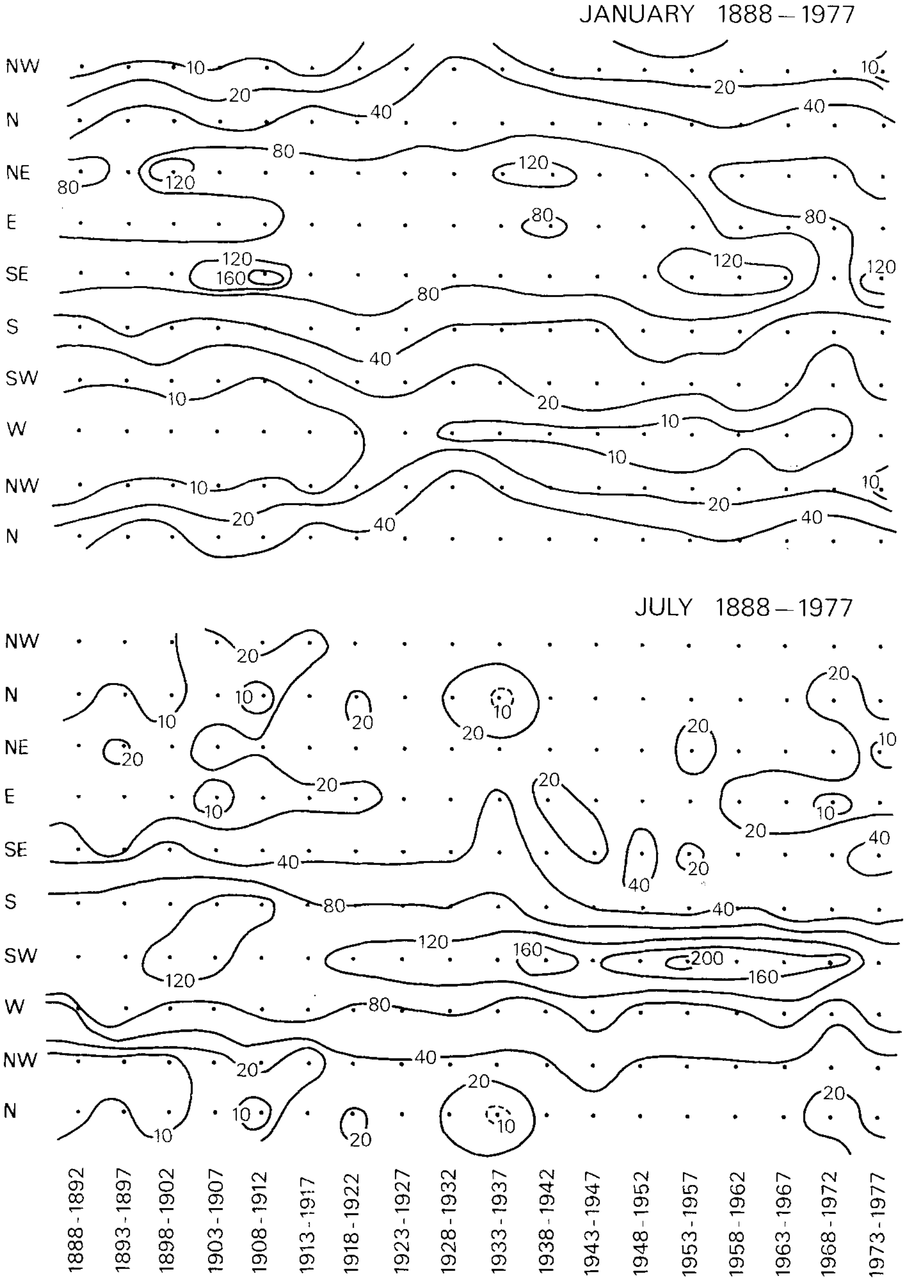

Fig. 4. Wind frequency *v.* direction at Brisbane in January (top) and July (bottom); contoured values for 5-yearly intervals, 1888–1977. The observed numbers of winds from each direction in each 5-year interval are not shown separately in order to simplify presentation. Note that the contours are not separated by uniform intervals. Maps and aerial photographs show that coastal sand drifting from the southeast occurred at some time between December 1927 and August 1942.

more southerlies and considerably more south-south-easterlies than in the subsequent period.

