A Possible Method for Predicting Seasonal Tropical Cyclone Activity in the Australian Region

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ABSTRACT

An examination of data from 1950 to 1975 has suggested that interannual variations in the number of tropical cyclones are related to pressure anomalies at Darwin in the preceding winter. The closest relationship is with the number of early season (October–December) cyclones.

1. Introduction

During the Southern Hemisphere summer, the strong winds and heavy rainfall associated with tropical cyclones can cause considerable damage and loss of life in northern Australia. Since 1950 the number of tropical cyclones observed in a single cyclone season (October–May) in the Australian region (5°–32°S, 105°–165°E) has varied between four and 18. If this interannual variability in tropical cyclone frequency could be successfully forecast, extra precautionary measures could be taken in the years of predicted above-average activity.

There is considerable evidence that tropical cyclone genesis is related to the large-scale behavior of the tropical atmosphere (Gray, 1977) and interannual variations in the numbers of tropical cyclones appear to be related to deviations of the large-scale atmospheric circulation from the normally observed pattern (Namias 1969, Frank 1977). Thus, if the large-scale anomalies of the tropical atmosphere could be correctly forecast, it might also be possible to show some skill in predicting the incidence of tropical cyclone activity. At certain times of the year, large-scale atmospheric anomalies in the Australian region tend to persist for some months and might provide the means for forecasting the numbers of tropical cyclones expected.

2. Persistence and tropical cyclone activity

The high spatial coherence exhibited by surface atmospheric pressure in the Australian region is well known (Berlage 1957, Nicholls 1977). When

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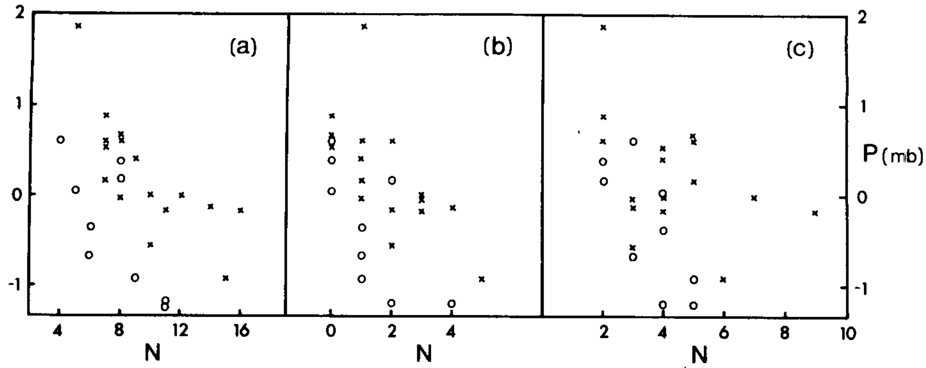

FIG. 1. Scatter diagrams of Darwin winter pressure (P) versus tropical cyclone frequency (N) during the following cyclone season. (a) Cyclone frequency, entire season; (b) cyclone frequency, October–December; (c) cyclone frequency, January and February. Data from before 1959 are shown as circles, data after 1959 as crosses.

pressure, averaged over a month or so, is anomalously high (compared to the long-term mean) at, say, Darwin, then anomalously high pressure is usually observed over the entire Australian region.

These large-scale anomalies in tropical Australian atmospheric pressure, once formed, tend to persist from winter, through spring and into summer (Priestley 1962). Nicholls (1978) proposed that air-sea interaction in the Australian region could be the cause of this strong persistence. To illustrate this persistence, data from 1882 to 1970 have been used to calculate the correlation coefficients between the seasonal average pressure anomalies. The correlation coefficients are 0.80 (winter–spring) and 0.63 (winter–summer). Thus large-scale pressure anomalies in the tropical Australian region during spring and summer can be forecast with some confidence from the observed winter pressure. Therefore, if the frequency of occurrence of tropical cyclones during spring and summer is influenced by the large-scale atmospheric circulation at this time of year, it might also be possible to forecast this frequency, with some skill, from the observed winter pressure. This supposition has been tested by examining the relationship between Darwin winter pressure anomalies and the number of tropical cyclones observed in the Australian region during the following cyclone season. A tropical disturbance is classified as a tropical cyclone if 10 min mean winds of at least 63 km h^{-1} occur.

TABLE 1. Correlation between Darwin pressure anomaly averaged over June, July and August, and tropical cyclone frequency during following cyclone season. (a) Cyclone frequency, entire season; (b) cyclone frequency, October–December; (c) cyclone frequency, January and February; (d) cyclone frequency, March–May. Significance levels are shown in parentheses. Correlations are quoted for all 25 years of data (1950–74), for the period before satellite observations (1950–58), and for the period with satellite observations (1959–74).

	1950–74	1950–58	1959–74
(a)	−0.40 (0.05)	−0.79 (0.02)	−0.68 (0.01)
(b)	−0.48 (0.02)	−0.75 (0.02)	−0.62 (0.02)
(c)	−0.19 (large)	−0.74 (0.02)	−0.39 (0.20)
(d)	−0.15 (large)	−0.06 (large)	−0.30 (large)

Tracks of tropical cyclones in the Australian region from 1909 to 1975 have recently been published (Lourensz, 1977). However, the data used in this study has been restricted to the period after 1950. Before this date little confidence can be held in the accuracy of the number of tropical cyclones observed, because of the sparse observing network.

