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Further Analysis of Semidiurnal Tidal Motions Between 30 and 60 Kilometers[1]

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ABSTRACT—All available meteorological rocket soundings through the summer of 1966 are harmonically analyzed to obtain the amplitude and phase of the semidiurnal variation of the meridional wind component in summer for stations located near 30° and 37°N and of the zonal wind component in summer for the stations near 30°N. The results support the earlier finding that a phase reversal occurs at a height of 45–50 km rather than at the theoretically predicted height of 25–30 km. It is suggested that the difference between observation and theory may be attributed to the neglect of the basic wind structure in the theoretical calculation.

1. INTRODUCTION

In an earlier paper, the author (Reed 1967) presented measurements of semidiurnal tidal motions between 30 and 60 km for locations near 30°N (Cape Kennedy, Fla., White Sands, N. Mex.) and 8°S (Ascension Island). The results appeared to conflict with theoretical predictions in that the phase reversal of the meridional wind component (and presumably of the zonal component, too) occurred at a height of 45–50 km rather than at the predicted height of 25–30 km (Chapman and Lindzen 1970). The purpose of this paper is to present further analyses of the semidiurnal tidal motions in the 30- to 60-km layer that offer added support for the earlier results.

2. DATA AND ANALYSIS

The same data set is employed here as in the study of the diurnal tide by Reed et al. (1969). This study yielded estimates of the diurnal tidal motions that were in good agreement with theoretical predictions (Lindzen 1967). For the months and stations involved, the observations include all available rocketsonde data through August 1966. Determination of the semidiurnal variations is made for two groups of stations: White Sands and Cape Kennedy near 30°N and Green River, Utah, Wallops Island, Va., and Point Mugu, Calif., in the vicinity of 37°N. The number of observations available from these stations during various hours of the days is shown in table 1 of the aforementioned paper by Reed et al. and will not be repeated here. The well-known and unfortunate dearth of observations during the hours of darkness is notable. This is the main factor contributing to the uncertainty of the results.

The data were analyzed by fitting a semidiurnal oscillation to the individual observations, treated as a time series covering a 24-hr period, by the method of least squares. This is the same method used in defining the diurnal tide. For the purpose of obtaining some measure of the reliability of the estimates, the data were divided randomly into two samples of equal size, and harmonic analyses were made of the two subsets.

The tidal parameters evaluated are the phase and amplitude of the semidiurnal variation of the meridional wind component at 1-km intervals in the 30- to 60-km layer for the months of June, July, and August. For the first group of stations (Cape Kennedy, White Sands), the phase and amplitude of the zonal component were also determined with use of the method for trend removal described in the earlier paper (Reed et al. 1969). Reliable estimates of the tidal parameters cannot be made at other times of the year because of the effect of synoptic scale disturbances that introduce large, irregular trends in the data.

3. RESULTS

The phase and amplitude of the meridional component at 30°N are shown in figure 1. The results are similar to those obtained previously, which is not surprising since the earlier determination contains 519 of the 663 observations entering into this estimate. As before, it appears that the amplitude of the *v*-component is small below 50 km (about 1 m/s), and that it reaches its maximum shortly after local noon. Above that level, the phase reverses suddenly and the amplitude increases, attaining a value of approximately 4 m/s at 60 km.

The results for 37°N (fig. 2) are somewhat more irregular, as one would expect from the smaller data sample. However, they essentially reproduce the features shown in figure 1 except that the phase reversal and increase in amplitude occur at a slightly lower elevation.

The behavoir of the *u*-component at 30°N is shown in figure 3. The amplitude is similar in size to that of the *v*-component and has a similar variation in the vertical. The phase also exhibits a reversal near 50 km, though not as pronounced as for the *v*-component. As required by

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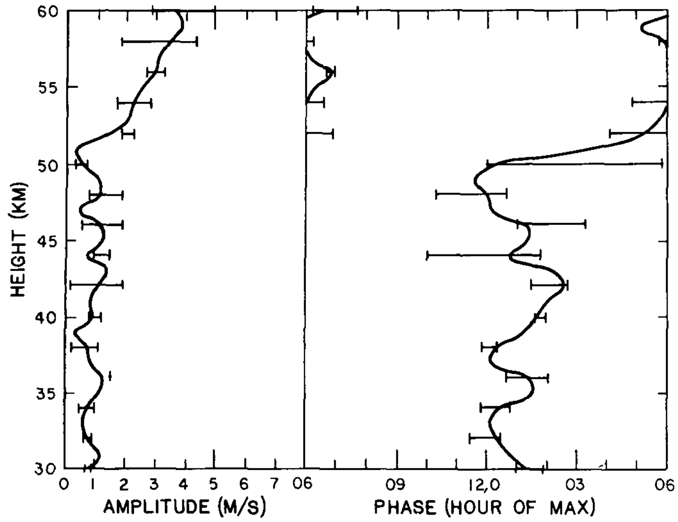

FIGURE 1.—Amplitude and phase of semidiurnal variation of meridional wind component at 30°N. Curves apply to total data sample; bars give estimates for same data divided randomly into two samples.