### *I.2. Interpretation of Wind Observations*

The direction of the wind in coastal southeast Queensland in July mostly reflects circulation patterns associated with anticyclones moving east across southern Australia. The wind is southwesterly when anticyclone centres lie in the western part of the Great Australian Bight, and swings steadily to the southeast as they move across the eastern bight, through New South Wales, and into the Tasman Sea. The onshore winds bring rain first to South Australia and western Victoria, then to New South Wales and finally to coastal Queensland as the anticyclones move across the continent. The higher numbers of southerly and southeasterly winds in Brisbane before 1933–37 imply that anticyclones then were developed less over the western bight than they are now, and remained longer in the eastern bight and in New South Wales. The increased southeasterly and easterly winds in the mid '30s suggest that in these years the anticyclones stayed longer over the Tasman Sea.

The pattern as described for July is typical of winter months. The situation in autumn and spring is similar except that low pressures develop in these seasons. In autumn especially the lows usually form as depressions cut off from tropical lows further north. It could be supposed that the July wind patterns of 1933–37 were produced partly by lows which occurred over the Tasman Sea in July at that time. However, if that had happened in the years with the most southeasterlies there would have been an increase in the numbers of rainy days with winds from the north and west also, but that was not observed.

In summer the anticyclones shift south of Australia and the Intertropical Convergence Zone, with its variable cyclonic activity, enters the northern part of the continent. Heat lows form in the interior and their associated wind circulations become significant. In January in southeast Queensland the slow-moving high-pressure centres in the south control the weather, and when an anticyclone is over the Tasman Sea a ridge of high pressure usually lies along the coast north of Brisbane. As a consequence, northeasterly and southeasterly winds prevail in southeast Queensland. The low-pressure trough in the interior of the state produces isolated showers and thunderstorms in the east as the coastal ridge weakens, and widespread rain can develop if its expansion coincides with a cold front to the south. In northern Queensland a series of low centres associated with the Intertropical Convergence Zone dominates the weather in January and usually one of these, a rain depression or a tropical cyclone, can bring strong winds and heavy rains to the south Queensland coast. The Brisbane wind records for January show that the numbers of southeasterly winds reached their lowest values in the 1930s whereas the frequencies of easterly and northeasterly winds increased. From 1923 to 1942 the numbers of northwesterly and westerly winds increased, and after 1935 the numbers of southwesterly winds doubled. These changes suggest a greater development of anticyclones in the 1930s, changes in the movements of the anticyclones resembling those inferred for July, and greater development of the central Queensland summertime low-pressure trough since 1930. This implies higher summer rainfalls in central Queensland since the 1930s. To check this and other implications of our interpretation we now examine the long-term rainfall records.

### *I.3. Rainfall in Australia During 1895–1974*

The assessment of rainfall changes with time is difficult because of variation in the amount of annual rainfall from place to place and the large variations from year to year at each locality. Furthermore, if records from low- and high-rainfall stations are to be compared without introducing bias for volume of rainfall, the observations need to be normalized and standardized (zero mean, unit variance). The rainfall each year for each station can then be expressed in terms of its deviation from the station's long-term mean. In this way, departures from the mean can be placed in true perspective of relative significance and variations at different localities can be expressed in equivalent terms. Long term trends, which are obscured by the large variations in rainfall that occur from year to year, can be assessed by the summation of the series of annual standard deviations. This "residual mass" approach (Kraus 1955, 1956, 1963) is particularly useful as it brings out long-term trends, and accentuates points of change. With the development of numerical pattern analysis techniques it is possible to compare and group residual mass curves from individual stations. In this way regions with similar histories can be defined.

For this study, rainfall data for 200 widely spread stations covering the 80-year period 1895–1974 were examined (Russell, in prep.). Although stations with longer records were available, these are located only in the south and on the coast. The year 1895 was the earliest that provided a significant length of record and reasonable geographic coverage. For convenience, the records for each year were divided into two parts, summer (October through March) and winter (April through September). Seasonal rainfalls are not normally distributed about the mean at most stations, and normalization was achieved by using a square root transform. The deviations from year to year were then accumulated for each station, beginning with 1895 (winter) and 1895–1896 (summer). The results for Brisbane are shown in Figure 5. The residual mass curves for each station were then compared. Because they show up periods of above-average and below-average rainfall, and define points of change, their shapes are as important as the magnitudes of the values. For this reason, correlation coefficients were used as a measure of similarity, because of their sensitivity to differences in shape (Sneath and Sokal, 1973). The stations were grouped according to similarity using MULCLAS (Williams, 1976) a clustering program that incorporates the flexible sorting procedure of Lance and Williams (1967). This is a hierarchical program which allows the intensity of clustering to be varied. Grouping is agglomerative, and relationships can be shown in a dendrogram.

