

OPPOSITION OF ANOMALIES OF UPPER TROPOSPHERIC WINDS AT SINGAPORE AND CANTON ISLAND

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ABSTRACT

Anomalies in monthly mean upper tropospheric zonal winds at Canton Island and Singapore tend to be of opposite sign in the same month. Correlation coefficients have been computed, for each quarter, between monthly anomalies at 150 mb at Canton Island and at 50,000 feet at Singapore, using twelve years' data. All were negative: the largest negative value was -0.65 in the December-February quarter. This opposition is associated to some extent, most strongly in December-February, with variations of the Southern Oscillation, as represented by the departures from average of the monthly mean Papeete (Tahiti) minus Darwin pressure difference. When this index is positive, stronger than normal upper west winds occur at Canton Island and stronger than normal upper east winds at Singapore.

The amplitude and phase of the 26-month oscillation at each station, at the levels considered, was found by harmonic analysis. The amplitudes were two knots at Canton Island and one knot at Singapore. There was a phase difference of 11 months between the two stations. Hence the 26-month oscillation is not simply propagated downward from the stratosphere at all longitudes.

1. INTRODUCTION

In the tropics, wind variations in the upper troposphere are of considerable importance for the development of weather and weather systems. It would therefore be expected that teleconnections between upper winds, on the scale of monthly mean anomalies, would be relevant to the understanding of the large-scale surface circulation changes.

Reed and Rogers (1962) pointed out that between the monthly mean zonal winds at fifty thousand feet at Canton Island (2.8°S , 171.7°W) and Singapore (1.4°N , 103.9°E) there was an inverse correlation, which they remarked upon as "a peculiar and perhaps accidental feature". It was thought worth-while to investigate the phenomenon further, since it was possible, considering the regions involved, there was some relation between it and the Southern Oscillation. There was some prior support for this possibility, in that it had been shown that in the December-February quarter the zonal wind at Singapore at forty thousand feet was negatively correlated with the surface pressure at that station (Troup 1962); and at that time of year Singapore lies well within the region of high negative correlations with the Southern Oscillation Index. Again, in January 1958, a month of low Southern Oscillation Index (above normal pressure in the Indian and Australian regions, below normal over the South Pacific), there was a positive anomaly in 200 mb zonal wind at Singapore, a negative anomaly at Canton Island (Troup 1961). (In this paper a west wind stronger than average, or an east wind weaker than average, is regarded as a positive anomaly.)

2. DATA AND EVIDENCE OF OPPOSITION OF ANOMALIES

To express the opposition in departures of zonal wind components from averages in the upper troposphere at Canton Island and Singapore quantitatively, correlation coefficients were computed between zonal components at fifty thousand feet (15.2 Km) at Singapore, and zonal components at 150 mb (14.2 Km) at Canton Island. Monthly mean winds or components were taken from various publications (Clarkson 1956, 1958; U.S. Joint Task Force 7, 1960, 1961; Farkas 1954; Monthly Climatic Data for the World; U.S. Weather Bureau, Climatic Data, National Summary) or were evaluated from the daily data published by the Malayan Meteorological Service for Singapore, and published by New Zealand Meteorological Service in its Daily Weather Bulletin (Pacific Islands Section) for Canton Island.

The period employed extended from November 1953 to November 1965. Because of insufficient observations at Singapore, the months of December 1954, January 1955 and 1965, July and August 1964, and September 1957 and 1958, were not used. Correlation coefficients were computed using departures of each monthly value from the overall average for that month, combined in three-monthly sets, so that four sets with from thirty-three to thirty-six pairs of observations were available. The correlation coefficients are given in Table 1, together with the number of months and the number of occasions on which anomalies of opposite sign occurred. The significance of the correlation coefficients is also indicated; this has been found on the assumption that consecutive monthly values are independent. Persistence between months would reduce the statistical significance. In Table 1 are also presented the relevant one month lag correlation coefficients at each station; for example, those given for December-February are the lag correlations determined from December and January, and January and February values. There is only a small lag correlation at one or other of the stations in March-May and December-February, and in these two seasons the significance levels quoted are appropriate. In the other two seasons the true significance is actually much less than that for independent observations.

Table 1 - Correlation coefficients between monthly mean anomalies of zonal wind at 150 mb at Canton Island and at 50,000 ft at Singapore.

