Detection of a 40–50 Day Oscillation in the Zonal Wind in the Tropical Pacific

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(Manuscript received 21 December 1970, in revised form 29 March 1971)

ABSTRACT

Nearly ten years of daily rawinsonde data for Canton Island (3S, 172W) have been subjected to spectrum and cross-spectrum analysis. In the course of this analysis a very pronounced maximum was noted in the co-spectrum of the 850- and 150-mb zonal wind components in the frequency range 0.0245–0.0190 day^{-1} (41–53 days period). Application of *a posteriori* sampling theory resulted in a significance level of $\sim$6% (0.1% prior confidence level). This type of significance test is appropriate because no prior evidence or reason existed for expecting such a spectral feature. Subsequent analysis revealed the following structure of the oscillation. Peaks in the variance spectra of the zonal wind are strong in the low troposphere, are weak or non-existent in the 700-400 mb layer, and are strong again in the upper troposphere. No evidence of this feature could be found above 80 mb, or in any of the spectra of the meridional component. The spectrum of station pressure possesses a peak in this frequency range and the oscillation is in phase with the low tropospheric zonal wind oscillation, and out of phase with that in the upper troposphere. The tropospheric temperatures exhibit a similar peak and are highly coherent with the station pressure oscillation; positive station pressure anomalies are associated with negative temperature anomalies throughout the troposphere. Thus, the lower-middle troposphere appears to be a nodal surface with u and P oscillating in phase but 180° out of phase above and below this surface. Evidence for this phenomenon was found in shorter records at Kwajalein (9N, 168E) but not at Singapore (1N, 104E) or Balboa, Canal Zone (9N, 79W). We speculate that the oscillation is a large circulation cell oriented in zonal planes and centered in the mid-Pacific.

1. Introduction

The application of spectrum analysis techniques to tropical wind time-series has so far been productive. The work by Japanese scientists and by researchers in this country has been summarized by Wallace (1969). In all these studies relatively short (4–6 months) record lengths were employed with the principle interest centering on wave modes whose intrinsic temporal frequencies $\gtrsim 0.070\ \text{day}^{-1}$. In the course of an investigation of tropical wind data designed to provide analyses over a broader frequency range and to study the non-stationary aspects of the aforementioned wave modes, we stumbled upon an apparent long-period oscillation in the station pressure and zonal wind components at Canton Island (3S, 172W). The frequency of this oscillation is much lower than that of any wave mode yet hypothesized, but is higher than can be expected from any component of a seasonal variation.

Since the inventory of well-established meteorological quasi-periodicities (other than astronomically related ones) is quite small, the strength of the evidence for this oscillation came as a distinct surprise. We must emphasize that we had no reason whatsoever to suspect that such an oscillation might exist. Therefore, we took some pains to examine the spectra using *a posteriori* significance theory. In addition, we emphasize that the oscillation is not a "periodicity" in the sense of a tidally induced oscillation, but almost certainly is a relatively broad-band phenomenon.

For convenience, we have limited the range of the spectra included in this discussion to periods > 14 days. In particular, when reference is made to the "frequency range of interest" we mean specifically the frequency interval 0.0245–0.0190 day^{-1} or roughly the range of period 41–53 days.

After explaining the necessary statistical considerations and giving a description of the oscillation, we speculate as to the physical basis for the phenomenon. As is, unfortunately, often the case with atmospheric behavior revealed in *a posteriori* fashion by statistics, this speculation is less than satisfying.

2. Spectral estimation and sampling theory

The method of estimating the spectra was that suggested by Bingham *et al.* (1967) which utilizes the fast Fourier transform (fFt). The algorithm makes use of the modified Fourier periodogram obtained by 1) removing the sample mean of the N members of the time series, 2) "tapering" the first and last 10% of the resulting N members by multiplication by a segment of the cosine curve so that the ends of the series are zero, and 3) performing the fFt to obtain all $N/2$ harmonic coefficients. The squared amplitudes or modified periodogram estimates are then averaged by a running

[1] The National Center for Atmospheric Research is sponsored by the National Science Foundation.

average of length L coefficients; this averaging produces an estimate of the continuous spectra viewed through a rectangular spectral window of bandwidth equal to $(2L/N)f_{Ny}$ where f_{Ny} is the Nyquist frequency.