A detailed account of the rainfall study is being reported elsewhere (Russell, in preparation). For each season, summer and winter, five regions defined by MULCLAS were separately recognized. For summer, most records began with below-average rainfall except in the northern tropics (Northern Territory and Cape York). Dry summers con-

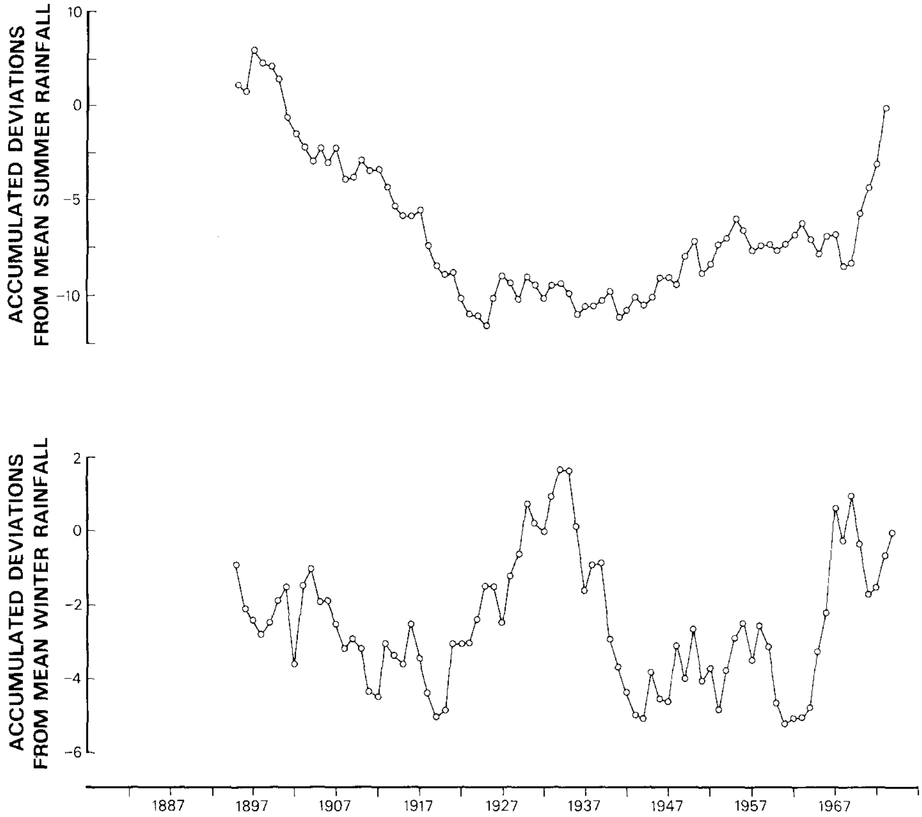

Fig. 5. Accumulated deviations of normalized summer rainfall (top) and normalized winter rainfall (bottom) from the 1895–1974 seasonal means for Brisbane. Correlation coefficients with the 80-year accumulated deviations of sunspot numbers (Figure 2): 0.69 (summer), –0.05 (winter).

tinued in the southeast until 1934 when above-average summer rainfalls prevailed except in New South Wales, where a general recovery did not begin until 1946. In the north summer rainfalls were high until 1918 but after that they stayed below average until 1966. The early to middle '30s were dry everywhere, except on the eastern coast, which had average rainfalls.

For winter, slightly below average rainfalls affected the east and southeast coasts until about 1915. The east coast then had better than average winter rainfalls until 1935. To some extent these were shared by southern Victoria and Tasmania. Drier seasons followed until 1946. The 1930s began with better than average winter rains everywhere but finished with dry winters except in north central Queensland which continued to receive good rains.

These changes are consistent with the long-term changes in ambient weather systems inferred from the wind records at Brisbane. The above-average winter rains on the east coast, and the below-average rains in South Australia, New South Wales and coastal Victoria before 1935 suggest, for instance, that longer-lasting anticyclonic conditions occurred then over eastern Australia. The above-average winter rain enjoyed by the east coast in the early 1930s would imply well-developed anticyclones over the Tasman Sea. High winter rainfalls in coastal Victoria and Tasmania since 1935 indicate increased anticyclonicity in the west. For summer, relatively low rainfalls before 1935 and higher rainfalls afterwards in southeast Queensland, New South Wales (and perhaps South Australia) suggest significant development of the central Queensland low pressure trough since that date. Summertime changes in northern Australia indicate that periods of relative calm, in the Brisbane wind record, coincide with periods of high rainfall in the north.

