On Predicting the Onset of the Australian Wet Season at Darwin

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ABSTRACT

An index of the date of onset of the North Australian wet season is defined based on rainfall received at a single station (Darwin). It is demonstrated that this index can be predicted some months ahead.

The amount of rain received during the wet season is only weakly related to the date of onset, and the amount of rainfall received in the middle and late portion of the season is totally unrelated to either the date of onset or to the amount of rain received in the early part of the season.

Discussion is presented on the relationship between the wet-season onset as here defined and the Australian monsoon onset as defined by Troup (1961). A distinction is made between the monsoon portion of the season and an earlier transition season which also accounts for a large proportion of the total rainfall.

1. Introduction

Over 50 years ago Quayle (1929) suggested, after an examination of some 44 years of data, that seasonal forecasting of southeast Australian rainfall is possible during the Southern Hemisphere winter and spring. The proposed predictor is monthly mean Darwin pressure anomalies observed in prior months (see inset, Fig. 1 for location of Darwin). Nicholls and Woodcock (1981) successfully verified this suggestion on recent data and also showed that the area for which seasonal rainfall predictions can be made is considerably more extensive than that proposed by Quayle. The area for which statistically significant lag correlations are found between rainfall and prior Darwin pressure covers most of eastern and tropical Australia. The strength of these correlations is particularly high over northern Australia in spring [as noted by Priestley (1962)]. Fig. 1, for example, shows a scatter diagram of Darwin Airport pressure anomalies, averaged from June to August, versus Darwin Airport total September–November rainfall. Data from 1952 to 1980 have been used for this diagram. The lag correlation coefficient is −0.661.

Rainfall in the tropical parts of Australia is highly seasonal, over 90% occurring in the six months from November to April. This summer-wet versus winter-dry variation is associated with the seasonal movement of the equatorial trough. As seen in Fig. 1, quite good predictions of rainfall in the early part of the wet season can be prepared from prior observations of Darwin pressure. The principal question addressed here is whether the same predictor can be used to predict the date of "onset" of the summer rains. In a related study, Kung and Sharif (1980) demonstrated the predictability of the onset date of the monsoon rains in southwest India. They based their forecast scheme on antecedent values of selected 700 and 100 mb parameters at the forecast point.

Two problems related to the prediction of onset date are also studied, viz: "is a definition of onset realistic when based on rainfall at only a single station?", and "does the early or late onset provide any clue to total wet season rainfall?"

2. A wet season onset index

Most previous work on the determination or definition of a wet season onset has been in the context of monsoon circulations. For the Indian monsoon rainfall received at a number of stations has been used. Kung and Sharif (1980) quote the criterion used by the India Meteorological Department as "beginning from 10 May if at least five out of seven stations report 24 h rainfall of 1 mm or more for two consecutive days the forecaster should declare on the second day that the monsoon has advanced over Kerala".

Troup (1961) has demonstrated that the Australian wet season also is monsoonal in nature, the large-scale organized rain events in the peak of the season being accompanied by spells of moderate westerly winds at the gradient level (915 m). Troup used observed rainfall at six stations close to Darwin to define his rain events. He considered monsoon onset to be the commencement of the first event. It was defined as the first occasion after 1 November on which four or more stations recorded rainfall *and* the area-averaged rainfall over N days exceeded 0.75 (N

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+ 1) inches. As shown by Troup, monsoon onset defined in this way occurs typically between mid-December and mid-January. It is accompanied by marked changes in the upper tropospheric flow with the tropical easterlies increasing and the subtropical jet stream shifting abruptly poleward. In a preliminary report of a study in progress McAvaney *et al.* (1981) looked at the onset of the Australian monsoon during the year of the Global Weather Experiment. They defined the onset in terms of large-scale atmospheric circulation changes and found that it fell within Troup's range of late December to early January. Following a similar philosophy Saha and Saha (1980) have discussed means of defining the onset of the Indian monsoon synoptically rather than by a rainfall-based criterion.

The current study, however, derives from the belief that many potential users of a long-range weather forecast are primarily interested in rainfall rather than in any large-scale rearrangement of the troposphere. Accordingly no attempt is made here to predict the onset of the monsoon, but rather the concern is with the onset of the wet season or summer rains. The simplest possible criterion is chosen to quantitatively define the onset. An onset *index* is defined based on rainfall records at a single station, Darwin airport. The index is the date by which Z (mm) is accumulated after 1 August. For the purposes of this study five values of Z have been arbitrarily selected: 10, 50, 100, 250 and 500 mm. The average wet-season (September–May) rainfall at Darwin Airport is 1620 mm, so the selected values of Z range from about 0.6% to 30% of total rainfall. If all the dates by which the various values of Z (mm) rainfall have been received are earlier than