The Canton rawinsonde record analyzed consisted of 3584 observations taken once daily at 0000 GMT. The record extended from June 1957 to March 1967. Approximately 2.5% of the observations at the lower troposphere levels had to be interpolated. In the upper troposphere this percentage was 5%. Interpolation in time, using available 1200 GMT data, was used to fill in the missing data. Some subjective adjustment of the interpolated values was performed if 0000 data at lower pressure levels were available. The value of L was chosen so that the bandwidth of the spectral window was 0.0081 day^{-1}.

The averaging of blocks of adjacent modified periodogram estimates produces a rectangular spectral window with the number of degrees of freedom appropriate for the chi-square distribution of smoothed spectral estimates equal to $2L$ (there are two degrees of freedom associated with each Fourier component). Because of the tapering applied to the original N members of the series, fewer than N equivalent independent degrees of freedom are available to be distributed over the $N/2$ Fourier components. Therefore, a better estimate of the degrees of freedom is obtained by defining an equivalent series length

$$N_{\rm eff}=N-2(0.10N)\left\{\int_1^0 \cos\left(\frac{\pi x}{2}\right)dx\right\}\frac{2}{\pi}=0.873N.$$

The number of degrees of freedom associated with each spectral estimate is thus

$$D=\frac{2LN_{\rm eff}}{N}\approx 51. \qquad (1)$$

The particular algorithm used to estimate the spectra included an adjustment to eliminate the annual period and higher harmonics thereof from all series. This was accomplished by substituting the average of four adjacent modified periodogram estimates for the estimates at those frequencies nearest to the annual and semiannual frequencies. The object of this substitution was to insert values on the order of the background continuous spectrum for those estimates influenced by the annual component.

All spectral estimates have been normalized to unit bandwidth so all ordinate values shown for spectra and cross spectra are in meters^2 second^{-2} day^{-1}. The coherence statistic used here is given by

$$\mathrm{Coh}^2=\frac{\Phi_{xy}{}^2+\Phi_{xy}{}^{*2}}{\Phi_x\Phi_y}, \qquad (2)$$

where Φ_{xy} and $\Phi_{xy}{}^*$ are the real (co-spectrum) and imaginary (quadrature spectrum) parts of the cross spectrum, and Φ_x and Φ_y are the spectral estimates of individual series x and y. To prevent confusion, this statistic is termed the coherence-squared.

Because the detection of the spectral feature under consideration here was *a posteriori*, or "after the fact," the usual application of the chi-square sampling limits of the spectral estimates cannot be used to establish significance levels. Instead, we first depend upon a method of calculating an *a posteriori* significance level, and then the compounding of several different manifestations of the apparent oscillation which make it unlikely that it is a sampling variation.

If there are q independent spectral estimates in the frequency range $f=0$ to $f=f_{Ny}$, the Nyquist frequency, the application of the *a priori* conventional sampling theory to the spectral estimates would result in an expected number of $0.05q$ estimates to exceed the (one-tailed) 95% value of χ^2/D. It is therefore quite likely that at *some* frequency a "significant" peak will appear. In our analysis $q\approx N/(2L)=60$, so that three peaks should exceed the 95% sampling limits. Since we had no prior reason to expect a maximum in the co-spectra or spectra of the zonal wind in the frequency range of occurrence, it is likely on an *a posteriori* basis that this peak represents one of the three to be expected. One method of erecting an *a posteriori* sampling limit is to simply raise the χ^2/D significance level to a point where it is unlikely that any estimate exceeds that limit. For example, with 60 independent spectral estimates, raising the *a priori* confidence level to the 1% level would indicate that 0.6 of an estimate should exceed $\chi^2(1\%)/D$. In this case, the interpretation is that in ten such sample spectra such as ours, six estimates would exceed the 1% prior confidence level. We have decided to use the 0.1% prior confidence level which means that 0.06 estimate may be expected to exceed that level, or 6 estimates in 100 such sample spectra. The *a posteriori* confidence limit of an observed peak is then approximately 0.06 if the ratio of the peak in the sample spectra is equal to $\chi^2(0.1\%)/D=1.70$ times the background spectra above which it rises. These matters are explained more fully, for example, by Mitchell (1966). Using tabulations published by Amos and Koopmans (1963), the 0.1% prior confidence limit on the coherence-squared statistic ($D=51$) is 0.250 on the null hypothesis of no relationship.