## Part II: Apparent Relation with Sunspot Number

There have been many attempts to relate changes in solar activity, as measured especially by changes in sunspot number, to changes in terrestrial climate. Most attention has been focussed on the pronounced 11-year sunspot cycle and the longer-term fluctuations have received less attention, although the existence of a long, very roughly a 78–80 year cycle is well known. Claims for terrestrial responses to the 11-year sunspot cycle, critically reviewed by Pittock (1978), are shown by him to be poorly-founded or controversial, but the evidence for a climatic response to longer-term solar changes carries a large measure of conviction (Siscoe, 1978). The long-term changes in the sun are made evident by the varying amplitudes of the successive sunspot cycles, and by their occasional suppression altogether (Eddy, 1977). During these times of low solar activity the earth cooled, and glaciers advanced, while the episodes of enhanced solar activity correspond to periods of warming. Since the 1870s the overall envelope of sunspot numbers has decreased, and then increased again much as the trends we have noticed in rainfall and winds.

To define long-term trends in sunspot numbers, the mean and annual deviations of yearly sunspot numbers over the period 1887–1974 were calculated and deviations from the mean were then summed in the same way as the rainfall data had been treated (Figure 2). In adopting this approach we accept sunspot number as an indirect measure of solar activity and, as the record is greatly obscured by the short-term 11-year variation, define above-average and below-average periods by summing annual departures from the 1887–1974 mean. The 11-year cycle is not suppressed entirely but the longer effect is also evident. The overall pattern is of low solar activity from 1887 to 1935 and then increased activity afterwards, from 1935 to 1974. The defined intervals result from integration, but it does not follow that solar radiation varies integratively in any way. However, the integrated sunspot curve runs more-or-less parallel to changes in the weather on the earth for the period studied, and this suggests that the changes in the sun could be associated with terrestrial responses which increase with the duration of a change, in much the same way as a drought worsens when low rainfalls continue. It will take time, of course, before a change in solar activity can produce its full effect on a dynamic atmosphere.

### *II. 1. Relation of Winds in Southeast Queensland to Sunspot Activity*

The correspondence between the numbers of observed calms and the long-term trend in sunspot numbers is apparent in Figure 2. Before 1935 sunspot numbers were mostly below average so the accumulated deviations decrease until then. After 1935 they increase again, in the same way as the long-term changes in numbers of calms. There appear to be no meaningful relationships between the sequence of calms and the 11-year sunspot cycle.

We have not made monthly summaries of wind frequencies of different strength for Brisbane but did extract them for Double Island Point in view of the small number of calms observed there. Before 1915 wind strengths at Double Island Point ranged from 0 to Beaufort Force 7 in most years, and occasionally Force 10 winds were experienced in January. The same pattern has occurred in the years since 1945. Between 1915 and 1945 there were very few calms, and few winds stronger than Force 6 were recorded. In broad outline this record shows changes parallel to the accumulated sunspot one.

To summarize, the wind observations at Brisbane and Double Island Point describe (a) a southerly wind pattern in July from 1888 to 1932, with windiness increasing as sunspot numbers remained below the long-term average, (b) a short period with southeasterly and easterly winds from 1932 to 1937, followed (c) by a new wind pattern dominated by southwesterly winds and declining vigour as sunspot number continued above the average from 1937 to 1974.

### *II.2. Relation of Rain in Australia to Sunspot Activity*

In comparing the accumulated standard deviations from mean summer or winter rainfall with accumulated deviations from mean sunspot number, monthly sunspot numbers over the relevant half-year were used because of our interest in seasonal rainfalls. Correlation coefficients between these accumulated values and the accumulated values of standardized sunspot numbers were calculated and are shown against station location in Figure 6.

