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SHORT CONTRIBUTIONS

Interannual variability in the spectra of the daily surface pressure at four stations in the southern hemisphere

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1. Introduction

The work reported here was prompted to some extent by the work done by Preston-Whyte and Tyson (1973) who presented spectra for 1966 for 14 stations spaced along the coast of South Africa. At these stations, with the exception of the two northern-most along the west coast, a distinct peak at a period of 6 days was found. This figure has subsequently been widely quoted (eg. Gill, 1977; Bannon, 1981; Nelson and Hutchings, 1983) as typical of pressure oscillations along the coast.

However, evidence of large interannual variations in oscillations of less than 30 days duration, albeit at Gough island, was presented by Triegaardt (1985). This showed up in the sum of the amplitude of wavenumbers 3 to 8 (10–3.75 days) which, for any particular month, can vary by up to a factor of 3 between years. Indirectly, this variability can also be deduced from Walker et al. (1984) who present the progressive vectors of the wind at the Cape Point lighthouse (their Fig. 6) for the summer seasons of 79/80 and 82/83. The latter shows 10 wind reversals during the 90 day period as opposed to 3 during the former season.

Pressure oscillations of a longer period also show considerable interannual variability. This was shown to exist by van Loon and Rogers (1984a; 1984b) in the yearly and half yearly waves in the surface pressures at several locations in the southern hemisphere, inter alia at Marion Island. Meyers (1982) has further shown that the normal bimodal oscillation in the Pacific is strongly dominated by an episodic annual oscillation during El Niño years.

In this study, atmospheric surface pressures at 4 stations on the southern hemisphere were subjected to a spectral analysis to investigate the interannual variation of the periodic pressure fluctuations of sub-seasonal duration. The 4 stations and the years that were analysed were Alexander Bay at 29°S from 1970–1984, Cape Town at 34°S from 1970–1984, on the west and south coast of South Africa respectively, Gough Island in the southern Atlantic at 40°S from 1970–1982 and Marion Island in the south western Indian Ocean at 47°S from 1970–1980 (see Fig. 1 for the locations).

The data that were used in this study consisted of the 0600 and 1800 GMT surface pressures, corrected to barometer height and reduced to sea level, and were obtained from the South African Weather Bureau.

2. Methods

The annual spectra are based on the twice daily surface pressure readings giving 730 data points. The annual time series were first linearly detrended and smoothed by a cosine-Lanczos filter with 25 weights per wing in order to prevent aliasing close to the Nyquist frequency. The response function of this filter had a very narrow transition band with the half power point at 1.1 days per cycle, the Nyquist frequency being at 1 day per cycle. The autocovariance function was calculated over the remaining 680 data points with a

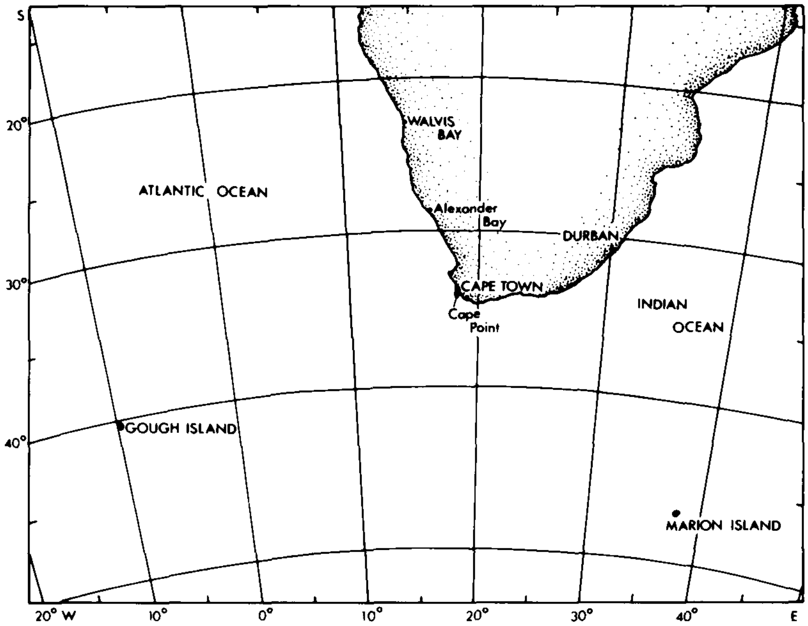

Fig. 1. Map showing the stations referenced in the text.

maximum lag 30 days. The Tukey lag window was used in the Fourier transform of the autocovariance function and 100 spectral estimates were calculated down to 1.6 days per cycle.