In addition, the confidence we have in the reality of a feature detected in *a posteriori* fashion is increased if the behavior of the feature is consistent in a sense dictated by wave theory or in some similar non-statistical context. For example, if velocity component, temperature and pressure data all individually exhibit a peak in the same frequency interval, and significance levels are attached to each, we may compound the level of significance if we find that the cross spectra between the variables behave in the manner predicted by, for example, the theory of internal gravity waves.

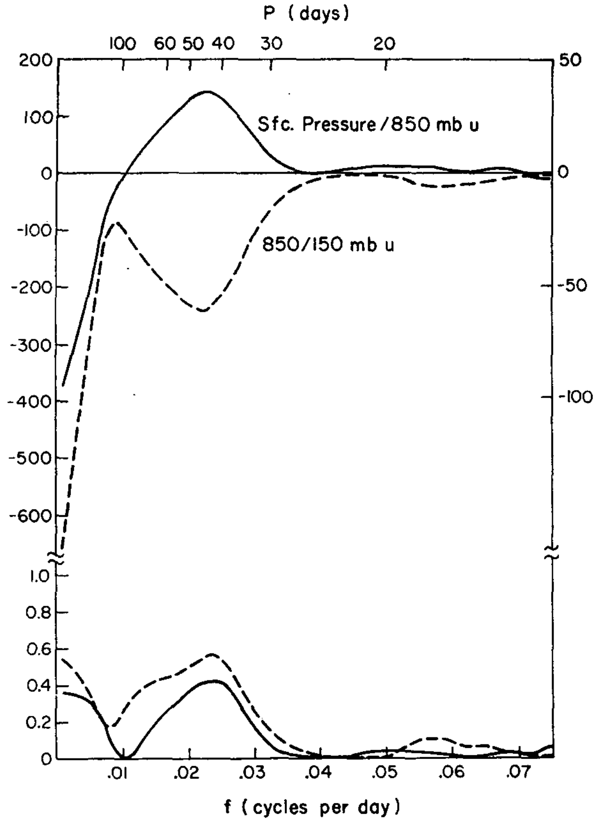

FIG. 1. (Top) The co-spectrum of the 850- and 150-mb zonal wind (u) (dashed, and left ordinate values) together with the co-spectrum of the station (sfc) pressure and the 850-mb zonal wind (solid, and right ordinate values) for Canton Island, June 1957 through March 1967. The ordinate is co-spectral density normalized to unit bandwidth (m^2 sec^{-2} day). (Bottom) The coherence-squared statistic for the 850- and 150-mb zonal wind and the station pressure and 850-mb u-series. The 0.1% prior ($\sim$6% *a posteriori*) confidence level on the null hypothesis of no association is 0.25. In this and the remaining spectra only the frequency range 0 to 0.075 day^{-1} is shown.

In order to examine the behavior of the oscillation as a function of time, the zonal wind component and station pressure data were band-pass filtered and plotted. The band-pass filter used had a maximum response function (equal to unity) at $f=0.0212$ day^{-1} (47-day period), and half-amplitude responses at $f=0.011$ day^{-1} (90-day period) and $f=0.029$ (35-day period). At $f=0$ and $f=0.0375$ day^{-1} (27-day period) the amplitude response was zero. The digital filtering was performed by obtaining the Fourier amplitudes of the data series and the weights by the fFt, performing a complex multiplication of the Fourier amplitudes, and an inverse transform again using the fFt. An order-of-magnitude decrease in computation time is realized over the running-weighted average algorithm involving successive multiply and add operations.

3. Description of the oscillation

The 41–53 day oscillation was first noted in the magnitude of the negative values of the co-spectra between the 850-mb zonal wind (u) and the zonal wind at pressure levels in the upper troposphere. A subsequent examination of the co-spectra between the station pressure and the u wind of the upper troposphere also revealed that the largest negative values were in the 41–53 day period range. The co-spectrum between the 850- and the 150-mb u components is presented in Fig. 1, along with the co-spectrum between the 850-mb u component and the station pressure. An important contrast is that in the frequency range of interest the co-spectrum of the 850- and 150-mb u components is negative while that of the 850-mb u component and the station pressure is positive. This relationship stipulates that positive u-wind anomalies at 850 mb (weak easterlies or westerlies) are accompanied by negative anomalies at 150 mb (weak westerlies or easterlies) and high pressures at the surface. Similarily, strong easterlies at 850 mb are accompanied by strong westerlies at 150 mb and low pressures at the surface. The coherence-squared between 850- and 150-mb u reaches a maximum of 0.56 at a period of 44 days, and at this period the co-spectrum combined with the quadrature spectrum reveal that the u wind at the two levels is almost out of phase with the 850-mb u, trailing that at 150 mb by 177°. The coherence-squared between the 850-mb u and the surface pressure is also 0.42 at a 44-day period. In this case the two series are nearly in phase with the 850-mb u, trailing the station pressure by $\sim$10°.

