

A Preliminary Radar Observation of Long-Period Waves in the Tropical Mesosphere Over Jicamarca

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Zonal wind velocity in the tropical upper mesosphere was observed on 3 contiguous days in November 1977 by the VHF radar at Jicamarca, Peru (12.0°S, 76.9°W). A day-to-day recurring wind pattern was not always evident in the height range observed, but rather long-period oscillations with a period longer than 1 day seemed to coexist with tidal winds. The present observation suggests a possibility that the VHF radar technique is applicable to the study on large-scale waves on a time scale of the order of days.

INTRODUCTION

It is widely known that long-term behavior of the mean zonal wind in the tropical middle atmosphere exhibits some remarkable features such as quasi-biennial and semiannual oscillations. However, there still remains much to be solved on the dynamics of the tropical mesosphere. It is suggested that large-scale wave disturbances play an essential role in producing the zonal wind variation in the tropics, but very little is known about the nature of the wave disturbances in the upper mesosphere, except for atmospheric tides [e.g., Evans, 1978] mainly because of the sparsity of measurements in this region. It should therefore be emphasized that continuous observation with high resolution is required to study long-period waves in the wind field.

Recent progress in high-powered VHF radars, though yet limited by both observation station and period, makes it possible to investigate the temporal variation of mesospheric winds [Woodman and Guillen, 1974; Rastogi and Bowhill, 1976], and significant results have been obtained for the wind oscillations due to gravity waves [e.g., Balsley and Gage, 1980; Gage and Balsley, 1978; Röttger et al., 1978].

In the present study a preliminary attempt to find evidence of long-period waves in the tropical upper mesosphere is made with the aid of radar observations at Jicamarca, Peru (12.0°S, 76.9°W).

OBSERVATIONAL TECHNIQUE

The 60- to 90-km region was probed by using the Jicamarca radar (50 MHz) for about 60 hours on November 14-16, 1977, when the season was just the opposite to that of our previous observation made on May 23-24, 1974 [Harper and Woodman, 1977; Fukao et al., 1978, 1979]. The Jicamarca antenna consists of two superimposed arrays of 9216 half-wave (3 m) dipoles, with the dipoles of each array arranged at right angles of each other in a square 288 m on a side. Each array provides an antenna beam about 1.06° wide at half-power width. It is possible to point the antenna beams along several pointing directions, up to a few degrees off the normal pointing position,

by a suitable choice of phasing [Ochs, 1965]. For the present observation, one antenna beam was directed toward the zenith, while the other beam was tilted from the zenith by an angle of 3.45° toward the west [Fleisch, 1976].

A sequence of pulses of 25-μs width at 1 MW peak output power (nominal) were transmitted on both antennas with an interpulse period of 1 ms. Thirteen heights spaced at 2.5-km intervals over the 60- to 90-km region were simultaneously observed in each of two antennas. Note that no data were available at night, since the nighttime mesospheric signals were weaker than the sky noise level.

The signal correlation time in the mesosphere is of the order of 1 s, considerably longer than the interpulse period. Thus digital filtering (or coherent integration) was done over more than 100 pulses, yielding an averaged sample every 126 ms (see Fukao et al. [1980] for details). Then the time sequence of the samples was divided into consecutive sections of 30-s period, and 50-point Doppler spectra were calculated with a fast Fourier transform program [Singleton, 1969].

Line-of-sight velocities were inferred from the mean Doppler shifts. Zonal winds were calculated from the two line-of-sight velocities by a simple transformation which assumes that the vertical velocities in the scattering volumes of the two antenna beams are equal:

$$U_z = -(V_w - V_v) / \sin 3.45^\circ \quad (1)$$

where U_z is the zonal wind and V_w and V_v are the line-of-sight velocities in the westward and vertical beams, respectively. The assumption of equal vertical velocities does not introduce significant errors in the estimation of long-period components because of the large horizontal scale of these variations relative to the antenna beam separation.

RESULTS

Figure 1 compares daytime averages of zonal wind velocities at Jicamarca (12.0°S, 76.9°W) with meteorological rocket observations made at Ascension Island (8.0°S, 14.4°W) in the periods closest to every radar observation. The profile on May 24, 1974, is reproduced by Fukao et al. [1979, Figure 6]. The longitudinal dependence of the prevailing wind is thought to