The 200 rainfall stations give correlation coefficients ranging for example from +0.93 to −0.80 over the 80-year period 1895–1974 (summer). These varied results could substantiate points of view both for and against a real connection between sunspots and rainfall. However, sensible geographic patterns are associated with the values. In some areas, as in Brisbane, Figure 5, a positive relationship between summer rainfall and sunspot activity occurs but in other areas there is a negative relationship. While this might indicate that the correlations are fortuitous and ought to be disregarded, our opinion is that this view is superficial. A simple link between sunspots and weather is unlikely, and of course opposite changes in different places such as these data show are to be expected with changes in atmospheric circulation. As Pittock (1978) has pointed out, "any real correlation of rainfall with solar activity might well be of opposite sign poleward as opposed to equatorward of a given climatic zone or across a major mountain barrier."

A prominent feature of our results, for summer, is the large area of high positive correlation coefficients in eastern Australia. When sunspot numbers are high, relative to the

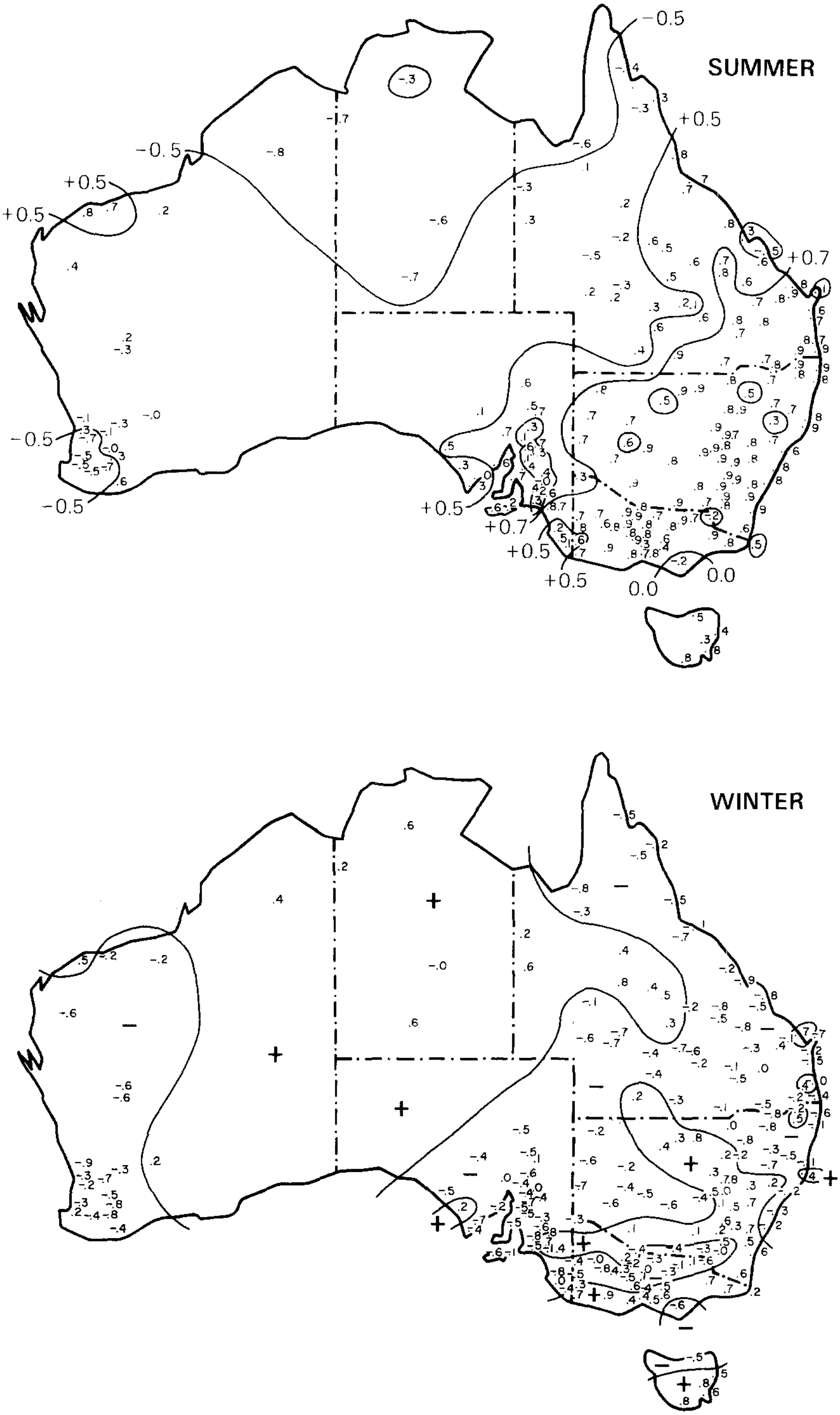

Fig. 6. Correlation coefficients between accumulated deviations of normalized rainfall station by station and the 80-year accumulated deviations of sunspot numbers, summer (top) and winter.

