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ON THE NON-NORMALITY OF WIND DISTRIBUTIONS

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It is usually assumed that individual winds tend to be distributed about the vector mean wind in accordance with the normal law of errors (Brooks and Carruthers 1953). Crutcher and Baer (1962) suggest that certain wind distributions may not be normal, e.g., observations near the earth's surface, land and sea-breeze mixtures, mixtures near the trade wind inversion or tropopause, or mixtures of seasonal flows. Also, considerations of the angular-momentum balance of the atmosphere preclude exact satisfaction of the normal distribution (Hutchings 1952). However, in the upper air homogeneous distributions of wind vectors (and their components) are expected, in general, to approximate the normal (e.g., Brooks and Carruthers 1953, Crutcher and Baer 1962, Tucker 1960). More recently evidence of significant departures from normal has been presented (Maher and McRae 1964). The intent of this study is to exhaustively test the accuracy of the supposition that homogeneous distributions approximate the normal.

Simple tests for normality, based on skewness and kurtosis, of wind distributions have been described by Maher and McRae (1964). These tests were applied to 3456 different, homogeneous frequency distributions of wind components in the Australian region (9 stations, 16 atmospheric levels from surface to 70 mb, 12 months of the year, west-east and north-south components). All 2300 GMT data from 1961 to 1970 were used. For example, one sample distribution tested was all 2300 GMT, June, west-east components of the 500 mb wind at Darwin from 1961 to 1970. The numbers of observations in the samples varied from 200 to 310.

Of the 3456 samples examined, 62 per cent had values of skewness and/or kurtosis significantly different from normal (5 per cent significance level, see Table 1 for details of significance levels). The maximum frequency of distributions differing from normal occurred at levels near the surface, however even in the layer 900 mb to 200 mb, 55 per cent of the distributions were significantly different from normal. At every level at least 40 per cent of the tested distributions were significantly different from normal.

Table 1 Range within which the skewness or kurtosis may be expected to lie on about 95 occasions out of 100 if samples are selected from a normal distribution

	Number of observations	95% range
Skewness	200	-0.337 to +0.337
	250	-0.303 to +0.303
	300	-0.288 to +0.288
Kurtosis	200	2.45 to 3.76
	250	2.48 to 3.69
	300	2.53 to 3.63

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These distributions were also tested in pair-wise combination of components (i.e., vector wind distributions). Of the 1728 vector wind distributions examined, 84 per cent were found to have values of skewness and/or kurtosis significantly different from normal (at the 5 per cent significance level) in at least one of their two components (west-east or north-south). The variation in the vertical of the frequency distributions significantly different from normal is illustrated in Fig 1, which shows that the maximum frequency occurred at the surface, but at every level, at least 70 per cent of the vector wind distributions were significantly different from normal.

The nine stations used in this study varied in latitude from 9°S to 43°S and the latitudinal variation in frequency of distributions significantly different from normal was examined. The only notable relationship revealed was a lower frequency of non-normal west-east components at the lower latitudes (9° to 20°S).

To examine the effects of increasing the number of observations the distributions of 2300 GMT wind components and vector winds at Giles (25°02'S, 128°18'E) from 1956 to 1974 at each of 12 atmospheric levels for each month of the year, were examined. A total of 228 sample distributions of wind components each with 350-550 observations were tested and 67 per cent were found to be significantly different from normal (5 per cent significance level). Eighty-eight per cent of the 144 vector wind distributions had one or both components significantly different from normal. These results are much the same as those reached with sample sizes of 200 to 310 observations, suggesting that the departures from normal cannot simply be ascribed to the size of the samples tested.

The consequences of the above findings can be illustrated by the parameter usually called constancy and defined as the ratio of the vector mean wind speed to the scalar mean wind speed. This parameter has often been assumed to be a measure of the directional steadiness of a wind distribution (e.g., Singer 1967, Brummer *et al.* 1974). If the wind frequency distribution approximates normal circular then this assumption may be justified but if not, then the meaning, in terms of directional steadiness, of a particular value of constancy cannot be univocally defined.