3. Discussion

The spectra for the 4 stations for the successive years appear in Fig. 2. The abscissas represent the number of days per cycle with, for ease of reference, the 3- and 6-day periods indicated by the vertical dotted lines. The ordinate scale is the logarithm of the variance associated with each period. On such a log scale, the confidence limits are constant over the whole spectrum (Jenkins and Watts, 1968). Indicated along the side of the diagrams are the 95% confidence limits and the appropriate bandwidth.

3.1. General features

Before discussing the particulars of some of the plots, a few general observations can be made. Firstly, it will be noted that the relative intensity of the 4 spectra follow the same sequence for all the years over practically the entire frequency range, i.e., Marion the most energetic followed by Gough, Cape Town and Alexander Bay. Only in some years does the variance in the Gough spectrum equal or surpass the variance at Marion at a particular frequency or frequency range and Alexander Bay that of Cape Town. The reason for the consistent difference in energy levels must be related to the geographical location of the stations, i.e., Alexander Bay and Cape Town on the continent, which will be referred to as the continental stations, and Gough and Marion in the vast spaces of the southern ocean, the oceanic stations, further to the south.

Essentially the same feature could be inferred from the results of van Loon and Rogers (1984a; 1984b) in that the residual variances available to the higher harmonics after removal of the 12- and 6-month harmonics, would be in the same sequence as the spectra presented here.

A second general feature is that the Alexander Bay spectra seem to follow those at Cape Town fairly well but are less energetic, especially over the middle frequencies, say from 3–12 days. This means that the effect of pressure variations, associated with transient features such as coastal