The largest negative co-spectral values are also evident in the 41–53 day period range in the co-spectra between the 850-mb u and the 200- and 300-mb u's. Corresponding estimates of the coherence-squared are 0.51 and 0.28, respectively. While peaks occur in the co-spectra between 850-mb u and the 400- and 500-mb u winds, the coherence-squared between these levels is less than that significant at the *a posteriori* 6% level (0.25). The entire co-spectra between the 850-mb u and the 600- and 700-mb u winds is positive at periods $>$14 days with no indication of any significant peaks in the 41–53 day range. Table 1 lists the average or

TABLE 1. Average or maximum (peak) values of the coherence-squared statistic and the phase lag between the 850-mb zonal wind and the zonal wind at the level indicated. The frequency interval ranges from 0.0190–0.0245 day^{-1} (53–41 day period); the phase lag is positive for levels leading 850 mb.

Level (mb)	Average or peak	Coherence²	Phase (deg)
1000	? peak	(0.75) 0.15 above continuum	0
700	average	0.15	13
500	rel. minimum	0.02	140
400	peak	0.17	155
300	peak	0.28	170
200	peak	0.51	175
150	peak	0.56	177
100	peak	0.35	175
60	? peak	0.15	10

peak value of the coherence-squared in the 0.0245–0.0190 day^{-1} frequency interval and the phase lag between the 850-mb u and the zonal wind at other levels. The lack of any clear association from 850 mb to mid-tropospheric levels and the maximum association in the upper troposphere is evident. Apparently rather than a smooth variation in phase with altitude, the entire upper troposphere and extreme lower troposphere tend to each have a rather homogeneous phase relationship which shifts abruptly by almost 180° through the 600–500 mb region.

The low-frequency portion of the individual spectra for the station pressure, 850-mb u, and 150-mb u is presented in Fig. 2. The peak in the station pressure spectrum is at 44 days. The 850- and 150-mb u spectra reach peaks at 52 and 45 days, respectively. Though not as large, there are resolvable peaks in the u spectra in the frequency range of interest at several other levels. At 1000, 500 and 400 mb the u spectra tend to peak at periods slightly greater than 50 days, and at 300, 200 and 100 mb the peaks are at periods slightly less than 50 days. No peaks are evident in the 41–53 day period range on the 700-, 600-, 60- or 40-mb u spectra.

Spectra of temperatures at several levels and the 850-mb mixing ratio were also examined to see what relation these variables had to the wind and pressure oscillation. No features related to the oscillation in the zonal wind and station pressure were present in the 850-mb mixing ratio spectrum or cross spectra. On the contrary, the temperature spectra and cross spectra revealed an excellent relationship with station pressure. Peaks in the frequency band of interest were evident in the temperature spectra in the lower and upper troposphere although they were not as pronounced as those peaks shown in Fig. 2. The cross spectra between station pressure and temperatures at upper levels gave surprisingly large coherence values in the frequency band. Table 2 presents the values of the coherence-squared statistic and the phase lag between temperatures at levels from 850 to 100 mb and station pressure for the frequency band of interest. In all instances a peak value of the coherence-squared occurred in the frequency interval. Maximum values of about 0.55 were reached in the 600–500 mb altitude range. From the phase-lag information (positive phase angles indicate that the temperature wave leads the pressure wave) we conclude that the phase of the temperature wave is virtually independent of height throughout the troposphere. Combining this information with that of the structure of the wind oscillation shown in Table 1, and using the hydrostatic relation, a consistent structure emerges. In the lower troposphere (to ~600 mb) a nearly vertical phase structure exists with positive pressure deviations associated with positive (westerly) zonal wind deviations. In the 600–400 mb region the vertical temperature structure results in a very rapid, nearly discontinuous shift in the phase of the wave so