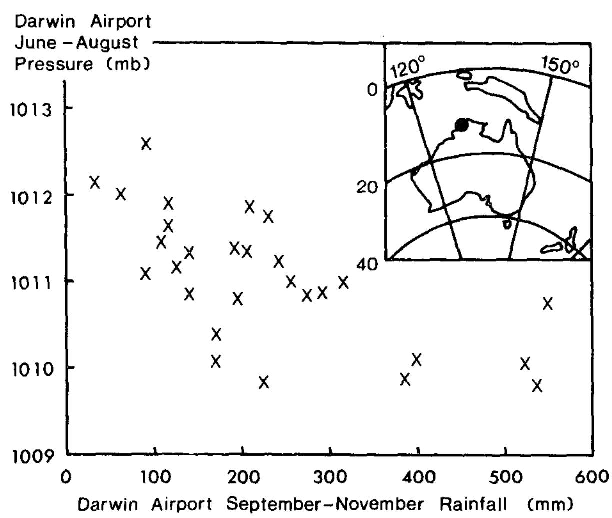

FIG. 1. Scatter diagram of Darwin Airport June–August pressure versus Darwin Airport September–November rainfall. Data from 1952–80. Inset shows location of Darwin.

TABLE 1. Mean and range of dates by which cumulative rainfall amounts are recorded at Darwin Airport during the wet season. Data from 1952–80.

	Mean date	Range
Date of 1st 10 mm	4 Oct	29 Aug–7 Nov
Date of 1st 50 mm	26 Oct	6 Sep–4 Dec
Date of 1st 100 mm	11 Nov	9 Oct–16 Dec
Date of 1st 250 mm	6 Dec	24 Oct–13 Jan
Date of 1st 500 mm	1 Jan	26 Nov–3 Feb

normal, it seems reasonable to conclude that the wet season onset was early.

As noted above, previous studies defining monsoon or wet-season onset in terms of rainfall have used rainfall from several stations. This approach is probably based on the belief that some form of areal averaging is necessary to reduce the importance of isolated heavy thunderstorm rainfalls. It is well documented, however, that the bulk of tropical precipitation falls not in isolated storms but rather in organized synoptic-scale systems (Riehl, 1954, 1977, 1979). Thus, it seems that the information content of the rainfall record at a single station might well be sufficient to provide a useful guide to wet-season onset. That such is the case is verified by our results, as discussed below.

Table 1 lists the mean and range of values for each of the five indices. The major point of note is that the mean dates of the first four indices occur well before Troup's date of monsoon onset, and that the average date by which 500 mm of rainfall has been received is within Troup's range of onset dates. Thus a considerable portion (~30%) of total wet-season rainfall has fallen before the large-scale rearrangement of the tropical circulation takes place. This premonsoon part of the wet-season is known as the transition season and was described by Troup (1961) as "a period of disturbed weather in which thunderstorms and line-squalls become more frequent".

3. Predicting wet season onset

Since Darwin June–August pressure can be used to predict transition season (September–November) rainfall at Darwin (Fig. 1), it was decided to correlate this variable with the five values of the onset index. The correlations (calculated using data from 1952 to 1980) are shown in Table 2. Significant correlations are found for the dates by which the first 50, 100, 250 and 500 mm rainfall are received. These dates can thus be predicted from the observations of pressure several months ahead. An impression of the accuracy of the predictions can be gained from an examination of Fig. 2 which shows a scatter diagram of Darwin June–August mean pressure against the date by which 250 mm of rain is accumulated. As

TABLE 2. Correlation of winter pressure at Darwin with the five wet-season onset indices. Data are for 28 seasons. Correlations > 0.374 are significant at the 5% level.

	Correlation with Darwin pressure June–August
Date of 1st 10 mm	0.047
Date of 1st 50 mm	0.455
Date of 1st 100 mm	0.566
Date of 1st 250 mm	0.590
Date of 1st 500 mm	0.465

would be expected from a correlation coefficient of 0.6 there is considerable scatter. Nevertheless the relationship still looks strong enough to be useful for operational forecasting purposes. For instance, of the 12 years when Darwin pressure was below 1011 mb, in eight the first 250 mm of rain was received earlier than the average date (6 December). On the other hand, there were 16 years when Darwin pressure was above 1011 mb. In only four of these years was the first 250 mm of rain received earlier than average.

An interesting aspect of the correlations in Table 2 is that even the date of accumulation of as small an amount as 50 mm of rain at Darwin is significantly correlated with the prior June–August pressure. This implies a considerable degree of temporal organization of the transition season rainfall. Such a degree of organization is consistent with the observation by Priestley (1962) that Northern Australian rainfall at that time of the year is associated with the planetary-scale phenomenon known as the Southern Oscillation.

In the previous section the question was raised as to whether the rainfall records from a single station contain sufficient information on the large-scale precipitation patterns to be useful in forecasting. The simple fact that a single-station-based index *can* be forecast (as shown in Table 2) verifies that this is so. The geographical limits to the region of northern Australia over which the forecasting relationship applies have not been explored, but Table 3 shows that it holds for several other stations near Darwin. For each station an onset index has been defined as the date of accumulation of 15% of the median annual rainfall. The table shows for five stations and for Darwin the correlation between this single-station index and the preceding winter's Darwin pressure. For all stations the correlations indicate approximately the same level of forecast skill as has already been indicated for Darwin in Table 2. Also shown in Table 3 is the correlation obtained by averaging the rainfall from the six stations. It is interesting that only the same level of forecast skill is indicated for the area average as is indicated for several of the individual stations.