Season	Mar. -May	June-Aug.	Sept. -Nov.	Dec. -Feb.
Correlation Coefficient	-0.34*	-0.49**	-0.49**	-0.65**
No. of months	36	34	35	33
No. of months with anomalies of opposite sign	18	20	26	28

Lag correlations (1 month lag)
of zonal wind at each station

Canton Island	0.45	0.59	0.76	0.21
Singapore	-0.09	0.61	0.40	0.50

* Significant at 5% level

** Significant at 1% level

3. DISCUSSION OF NEGATIVE ASSOCIATION

A simple explanation can be proposed for this opposition in zonal wind anomalies. If the contour heights on the equator reached a maximum between the two stations, then one would expect that being so close to the equator motion would be down the pressure gradient: such a configuration is suggested by the fact that the mean zonal wind is easterly in all months at Singapore, and westerly in all months except July at Canton Island, at the levels investigated here. Then an increase in intensity in this contour maximum would result in increased westerlies

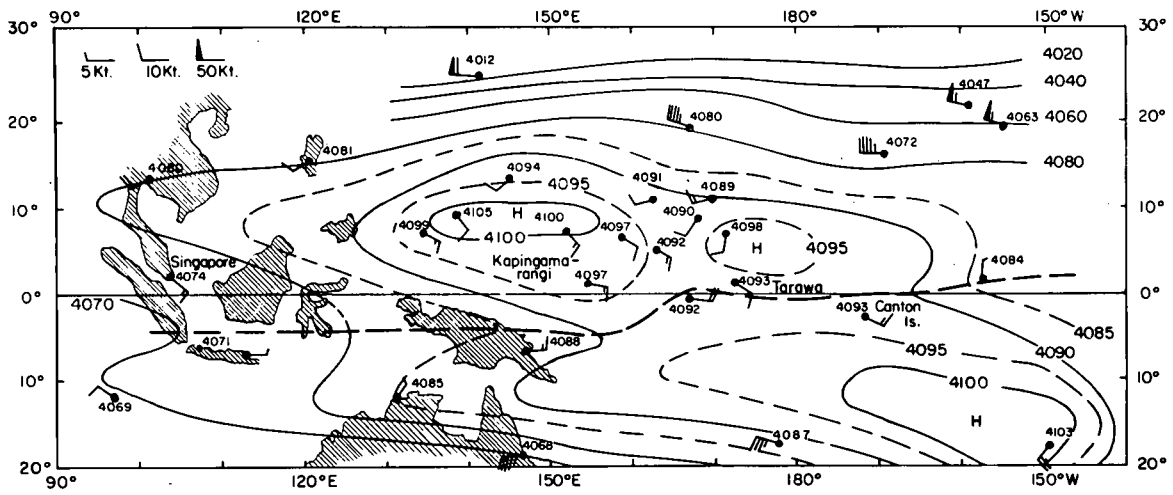


Fig. 1 Mean 200 mb chart for April 1958. Heights in tens of Geopotential feet. Observations from Joint Task Force publication (1960) and from Rudloff et al. (1965).

at Canton Island and increased easterlies at Singapore. However, from the charts and mean contour-heights given by Heastie and Stephenson (1960) such a simple configuration exists only in April. As a further test on this possibility, the 200 mb contour height and wind variations in the equatorial region during the Marshall Islands atomic test periods in 1956 and 1958 were examined. The examination confirmed the findings of Ballif, Palmer, Sinclair and Viezee (1958) that at high levels it is very difficult to draw monthly mean contour charts near the equator, with the weaker gradients found there, probably because of radiation and instrumental errors in the radiosonde observations. An example of such a chart, for April 1958, is shown in Figure 1. The observations on this chart suggest that it is possible on occasion for mean motion to be up the mean contour gradient. For detailed comparison, in Table 2 are set out the contour height differences and vector mean winds at Kapingamarangi ($1^{\circ} 02'N$, $154^{\circ} 46'E$) and Tarawa ($1^{\circ} 21'N$, $172^{\circ} 57'E$) at 200 mb for seven months*. This table suggests, if anything, motion up the gradient. Then it is possible that on the average a contour height minimum lies between Canton Island and Singapore, and that with a lower than average contour height at this minimum, a westerly anomaly at Canton Island and an easterly anomaly at Singapore would result. However, in view of the random and systematic errors present in the data, it is probably better to suspend judgment at present.