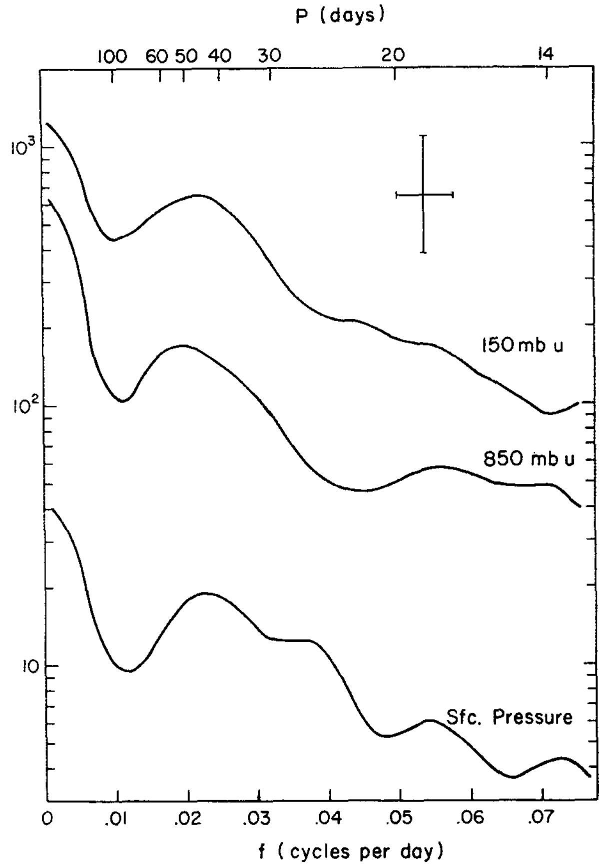

FIG. 2. Individual variance spectra for the 850- and 150-mb zonal wind component and station (sfc) pressure for the Canton Island record. The use of a logarithmic ordinate permits a constant scaling to be used for the chi-square degrees of freedom sampling analysis. This scaling [$\chi^2(0.1\%)/51$] and the bandwidth of the analysis, $\Delta f=0.0081$ day^{-1}, are shown by the cross. Spectral densities are normalized to unit bandwidth (m^2 sec^{-2} day^{-1}).

that above 300 mb a similar nearly vertical structure exists to the tropopause. We can discuss this feature in a more quantitative manner by considering the following. When the station pressure and upper air temperature data are subjected to a 47-day band-pass digital filter, the amplitudes of the resulting filtered oscillations are 1–2 mb and 0.5–1K, respectively. At 30C, a 1-mb station pressure increase represents about a 10-gpm increase in the height of the 850-mb surface. The phase relationship between station pressure and tropospheric temperature suggests that high station pressures are accompanied by low temperatures in most of the troposphere; therefore, this 10-gpm increase at 850 mb must be reduced to about a 7.5-gpm increase (a 0.5C drop in the mean temperature of 22C results in a 2.5-gpm reduction in the thickness between 1010 and 850 mb). Near 500 mb this height increase would go to zero producing a nodal point for the heights of the pressure surfaces. Above 500 mb, heights of constant pressure surfaces would be somewhat below normal when station pressure was above normal. At 100 mb

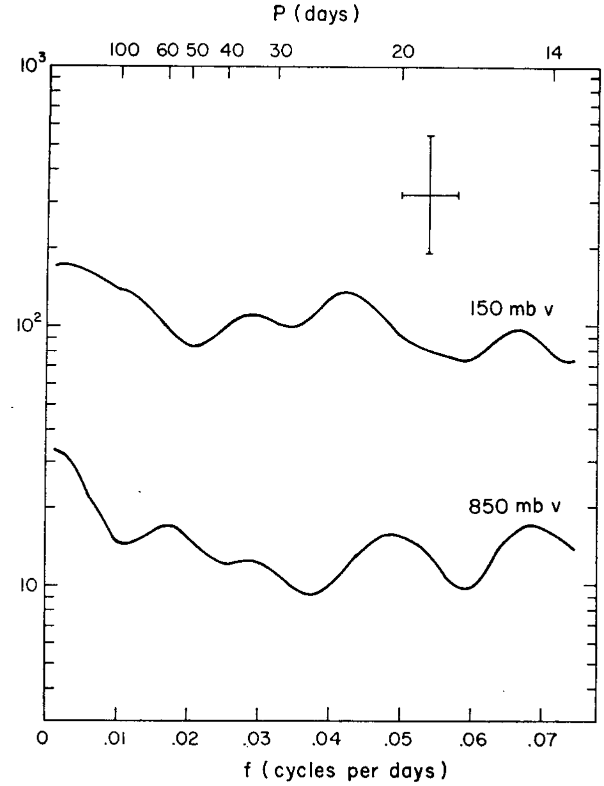

FIG. 3. Variance spectra for the 850- and 150-mb meridional wind (v) component. See legend for Fig. 2.

relatively high temperatures accompany high station pressures and the attendant thickness increases would again bring the height variation back to zero somewhere in the low to middle stratosphere.