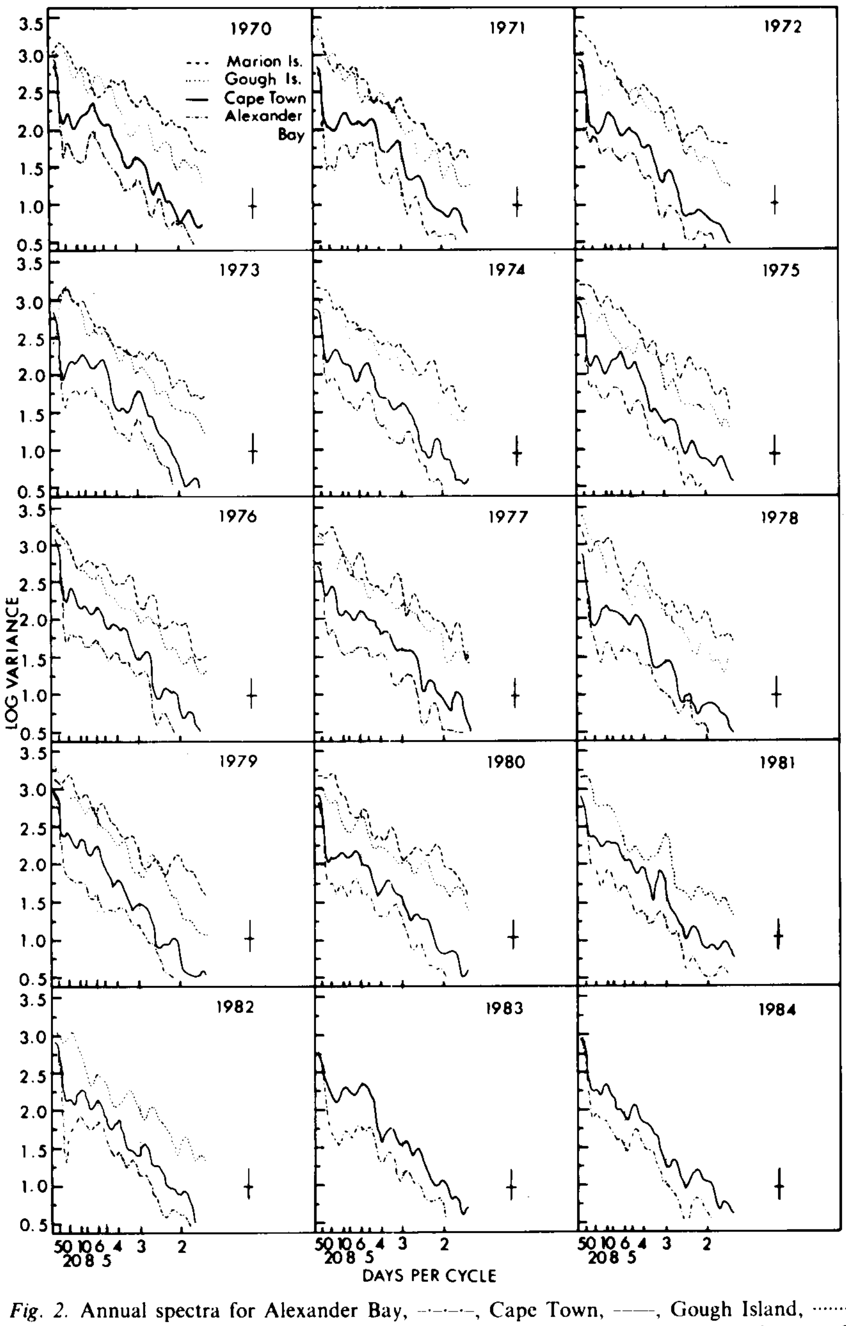

Fig. 2. Annual spectra for Alexander Bay, –·–·–, Cape Town, ——, Gough Island, ········, and Marion Island, – – – – –. Indicated are the 95% confidence limits and the bandwidth, based on 30 degrees of freedom.

lows and cold fronts, are less intense at the northern site. Coastal lows are the shallow, warm core depressions which frequently migrate down the west coast and are thought to be the result of the strong ridging of the South Atlantic anticyclone south of the continent. They usually herald the approach of frontal systems to the southwest (De Wet, 1984).

At the longer periods, say more than 30 days per cycle, the variances at the two continental stations are roughly equal. These stations are well within the latitudinal zone that is critically affected by the seasonal meridional shift of the mean position of the subtropical high-pressure belt (Taljaard, 1953). Thus the long-period variations at these 2 stations result from the same seasonal forcing embodied in the large-scale oceanic and continental systems at this latitude belt, such as the South Atlantic anticyclone and continental heat low. That the forcing on this timescale is dominant at these stations can be seen in the marked step to the lower intensities of the higher frequencies which is greater at Alexander Bay than at Cape Town. However, at the 2 oceanic stations, which may be assumed to be typical of the middle latitudes, this step is virtually non-existent, the spectra showing an almost linear (on the log scale) cascade of energy to the higher frequencies. The lack of this step in the latter stations and the sequence of the spectra pointed out before, suggest the middle latitudes to be altogether more energetic, specifically near the "step" frequencies, than the subtropics, where the annual cycle strongly dominates the total variance.

3.2. Particular observations

None of the spectra show any consistent peak through the successive years. The 6-day peak in the Cape Town pressures, discussed by Preston-Whyte and Tyson (1973) is most clearly defined in 1970, 1975 and 1983 and a 5-day peak in 1974. A very distinct 3-day peak occurs in 1973 with lesser peaks in 1971 and 1981. The definite presence of such a peak in some years indicates that the 3-day peak in 1966 need not necessarily have been spurious as was suggested by Preston-Whyte and Tyson. The same conclusion was drawn by Hunter (1984), who presented spectra for the pressures at Durban and also found a 3-day peak in 1978, suggesting this to be quite a common period between the passage of coastal lows along the southeast coast.

A common feature in some of the spectra for Cape Town, and to a lesser extent Alexander Bay, is a plateau of almost constant spectral estimates over the interval from about 5 to 20 days, usually followed by a second step to much lower densities, as, for example, in the years 1971/73/78 and 1980. (It is this feature which tempts one to speculate on the conservation of the total available energy. Indeed, the sum total of the spectral densities, or the area under the spectral curves at Cape Town, does not vary by more than 10% between the available years. The figures for the remaining stations are 11.5% for Alexander Bay, 5.5% for Gough and 4.5% for Marion.) Lastly, years with an almost featureless or red spectrum were 1976/77 and 1979.

The spectra of the 2 oceanic stations do not follow one another at all but individually show much the same interannual inconsistencies. For example, years with distinct peaks at either one of the stations were 1970/76/81 and 1978, the latter being the only year with a coinciding peak at 4 days. Years with no distinct peaks at all were 1971/73 and 1974 (Marion) and 1976 (Gough).