long-term mean, summer rainfall has tended to be above average; when spot numbers are below the long-term mean, the rainfall has generally been low. At many stations 80% of the variation of the accumulated deviations is explained by this relationship. The highest correlation coefficients in the east lie mostly in New South Wales, where the greatest values coincide in the main with the Great Dividing Range. High negative correlation coefficients were obtained for rainfall stations in northern Australia but unfortunately the number of stations there is very small. Correlation coefficients ranging from +0.86 to −0.91 were found for winter rainfall, but the connection with sunspots is much less marked than in summer. In winter positive correlations (high sunspot numbers, better than average rain; low numbers, less rain) occur in the southeast and in Tasmania, and are developed widely in northern Australia. The belt of negative values north of the Great Dividing Range in Victoria could indicate a rain-shadow effect.

The changes that have affected the winds in southeast Queensland and the rainfall over Australia have coincided with other meteorological changes. Mean annual maximum temperatures at Adelaide, for instance, when examined in the light of our results are seen to correlate negatively with the long-term sunspot trend. They declined sharply in the late 1930s after a steady rise over the preceding fifty years (Cornish and Evans, 1964).

Strong anticyclonic circulation in the mid-30s is also implied by studies of atmospheric pressures in New Zealand where a marked contemporary decline in the relative strength of the zonal westerlies is evident (Salinger and Gunn, 1975). Winter snowfalls, which are favoured in southern New Zealand when anticyclones are situated over the Tasman Sea, were frequent during the 1920s and 1930s (Burrows, 1976). Glacial behaviour in New Zealand, attributed by Salinger (1976) to changing temperatures, seems also to be in accord with changes in position of Australian pressure systems. From 1870 to 1935 the Franz Josef and Fox glaciers retreated slowly, but since 1935 wasting of the terminal faces has been rapid. The parallel could extend to earlier years, for the changes in rate of glacial ice retreat since 1800 coincide with changes in the curve showing cumulative departures of annual sunspot number from the long-term mean. Sunspot counts allow this curve to be extended back to 1750, and even earlier (Waldemeier, 1961; Eddy, 1976). It seems likely that the attention given in the literature in the 11-year sunspot cycle has obscured these longer trends.

It must be asked why winds and rain should vary according to sunspot number in the long term, but not respond to the larger short-term changes shown by the 11-year sunspot cycle. The question mistakes cause and effect, and confuses sunspots as a presumed direct cause of changes in the weather, with sunspots as an indirect measure of long-term solar radiation. Although sunspots are a convenient indicator of solar activity, measurements of solar radiation have not shown significant variation through the 11-year cycle. But as time passes the amplitudes of the 11-year cycles vary, and these variations appear from some direct evidence and much indirect evidence (Eddy, 1976, 1977) to be associated with small changes in the solar constant, and so lead naturally to a comparison with changes on the earth. Our meteorological records are reasonably long, but they are still short compared to the period of the long-term solar signal. They barely cover one full solar cycle, if that is what it is, and this period is much too brief to permit reliable conclusions as to the relationships with weather. It could well be that the relationship which we report is an accidental one. More extensive data are needed for a proper test, or else the discovery of a functional basis for the connection.

## Conclusions

The field evidence for different environmental conditions on Queensland's coast in the 1930s is confirmed by our study of local wind records and Australian rainfalls. The 1930s were different from other times. Departures from "normal" weather occurred in many places, in Australia and elsewhere; the changed conditions being shown by changes in wind, rain, and snow. In sensitive places such as coastal sandfields, deserts, and mountain environments there were consequent morphological changes. In some places the climates were improved but in other places there was marked deterioration. Except for their short duration, the observed changes seem appropriate for a minor glacial age.

The similar trends shown by sunspot and weather elements are impressive, and a genetic connection is not contradicted by a positive response in one place and a negative one in another. Sunspots and weather have been observed for too short a time to tell whether the connection is real or casual. It is too soon to conclude that there is no link between evident changes in the sun and changes in the weather.

## Acknowledgments

We are indebted to John Chapman for introducing us to the literature on sunspots.

Thanks are also due to the staff of the Bureau of Meteorology, Department of Science and the Environment, Brisbane, for assistance with the wind records.

(Received 1 January 1980; in revised form 29 July 1980)

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