Table 2 Contour Height difference Kapingamarangi minus Tarawa, and vector mean winds, at 200 mb.

Month	Height difference (tens of feet)	Vector mean wind (degrees and knots)			
		Kapingamarangi		Tarawa	
May 1956	0	305	3	300	16
June	-2	295	1	290	9
July	0	080	10	049	8
April 1958	4	102	16	127	10
May	4	095	7	226	5
June	11	086	16	106	6
July	5	082	20	085	17

4. SOUTHERN OSCILLATION AND NEGATIVE ASSOCIATION

To investigate the relationship with the Southern Oscillation of the negative association found, correlation coefficients were calculated between the monthly mean wind components and an index of the Southern Oscillation. This index is the normalised monthly mean pressure difference Papeete ($17.5^{\circ}S$, $149.6^{\circ}W$) minus Darwin ($12.5^{\circ}S$, $130.9^{\circ}E$): normalisation was achieved by dividing the departures from average for each month by the standard deviation for that month. Both the averages and the standard deviations were obtained from 33 years' observations. Then the partial correlation between the zonal winds, eliminating the correlation of each with this Southern Oscillation index, can be computed. If the correlation is considerably reduced thereby, then it is clear that the negative association of the upper tropospheric zonal winds is connected to a considerable extent with the Southern Oscillation. These correlation coefficients are set out in Table 3.

* Data were taken from the Joint Task Force 7 publications. For July 1958 the difference obtained from the published heights seemed much too great, and it was re-evaluated from the 1000 mb heights and the mean temperatures.

Table 3 - Correlation coefficients of Canton Island 150 mb and Singapore 50,000 ft zonal winds with Southern Oscillation index, and partial correlation coefficient between these zonal winds after elimination of effect of index.

	Mar. -May	June-Aug.	Sept. -Nov.	Dec. -Feb.
Canton Island	+0.51	+0.57	+0.85	+0.75
Singapore	-0.31	-0.49	-0.39	-0.77
Partial correlation coefficient	-0.22	-0.29	-0.33	-0.16

The strongest association with the Southern Oscillation is found in December-February, when zonal winds at both stations are highly correlated with the index. In other seasons there is some association; the partial correlation coefficients are smaller by one third than the total correlations (see Table 1), but much of the negative association is independent of the Oscillation. Throughout the year the index is better correlated with wind variations at Canton Island than with those at Singapore.

5. QUASI-BIENNIAL COMPONENT IN OPPOSITION OF ZONAL ANOMALIES

It is not known what frequencies or spectral peaks contribute most strongly to the opposition of anomalies at these two equatorial stations. But it is of interest to see whether a period in the spectrum in the vicinity of two years is important in this connection. Angell and Korshover (1963) have studied the occurrence of the quasi-biennial or 26-month oscillation in the troposphere. They found such an oscillation at Canton Island; interpolating from their values at 100 mb and 200 mb, the amplitude at 150 mb is about three knots, with phase (defined as time of maximum west wind or minimum east wind) September 1960. They inferred a downward propagation of the stratospheric oscillation into the troposphere from the continuity of phase, the phase at 50 mb for example being February 1960. However, Canton Island was the only equatorial station they used. Accordingly the amplitude and phase of the 26-month periodicity at 50,000 ft at Singapore was found by a 26-month Buys Ballot tabulation, averaging, and harmonic analysis. The period used was from January 1954 to October 1964. The same period and procedure were used for an analysis at 150 mb at Canton Island, for comparison. The results were: at Canton Island the mean 26-month oscillation has an amplitude of 2.4 knots, with phase about 1 June 1960; at Singapore the amplitude is 1.1 knots, but the phase was 157°, i. e. 11.3 months or nearly half the period different from that at Canton Island, so that a westerly maximum or easterly minimum would be found about 20 June 1959. Thus there is a contribution to the opposed anomalies at these two stations by variations with period 26 months. And hence, while it is possible that the oscillation is simply propagated downward into the troposphere in the Pacific, this is not the case at Singapore; it is evident that relations between troposphere and stratosphere are by no means simple.

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