3.3. Significant interannual variations

Taking the average of the spectral estimates for each frequency over the available number of years at each station provides a criterion against which individual years can be tested. These "mean spectra" are shown as the middle trace in Fig. 3. The upper and lower traces in this figure represent the extreme spectral estimates which occurred during the available years for each frequency. Thus the 3 traces are not actual spectra but composite plots. Indicated are those frequencies, and the year in which they occurred, that were significantly different from the "mean spectrum" at the 95% confidence level using the two-tailed Student t-test. From the occurrence of such anomalies, we may conclude that there is significant interannual variation and that the spectrum for any one year cannot be assumed to be typical for that location.

In general, interannual variability is reflected in the range of the spectral estimates for each frequency that is in the vertical separation between the upper and the lower trace. As a visual aid, the ranges that exceed 0.44, which is the confidence limit on the individual estimates, have been indicated. The mean range at Marion is considerably less than at the other stations so that this station generally shows the least variability over the years. (It will be remembered that at Marion, the areal change under the spectral curves, at 4.5%, was also the lowest.) However, the variability that does occur is clearly confined

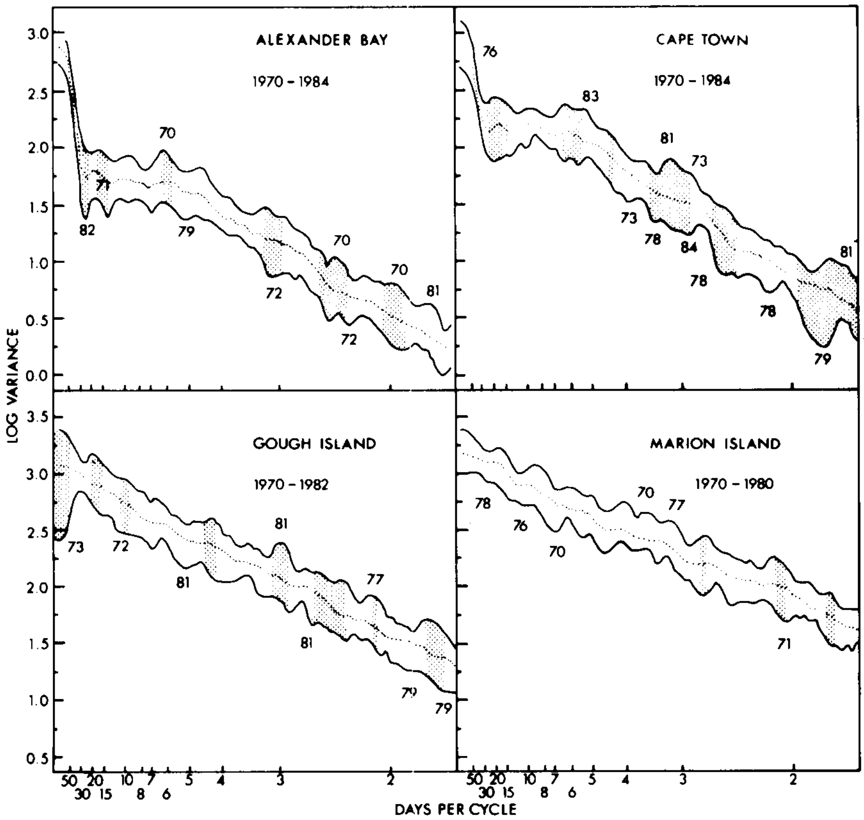

Fig. 3. Average (middle trace) and extreme (upper and lower trace) spectral estimates for Alexander Bay, Cape Town, Gough Island and Marion Island. The periods, that were significantly away from the "mean spectrum", are indicated by the year in which they occurred. The shading indicates a vertical separation between extremes exceeding 0.44 (i.e., one confidence interval).

to the higher frequencies judging by the range which is broadest here. Relatively large ranges at Gough appear throughout the spectrum with the mean range larger than at Marion.

A notable feature at the two continental stations are the alternating frequency bands with distinctly broad and narrow ranges. The implication is that the interannual variation is confined to specific periods, *inter alia* around 6 days at Cape Town.

4. Conclusions

In this study, it was shown that the intensity of the surface pressure oscillations of a subseasonal period at two continental and two oceanic stations in the southern hemisphere can change significantly between years. There did not appear to be selected frequencies, favoured by all four stations, for large interannual variation. Such variation is indicated by the range of the spectral estimates calculated over the available number of years. At the oceanic stations, and representative of the middle latitudes, this range was found to be fairly constant over all the frequencies. However, at the continental stations in the subtropics, this range was found to fluctuate far more so that the interannual variation tended to be confined to certain frequency intervals.

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