In general, the relative maxima or minima in all the statistics do not occur centered at exactly the same frequency, but the variations in peak frequency are of the same order of magnitude as the bandwidth of the spectral estimation scheme ($\Delta f = 0.0081$ day^{-1}).

Examination of the meridional wind spectra and cross spectra revealed no features comparable to those in the u spectra. There are no distinct peaks on any of the v spectra or the inter-level v cross spectra in the relevant frequency interval (Fig. 3). However, an interesting feature does occur in the cross spectra between the zonal and meridional components at the same pressure level. Fig. 4 shows the co-spectra and coherence-squared statistic for the 850- and 150-mb u and v components. Noteworthy are the relatively broad minima in these statistics which include the 41–53 day period range. A possible interpretation of this feature is that the oscillation in question is superimposed upon a general continuum of motions which are transporting momentum horizontally, but that the oscillation itself does not. In other words, a zero population coherence exists in the frequency range of interest superimposed on a non-zero coherence background continuum. A statistical test of this relative minimum has not been carried out because of the obvious difficulty in specifying the coherence-squared continuum across the frequency range.

It is, of course, very important to look at wind records for other stations in the tropics (and also elsewhere, for that matter) not only to establish something of the geographic extent of the phenomenon, but also to eliminate the possibility that it is a statistical accident caused by a data processing or other type of error. Seven years of record were available for Kwajalein (9N, 168E), $7\frac{1}{2}$ years for Singapore (1N, 104E) and about 3 years of record from Balboa, Canal Zone (9N, 79W). Examination of spectra at these stations revealed that only Kwajalein showed any clear indication of a similar oscillation. For example, two $3\frac{1}{2}$ year periods (November 1958–May 1962 and March 1954–September 1957) at that station showed the largest negative co-spectral values for the 850- and 200-mb u components in the frequency range of interest. Coherence-square values at 0.28 and 0.23 were obtained; with the 39 degrees of freedom available for these analyses the 5% prior significance level was 0.25. At Singapore the 4-year and $3\frac{1}{2}$-year records produced no distinct peaks in the frequency range of interest on the individual 850- and 200-mb u spectra. The coherence-square reached relative maxima of 0.20 and 0.25 in the expected frequency range, but owing to a continuum level of relatively high coherence in the very low fre-

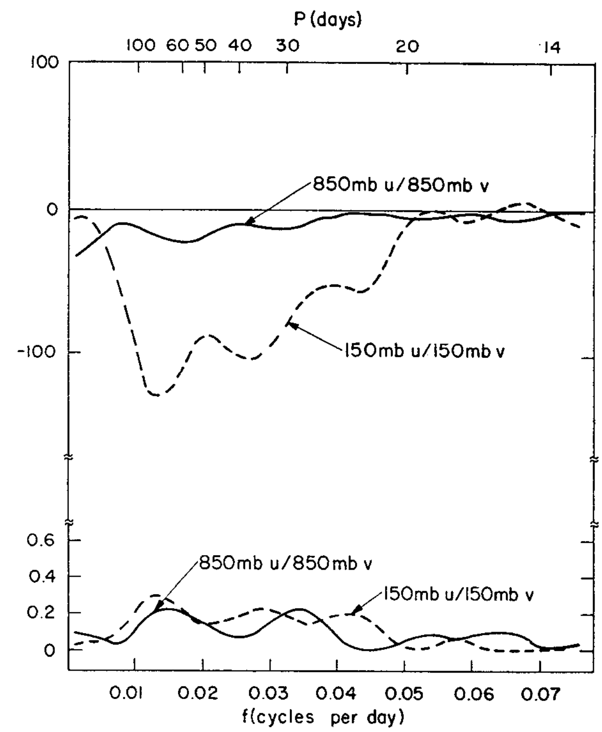

FIG. 4. (Top) The co-spectrum of the 850-mb (solid) and 150-mb (dashed) zonal and meridional winds for Canton Island. (Bottom) The coherence-squared statistic for the 850-mb (solid) and 150-mb (dashed) u and v series.