The quality of the observing network has not remained constant since 1950. The most important change during this period has been the use, since 1959, of satellite pictures to locate tropical cyclones. The satellite enabled the location of cyclones which in earlier days would not have been observed because they did not cross a populated coast-line or encounter a ship. An immediate result of the advent of satellite observations was an abrupt increase in the mean number of cyclones observed. Between 1950 and 1959 the mean number of cyclones observed in a cyclone season was 7.8. After 1959 this number increased to 10.7. This increase must be taken into consideration in the search for relationships between winter atmospheric pressure and tropical cyclone activity. Therefore, in addition to examining the total 25-year data set for such a relationship, two subsets of data consisting of the years before and after 1959 have also been examined separately.

Scatter diagrams showing winter pressure anomalies at Darwin (averaged over the period June–August) versus the number of tropical cyclones observed in the following season are shown in Fig. 1. This figure also shows similar scatter diagrams of the number of tropical cyclones observed in the early part of the season (October–December) and in the middle part (January and February). In Fig. 1 years prior to the 1959/60 cyclone season are shown as open circles and the later years are indicated by crosses. Correlations between Darwin winter pressure and tropical cyclone frequencies in the early, middle and late (March–May) parts of the season and in the cyclone season as a whole, are listed in Table 1. Correlations were calculated from the entire 25 years data and also from the two subsets (before and after 1959).

Considering first the entire data-set, Fig. 1 and Table 1 show that a significant negative correlation exists between winter pressure at Darwin and the number of tropical cyclones observed in the following season. That is, a year with above average winter pressure at Darwin would generally experience fewer than normal tropical cyclones in the following cyclone season. The closest relationship is with early season cyclone frequency (Fig. 1b). The correlation with mid- and late-season cyclone numbers is smaller and not significant. A similar decrease with increased lag is observed in the persistence of pressure anomalies.

Turning now to the two subsets of data, Fig. 1 and Table 1 indicate that the pressure-cyclone frequency correlations calculated from these two data-sets are larger in magnitude than, and at least as statistically significant as, the correlations calculated from the entire 25 years of data. For instance, the correlation between winter pressure and total cyclone numbers in the following cyclone season was −0.40 when the entire 25 years of data was used. The magnitude of this correlation increased to −0.79 (pre 1959) and −0.68 (post 1959) when the two subsets were examined. Similar increases in magnitude occurred in the separate parts of the cyclone season (Table 1). This implies that the comparatively small magnitudes of the correlations calculated from the entire 25 years of data, could be the result of inconsistencies or trends in the data, perhaps due to variations in the observing system.

Further evidence that the correct magnitude of the correlation between Darwin winter pressure (P) and seasonal cyclone frequency (N) is larger than that calculated from the entire 25 years of data was provided by calculating the partial correlation between P and N, controlling for the year of observation. This technique will remove any effect on the correlation coefficients of possible trends in the data. The partial correlation calculated in this way was −0.63, somewhat larger in magnitude than the simple correlation calculated without correcting for possible trends in the data.

The correlations in Table 1 are large enough to suggest that useful seasonal forecasts of tropical cyclone activity might be possible. To estimate the skill that might be attained by such forecasts, the 1959–1974 Darwin winter pressure data and the cyclone frequencies in the following cyclone season were each divided into two groups, above and below the median. Years with high (low) winter pressure were then "forecast" to be years of low (high) cyclone frequency. Over the 16 years, these "forecasts" would have failed only twice. If such a success rate was duplicated on independent data, seasonal forecasting of Australian region tropical cyclone activity would be possible.

A very limited independent test has been carried out using data from 1975 to 1978. The 1959–74 data shown in Fig. 1a were used to calculate a linear regression between Darwin winter pressure and total cyclone numbers in the following cyclone season. This regression was then used with the observed Darwin winter pressure to forecast cyclone frequency in the 1975/6, 1976/7 and 1977/8 seasons. In the first of these years Darwin winter pressure was considerably below normal, whereas in the second and third winters pressure was above average. The predicted numbers of tropical cyclones for the three years were 14.8, 7.5 and 8.0. The observed numbers were 14, 11 and 8. Thus the forecasts for the first and third years were successful while the 1976/7 forecast was poor. Further testing on independent data is obviously required before the relationships apparent in Fig. 1 and Table 1 can be conclusively accepted.

3. Conclusions

It has been shown that between 1950 and 1975, winter pressure at Darwin and tropical cyclone frequency in the Australian region in the following cyclone season were closely related. The closest relationship was found with the number of tropical cyclones observed in the early part of the season (October–December) and the worst relationship was with the late season (March–May) cyclones. After correction for variations in the observing network over the 25 years examined, the correlation between winter pressure and total number of tropical cyclones in the following season was estimated to be about −0.6; thus a considerable portion of the variance in tropical cyclone frequency can be explained by the preceding winter pressure anomaly.

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