The 26-Month Zonal Wind Oscillation in the Lower Stratosphere of the Southern Hemisphere

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ABSTRACT

Stratospheric winds observations over Australia for 7½ years show a quasi 26-month zonal wind cycle in both temperate and tropical latitudes. The amplitudes of the annual and quasi 26-month cycles obtained by harmonic analysis of the data reveal major differences between the oscillation in temperate and tropical regions. The phase of the oscillation is propagated downward in the tropics but is independent of height in middle latitudes. The vertical shear of the quasi 26-month component of the zonal wind is much larger in the tropics than elsewhere. The familiar amplitude maximum at about 25 km is found in the tropics, but for the southern latitude oscillation the amplitude continues to increase up to 30.5 km, the effective limit of observations.

1. Introduction

The 26-month oscillation in zonal wind in the tropics of each hemisphere is by now a fairly well established and frequently described phenomenon. There is general agreement as to the main features of the tropical oscillation, which are:

1) A rapid increase in amplitude from near zero values close to the tropopause to a maximum of about 20 m sec\(^{-1}\) (at the equator) at about 25 km. Above this, the amplitude decreases slowly with height to about half the maximum value at 50 km.

2) A decrease of amplitude with increasing latitude until it becomes very small near the 30° latitude circles.

3) A downward propagation of phase at the rate of approximately 1 km per month.

4) No significant variation of amplitude or phase with longitude.

Investigations of winds in the temperate stratosphere in the Northern Hemisphere have produced no convincing evidence of any oscillation with similar period and comparable amplitude north of 30N. The 26-month cycle was for some time regarded as a tropical phenomenon. However, Laby et al. (1964) extended the investigation to the Southern Hemisphere and found an oscillation, with a period near 2 yr in stratospheric zonal winds above Hobart (43S). Their findings were confirmed by later work (Sparrow and Unthank, 1964; Rofe, 1966; Berson, 1966).

The discovery that the 26-month oscillation is not confined to the tropical stratosphere is obviously of considerable importance. It seems reasonable to expect that a study of the difference between tropical and temperate latitudes will lead to an increased understanding of the whole phenomenon. The Australian observing network is well situated for such a study since it includes stations at latitudes between Lae (7S) in the tropics and Hobart (43S). Investigations into the nature of the oscillation over the Australian region are being carried out and some preliminary results were presented by Tucker (1966). The purpose of this article is to present further results.

2. Data

The data used were from six Australian and New Guinea stations; namely, Lae (7S), Darwin (12S),

| Table 1. Typical numbers of wind observations at stations over Australia. |
|---|---|---|---|---|---|---|---|---|---|---|
| Period of record | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| 1958–1963 | 15–20 | 10–15 | 10 | 0–5 | 0–5 | 0–5 | 0–5 | 0–5 | 0–5 |

| Typical numbers of wind observations over Lae. |
|---|---|---|---|---|---|---|
| Period of record | 60 | 65 | 70 | 75 | 80 | 85 |
| 1959–1963 | 20 | 20 | 15 | 0–10 | 0–10 | 0–5 |

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Fig. 1. Monthly values of the mean zonal wind component (m sec\(^{-1}\)) at 21 km: a., over Darwin (12S); b., over Hobart (43S).

Fig. 2. Twelve-month running means of the zonal wind component (m sec\(^{-1}\)):
  a., over Darwin (12S); b., over Hobart (43S).
Townsville (19S), Alice Springs (23S), Laverton (38S) and Hobart (43S) between June 1958 and December 1966, inclusive.

The zonal component of wind speed was computed at 5000-ft intervals from 60,000 to 100,000 ft. Typical values of the number of observations per month at each level are given in Table 1.

The scarcity of data at higher levels, most severe during the years 1958–1963, must necessarily decrease confidence in the validity of results obtained for these levels. The risk of available data being unrepresentative is particularly great if any bias towards special wind situations exists, e.g., if flights were consistently longer (higher) when winds were light. However, it is unlikely that any bias would operate only during alternate years so as to produce the marked quasi-biennial cycle found at these levels. The consistency of results for higher levels in the first half of the data period with those for the second half for which many more observations exist indicates that the paucity of data has not obscured the main features of the oscillation.

3. Use of 12-month running means

The oscillation in the equatorial stratosphere can be clearly seen by inspection of the monthly mean zonal wind pattern, but at higher latitudes the longer period cycle is masked by the annual wave. This is evident from Figs. 1a and 1b, which show monthly mean zonal winds at Hobart and Darwin. Positive values are westerly in all figures.

In Fig. 1b, the convergence of the enveloping curves (dashed) of the maximum during odd and even years is a crude indication that the major periodicity other than the annual one is not an integral multiple of 12 months.

Running 12-month means were used in order to emphasize longer periods (greater than 12 months) present in the data. This simple filter suppresses almost entirely cycles with periods near 12 months but reduces only slightly the amplitude of periodicities near 24 months. With this type of filter which has all positive weights there is no danger of introducing spurious cycles (Moran, 1959).

The results of applying this technique to Darwin and Hobart, representing the tropics and middle latitudes, respectively, are presented in Figs. 2a and 2b. These diagrams clearly show the existence of an oscillation with a similar period (approximately 26 months) at both stations. This is evident when the trace of the zonal wind at 28 km for Darwin is superimposed upon that for Hobart (Fig. 3). The two cycles also appear to be in phase at about the 28-km level although at the end of the data period there is some irregularity in the Hobart cycle. It may be noticed that the overall trend in both
Fig. 4. Amplitude, as a function of latitude and height, of the annual wave obtained from a harmonic analysis of monthly mean zonal wind components. Units are m sec⁻¹.