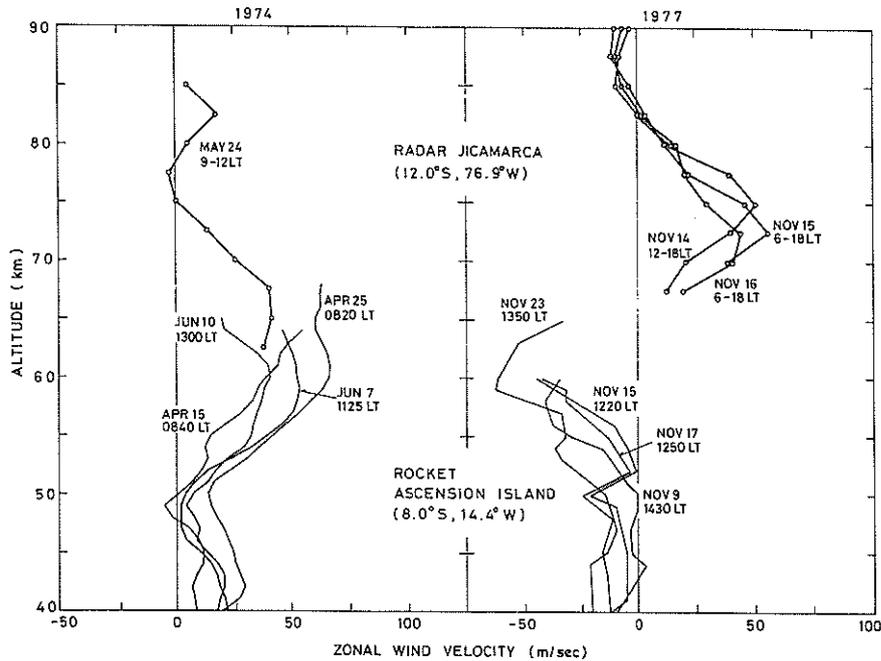


Fig. 1. Comparison of the zonal wind velocities (westerly positive) measured by the radar at Jicamarca (bold lines) and meteorological rockets at Ascension Island (light lines). The radar-inferred velocities are average values of all data available on the observed daytime period. Two radar observations are 6 months apart in the annual cycle.

be small so that the longitudinal difference of the two stations can safely be neglected.

It is apparent from Figure 1 that the rocket observations show general continuity to the wind profiles inferred from the

radar measurements around 60–70 km. In marked contrast to the wind field in the 50- to 60-km region the zonal velocities observed in the height range 70–80 km obviously indicate them to be westerly biased. Since the two observations are 6 months apart in the annual cycle, the mean value between both observations is principally caused by annual mean and semiannual wind components, while major portion of deviations from the mean value is due to annual wind component. The present result does not seem to conflict with the climatological winds in the tropical upper mesosphere [Groves, 1972; Belmont *et al.*, 1974; Hirota, 1978].

Temporal variation at each height is depicted for the November observation in Figure 2 where 120-min means of the zonal wind velocities are yielded every 60 min. Note that no smoothing is done in vertical direction. Although the data contain considerable scatter, the winds at each height show relatively systematic variations from hour to hour. And a marked phase change with height is also evident, especially on November 15. However, a day-to-day recurring wind pattern expected from the tidal winds does not always dominate in the height range considered. For example, the temporal variation at 75 km shows a period of the order of several days, while the wind at 82.5 km shows a variation with period of approximately 2 days. The similar nonrecurring wind variation was also noticed in the day-long May observation [Fukao *et al.*, 1979].

The dashed lines and chains in Figure 2 give the best fit to the data, in a least mean square sense, of linear combinations of a 24-hour sinusoid and a sinusoid longer than 24 hours. Because of the limited duration of the data the long-period component is assumed a priori to be monochromatic periodic oscillation with a period of 2 or 5 days. As is shown in the figure, both combinations are fairly well fitted to the data, and fitting was significantly improved by including the long-period components. Therefore it should be mentioned at this stage that there are substantial oscillations other than the diurnal tide present, the periods of which are likely to be of the order of days.

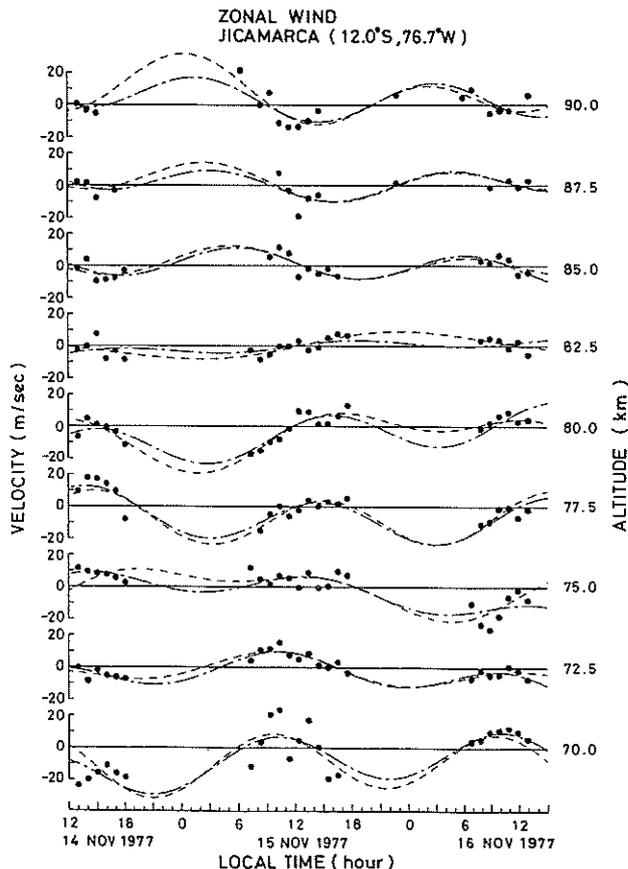


Fig. 2. The 120-min means (dots) of the zonal wind velocities observed on November 14–16, 1977. Dashed lines and chains give the 48- and 120-hour sinusoids, respectively, which fit best to the data in combination with a 24-hour sinusoid.

CONCLUDING REMARKS

Upper mesospheric winds were observed with the Jicamarca radar on 3 contiguous days in November 1977. The result indicates the existence of wind oscillations on a time scale of the order of days. In order to confirm the nature of these long-period oscillations, further continuous durations should be observed in the near future. The present observation suggests that the VHF radar technique will be a powerful tool for investigating upper mesospheric wind oscillations on a time scale of several days.

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