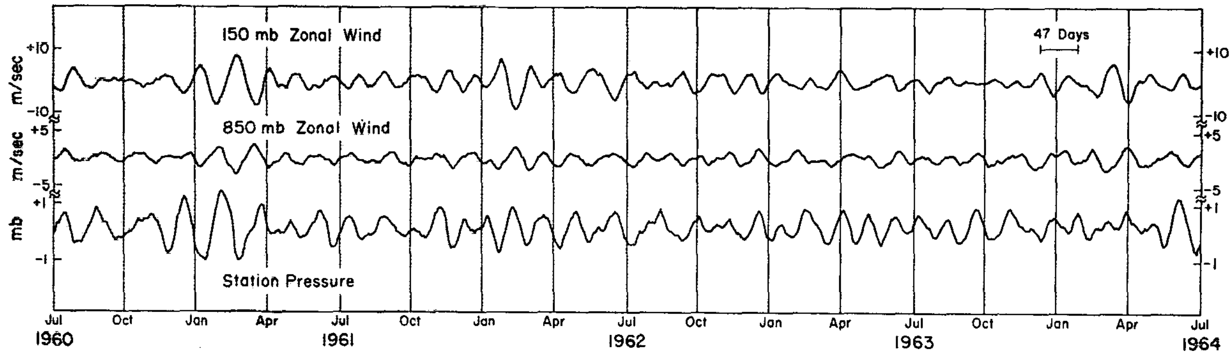

FIG. 5. The 150- and 850-mb u component and station pressure records for Canton Island from July 1960 through June 1964 treated with a 47-day band-pass filter.

quencies, it is questionable whether these peaks are significant as peaks. Two 16-month records at Balboa showed no evidence at all of the oscillation.

Considering the rather peculiar vertical structure of the wave, it seems important to map its spatial structure to determine not only the characteristic horizontal dimensions but also to establish the manner in which it propagates (if at all) horizontally.

4. Time-dependence of the oscillation

Fig. 5 presents the station (surface) pressure, 850-mb and 150-mb u series for four selected years after treatment with a 47-day band-pass digital filter. Only the period July 1960 through June 1964 is shown in the figure. The scale for each of the filtered series is indicated together with a reference scale for a length of 47 days. The very pronounced in-phase relationship between station pressure and the 850-mb u component and out-of-phase relationship between these variables and the 150-mb u component is evident in the figure.

There is an apparent annual modulation in the amplitude of the oscillation. In the months October through February of 1960–61 and 1961–62 the amplitudes are, respectively, about 2 mb, 5 m sec^{-1} and 15 m sec^{-1}. In the July–October 1960 and the March-September 1961 intervals the oscillation is of much smaller amplitude. Occasionally, however, the modulation at the annual frequency appears to break down; for example, the interval May-June 1964 includes a few strong waves. In the entire filtered record, the modulation appears to behave such that from the beginning of the record (July 1957) through the winter of 1960–61 the annual modulation is strong, but thereafter is weak and hardly noticeable—except for slightly larger amplitudes of the 47-day wave in the winter 1964–65.

5. Discussion of the oscillation

Our initial concern about the 41–53 day feature appearing in the spectra was the possibility that it was an alias of a higher frequency, possibly a lunar-tidal frequency. A calculation of the aliases of the lunar tidal period (12 hr 25.2 min) indicated that the observed frequency (0.021 day^{-1}) differed from that expected (0.035 day^{-1}) by an amount which exceeded the bandwidth of our spectrum analysis. However, to establish beyond any doubt that the oscillation was not an alias with a frequency near 1.0-2.0 day^{-1}, we employed the 47-day band-pass filter on station pressure data for March–July 1962 when observations at 0000, 0600, 1200 and 1800 GMT were available. All of the four filtered series were identical in amplitude and phase, eliminating any possibility that an alias was involved.

A fundamental characteristic of the oscillation, then, is its relatively low frequency. Considering that its amplitude is on the order of ± 5 m sec^{-1} (Fig. 5), that the mean zonal flow at Canton is about -5 m sec^{-1}, and that the frequency is 0.021 day^{-1}, it seems quite unlikely that linear wave propagation theory will be able to contribute to an understanding of the oscillation.