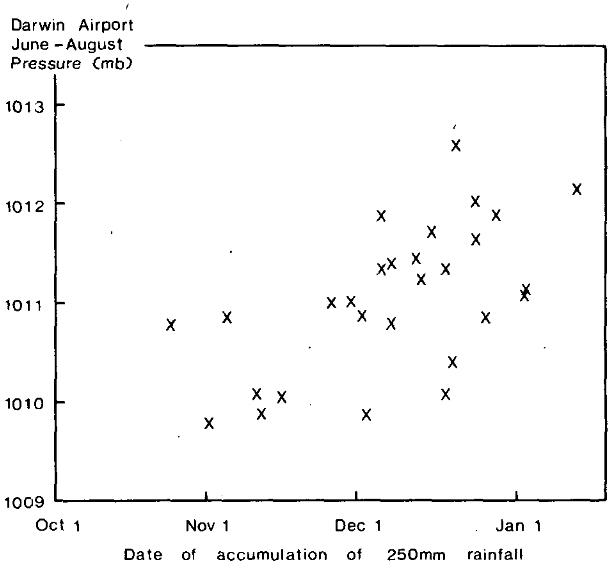

FIG. 2. Scatter diagram of Darwin Airport June–August pressure versus the date by which 250 mm rainfall has accumulated. Data from 1952–80.

TABLE 3. Correlation of winter pressure at Darwin with the date of accumulation of 15% of the median annual rainfall for stations in the Darwin region. (Each correlation is based on more than 25 years data.)

	Correlation with Darwin pressure June–August
Goulburn Island (290 km NE from Darwin)	0.70
Oenpelli (240 km east of Darwin)	0.67
Pine Creek (190 km south of Darwin)	0.50
Minjilang (230 km NE of Darwin)	0.67
Cape Don (160 km north of Darwin)	0.52
Darwin	0.59
Six-station composite	0.70

4. Wet-season onset and wet-season rainfall

Dhar *et al.* (1980) have shown that the total rainfall received in the Indian monsoon is independent of whether the onset is early or late. Table 4 shows

TABLE 4. Correlations between the onset indices and Darwin wet-season rainfall. The last row shows correlations between June–August pressure and seasonal rainfall. (The 5% significance level occurs at a correlation of 0.374.)

	Darwin rainfall		
	Sep–May	Sep–Nov	Dec–May
Date of 1st 10 mm	−0.267	−0.477	−0.084
Date of 1st 50 mm	−0.383	−0.707	−0.111
Date of 1st 100 mm	−0.289	−0.817	0.034
Date of 1st 250 mm	−0.394	−0.905	−0.040
Date of 1st 500 mm	−0.520	−0.819	−0.209
Darwin pressure: June–August	−0.335	−0.661	−0.079

correlations of seasonal rainfall with the five indices of onset for Darwin. Total wet-season rainfall (September–May) is negatively correlated to the indices (and to prior Darwin pressures). However this correlation is due solely to the close relationship between the indices and early (September–November) rainfall. Mid-to-late (December–May) rainfall is almost completely independent of the indices of onset. The generally weak correlations of the indices with total wet-season rain are a result of the combination of a strong relationship between the indices and early (transition season) rain and a total lack of a relationship between the indices and mid-late monsoon rainfall.

As a check on this, cross correlations have been calculated with the December–May rainfall split into a mid-season (December–February) and a late-season (March–May) component. It is found that the rainfall totals in each of these sub-seasons are totally independent of each other, are totally independent of the June–August Darwin pressure, and also are not significantly correlated with any of the dates of onset. There is thus no evidence that mid or late wet-season rainfall can be predicted from prior observations of Darwin pressure.

5. Concluding remarks

This study has provided evidence that, in the Darwin region of the Australian tropics, 1) a quantitative index for the onset of the wet season can be defined in terms of rainfall at a single station; 2) such an index can be predicted; i.e., whether wet-season onset will be early or late can be predicted; 3) total rainfall received over the period of the wet season is only weakly related to the onset index; and 4) mid-late (December–May) season rainfall is totally independent of the date of onset and of the amount of early (September–November) rainfall.

Furthermore, as documented by Troup (1961), the North Australian wet season is monsoonal in character. The current paper has provided evidence that 5) the monsoon onset is preceded by a transition season, as noted by Troup (1961), which at Darwin accounts for ~30% of the total wet-season rainfall; and 6) there is considerable temporal organization of transition season rainfall. This is supported by the fact that the date of accumulation of as little as 50 mm of rain is related to earlier months' pressure observations.

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