Fig. 5. Amplitude as a function of latitude and height, of the 26-month wave obtained from a harmonic analysis of the residue in the monthly mean zonal wind components after the annual cycle has been subtracted. Units are m sec⁻¹.
traces is similar, as are the relative positions of consecutive maxima and consecutive minima.

Equally clear from Fig. 2 are the marked differences between the characteristics of the tropical and temperate cycles. These differences are:

a) The amplitude of the oscillation above 24 km, at Darwin (15–20 m sec\(^{-1}\)) is greater than that at Hobart (5–12 m sec\(^{-1}\)).

b) Although the Darwin diagram displays a downward propagation of phase similar to that found throughout the tropics, there is no sign of any phase lag between higher and lower levels at Hobart.

c) As a consequence of the above two characteristics, the vertical shear of the zonal wind is greater at Darwin than at Hobart.

4. Harmonic analysis of mean monthly zonal winds

The mean monthly zonal winds at each station and level were subjected to a Fourier-type analysis to find the amplitude and phase of the annual wave. The value taken by the annual wave for each month was then calculated and subtracted from the monthly mean. The set of remainders was analyzed for the amplitude and phase of the 26-month wave. Figs. 4 and 5 show the annual and 26-month amplitudes as functions of height and latitude.

The amplitudes and phases for both annual and 26-month oscillations for every station are given in Table 2. The phase of the annual cycle varies little with height or latitude, although a systematic change (decrease) of phase with height occurs at both Townsville and Alice Springs. The significance of these results has not been tested.

The phase of the 26-month cycle at both Lae and Darwin has a downward rate of propagation of about \(\pi\) radians in 10 km which is consistent with previous estimates for the tropical cycle. The relative constancy of phase with height at the three southern stations shows up well by contrast. The variations of individual phase values about these trends are due to missing data, the use of monthly means, minor phase variations with time and, possibly, the form of the oscillation differing from that of a pure sine wave.

Several variants of this procedure, e.g., computation of the 26-month amplitude and phase without first subtracting the annual wave, were tried and the several sets of amplitudes, although not identical, displayed the same height and latitude dependence.

The amplitude of the annual cycle at any given level is smallest at Lae and increases fairly steadily with latitude. An increase with height occurs at all latitudes but is greatest south of 30S. The amplitude of the 26-month wave is greatest in the tropics and has a minimum near the latitude of Alice Springs (23S); it increases again, slowly, southward. In the tropics this amplitude increases with height up to about 25 km; above this level it becomes almost constant. However, at Laverton and Hobart the increase with height, although smaller than in the tropics, continues to the top of the region (30.5 km).

The amplitude results for these two stations are in agreement with the value of 5 m sec\(^{-1}\) estimated by Barbé and Reininger (1967) to be the amplitude of the quasi-biennial cycle at 26 km above Kerguelen Island (49S). The phase is also similar. From the material presented by Berson (1966), a figure of about 10 m sec\(^{-1}\)
can be inferred as the amplitude of the cycle at 18 km over McMurdo (78S). This seems a very high figure for such a relatively low level and implies that the amplitude continues to increase with increasing latitude until well within the Arctic Circle.

The values of the amplitudes in the tropics are in agreement with results of a similar analysis by Shah and Godson (1966) for stations between 90N and 15S. They found that the oscillation became insignificant polewards of 25N.

Figs. 6a and 6b show the total variance of the observations (full line) at each level at Hobart and Darwin and the percentage variance due to the annual (dotted line) and 26-month (dashed line) waves, respectively. At all heights the annual cycle accounted for about 60% of the variance at Hobart and the 26-month wave contributed only 5-10%. At Darwin 30-40% was contributed by the 26-month wave between 22 and 28 km; the amount due to the annual wave decreased from 70%

at 18 km to a minimum of 17% at 26 km. An interesting result is the increase in the relative contribution of the annual wave above 26 km at Darwin. At the 30.5-km level it accounted for a larger amount of the total variance (35%) than did the quasi-biennial wave (23%). This is in accord with Reed’s (1965) finding of pronounced fluctuation with periods of 12 months and less above 36 km at Ascension Island (7S).

5. Conclusions

The most noticeable feature of these results is the confirmation, from data at more stations and more levels than those treated by Sparrow and Unthank (1964), of the existence of zonal wind oscillations of a similar quasi 26-month periodicity in the lower stratosphere over southern tropical and southern temperate latitudes. Little can be inferred from the difference in vertical phase propagation in these two regions at this stage. There is an obvious need to define the southern zonal wind oscillation to greater heights and to higher latitudes, and also to include a temperature analysis.

The rapid fall-off in wind observations with height makes observational studies of large-scale horizontal fluxes difficult. Nevertheless, knowledge of the effect of horizontal and vertical transfer processes is essential if the mechanisms maintaining these oscillations are to be understood. Of particular interest will be the zonal interactions across the boundary between these two zones.

The promise of high-level observations from GHOST balloons in the next decade has an important bearing on the future study of the phenomenon. They should enable an examination of day-to-day flow patterns at high levels which must play a major role in maintaining these pronounced oscillations.

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REFERENCES


Reed, R. J., 1965: The quasi-biennial oscillation of the atmosphere between 30 and 50 km over Ascension Island. J. Atmos. Sci., 22, 331–333.