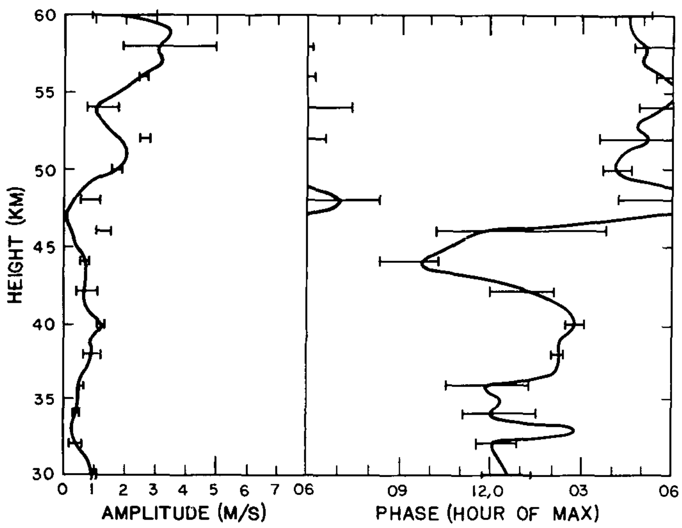

FIGURE 2.—Same as figure 1 for 37°N.

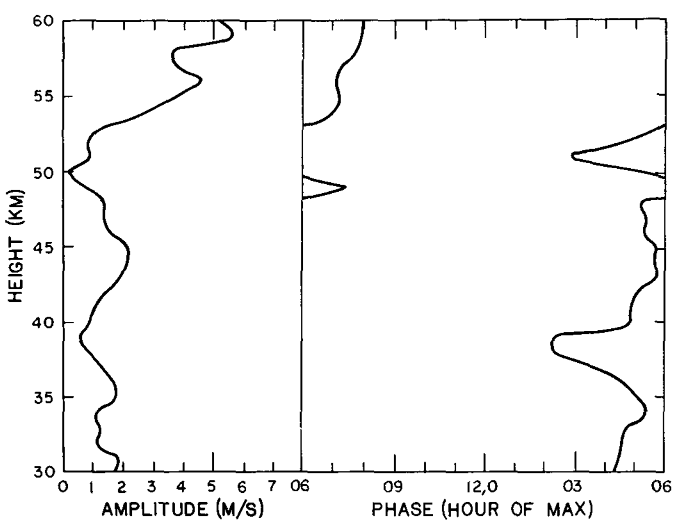

FIGURE 3.—Amplitude and phase of semidiurnal variation of zonal wind component at 30°N.

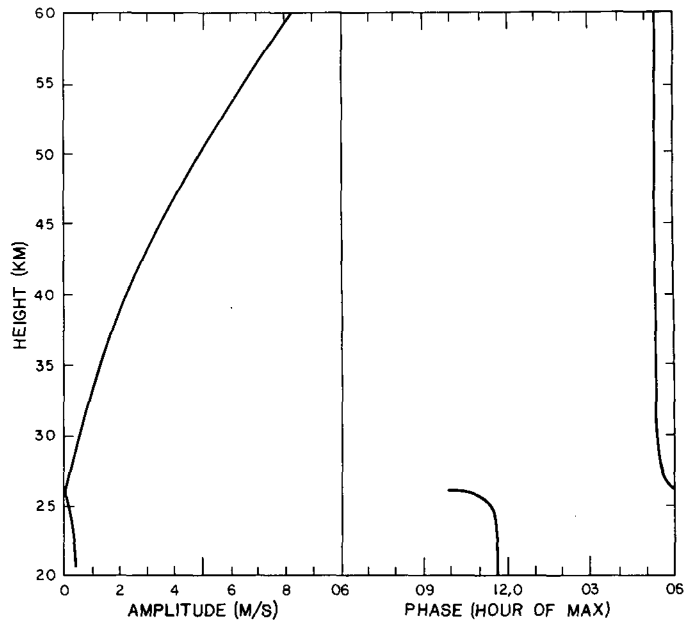

FIGURE 4.—Theoretically predicted amplitude and phase of the semidiurnal variation of the meridional wind component (Chapman and Lindzen 1970).

theory, the two components are nearly in quadrature at all levels, and the phase relationship is such that the wind vector rotates clockwise with time at a given height.

4. DISCUSSION

The latest theoretical estimate of the semidiurnal oscillation of the meridional wind component, taken from Chapman and Lindzen (1970), is shown in figure 4. As with earlier theoretical results, the phase reversal and rapid increase of amplitude with height are shown to occur at 30 km or below. By 60 km, an amplitude of 8 m/s is already attained. These predictions are plainly in disagreement with the observational findings. Despite the disagreement, we feel that the observational results should now be accepted as an essentially accurate description of the semidiurnal tidal characteristics at middle latitudes in summer for the following reasons:

1. Near 30 km, the results agree closely with those obtained from radiosonde observations (Harris et al. 1962). The theoretical results do not.
2. The results from the two groups of stations are too similar to be attributed to chance.
3. The estimates based on the subsets of data are similar to each other and to those based on the full sets.
4. The zonal wind oscillation is in approximate quadrature with the meridional wind, and its amplitude varies with height in a similar way. It is difficult to conceive of these similarities as chance occurrences.

In conclusion, it should be remarked that the theoretical results shown in figure 4 apply to an atmosphere at rest. The observational results, on the other hand, were obtained for conditions in which easterly winds and easterly wind shears prevailed at the altitudes in question. Thus, there may not be a real conflict between theory and observation if the basic wind structure exerts a significant effect on the tidal behavior. A theoretical model with a more realistic basic state might conceivably reproduce the results presented here.

ACKNOWLEDGMENT

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