Another fundamental characteristic of the phenomenon is the presence of a nodal surface at the 500–600 mb level (Tables 1 and 2). It is apparent that we can view the oscillation as a standing wave in the vertical and, therefore, infer that it does not transport momentum vertically. The observed minimum in the co-spectra between the zonal and meridional compo-

TABLE 2. Maximum values of the coherence-squared statistic between the station pressure and the temperature at the level indicated. The frequency interval ranges from 0.0190–0.0245 day^{-1}; positive phase indicates temperature leads station pressure.

Level (mb)	Peak coherence²	Phase (deg)
850	0.13	+150
700	0.40	+155
500	0.54	+145
300	0.53	+133
200	0.50	+138
150	0.32	+150
100	0.20	−45

Note: The 850-mb u component leads the station pressure by 12°, while the coherence-squared is 0.42 (see Table 1).

nents further suggests that no horizontal momentum transport is accomplished by the oscillation.

The spectral techniques used indicate that the meridional wind component is not involved in the oscillation. If the oscillation is indeed limited to the zonal component then this is a third fundamental characteristic, one which is a property of the so-called atmospheric Kelvin wave (Holton and Lindzen, 1968). Further, the relationship between station pressure, zonal wind, and tropospheric temperature variations implies that the wind may be in geostrophic balance, which is another property of the atmospheric Kelvin wave. However, as we have seen, the oscillation does not propagate in the vertical. The linear theory that provides a basis for the atmospheric Kelvin wave predicts that it will propagate vertically. We conclude, then, that this oscillation cannot be an atmospheric Kelvin wave similar to those discussed in the recent literature.

Summarizing the most fundamental characteristics of the oscillation evident from an analysis of Canton's record, we conclude that it can best be described as large circulation cell oriented in zonal planes rather than as a propagating wave.

We note that in some respects it is similar to the Walker-type of circulation, described by Bjerknes (1969) and related, according to him, to the Southern Oscillation. Bjerknes believes a circulation in the zonal wind in the region of the central Pacific, with the lower and upper tropospheric components out of phase, is essential in the mechanism producing the Southern Oscillation. [The Southern Oscillation is a broad-frequency-band phenomenon with a period range of 30–40 months,[2] involving, at least, the mass field in the eastern Pacific and Indonesian regions (Berlage, 1966).] The thermally direct circulation scheme of Bjerknes, however, stipulates that low station pressure is associated with low-level westerly zonal wind anomalies, rather than with maximum easterlies as observed (Fig. 5). We point out in this regard, however, the very large negative co-spectral estimates at the lowest resolvable frequencies in Fig. 1.

6. Conclusions

The statistical evidence presented here for a vertically-coherent tropospheric oscillation in the zonal wind, pressure and temperature fields in the central tropical Pacific seems to us insurmountable. Unlike the detectable wave modes with higher frequencies—the "easterly-waves" in the low troposphere of Wallace and Chang (1969) and the "Yanai" waves in the lower stratosphere (Yanai and Maruyama, 1966)—this oscillation encompasses the entire troposphere. Perhaps not inconsistent with this fact is the relatively (to the aforementioned waves) low frequency of the oscillation. We have concluded on the basis of the evidence available to date that the oscillation is most likely a manifestation of a large (thousands of kilometers) circulation cell oriented in a zonal plane near the equator.

The occurrence of this oscillating cell raises many questions other than the obvious one of its very existence. The fact that it is coherent through the entire troposphere and appears to have characteristics of a circulation cell suggests that deep convection is important as a driving mechanism. However, no signs of the oscillation were evident in the mixing ratio data at 850 mb. The fact that the organized motion is zonal while the temperature structure is undoubtedly three-dimensional raises some interesting dynamic questions.

We believe, on the observational side, that the most important immediate task is to obtain some information on the spatial characteristics of the oscillation. The unfortunate closing of the Canton Island station may make future observations of this phenomenon difficult. However, fairly long historical records are available for a few stations in the central-western Pacific and are currently being analyzed.

[2] From unpublished spectrum analysis of monthly station pressures at Santiago, Chile and Port Darwin, Australia, by the authors.

Acknowledgments. We thank W. L. Jones and R. Dickinson for productive discussions and reading of the manuscript. R. Jenne and D. Joseph of the NCAR Computing Facility are responsible for the initial acquisition and processing of the rawinsonde data.

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