This study has shown that wind distributions frequently show considerable deviations from normal. Such deviations may cause problems in the interpretation of parameters used to describe wind frequency distributions, if their interpretation relies upon the assumption of a normal distribution. Considerable care should therefore be exercised before applying such parameters.

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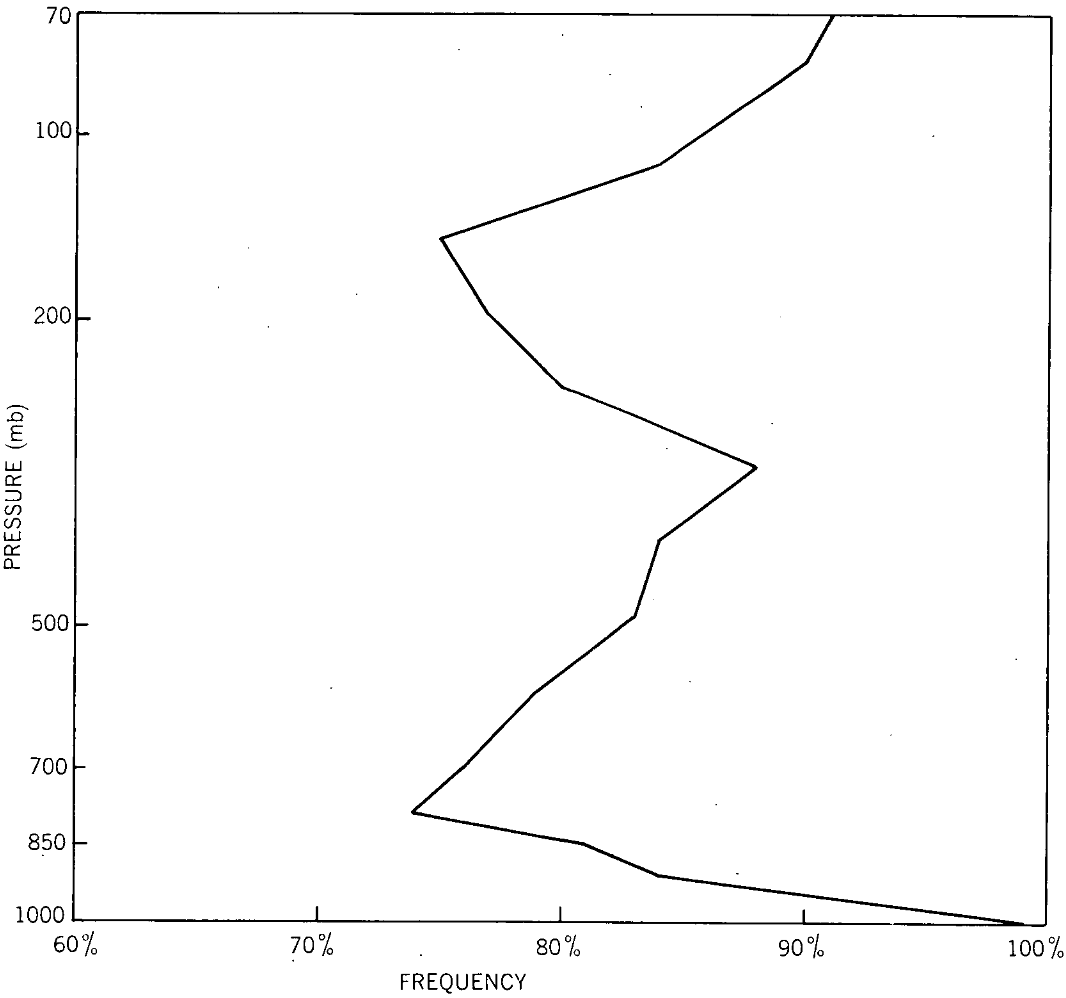

Fig 1 Vertical variation of frequency of occurrence of vector wind distributions differing significantly from normal (see text for details of significance levels)