N87-10465 D46-46 
5P.

# 3.7.6 OBSERVATIONS OF VERTICAL VELOCITY POWER SPECTRA WITH THE SOUSY VHF RADAR

M. F. Larsen[1], J. Rottger[2,3], D. N. Holden[1]

[1]Department of Physics and Astronomy
Clemson University
Clemson, SC 29631

[2]Arecibo Observatory
P. O. Box 995
Arecibo, PR 00612

## 1. INTRODUCTION

Recently LARSEN et al. (1985) have shown that the line-of-sight velocity power spectra measured at an oblique angle have a significant contribution from the vertical velocity out to periods close to 1 hr, in agreement with the earlier result of BALSLEY and CARTER (1982). The spectral slope of the inferred vertical velocity frequency spectrum was close to -1. The inferred vertical velocity vertical wave number spectrum had a slope that lay between -1 and -1.5. The frequency and vertical wave number spectra of the horizontal velocities had slopes in agreement with a number of earlier studies, namely -5/3 and -5/2, respectively.

In this study, we have used a data set taken with the SOUSY VHF radar from October 28 to November 13, 1981, to calculate the power spectrum of the vertical velocities directly from the vertical beam measurements. The spectral slopes for the frequency spectra have been determined out to periods of several days and have been found to have values near -1 in the troposphere and shallower slopes in the lower stratosphere. The value of -1 is in agreement with the value found by LARSEN et al. (1985) and BALSLEY and CARTER (1982) in the range from a few minutes to 1 hr.

## 2. DESCRIPTION OF THE DATA SET

From October 28 to November 13, 1981, the SOUSY VHF radar was operated in a mode that provided data for 12 min every hour on the hour. The radar was also operated continuously during three separate periods in the time span. Each profile consisted of a 1-μsec pulse sampled up to 4.5 km, and a 2-μsec pulse sampled from 3.0 km to 21.0 km. The signal-to-noise ratio was sufficiently good to determine the winds up to 18.0 km routinely.

Below 3.0 km, the 150-m resolution data were averaged to provide an effective height resolution of 300 m. Also, the profiles obtained over each 12-min interval every hour were averaged. Thus, the data set consists of one 12-min average profile every hour with height resolution of 300 m and covering the height range from 0.6 km to 18.0 km. Only six of the hourly profiles were missing, and they were replaced by linearly interpolated values.

## 3. FREQUENCY SPECTRA

The frequency spectra were calculated for the entire time series consisting of 360 points using the mixed radix transform developed by SINGLETON (1967). The spectra for all heights were then averaged to produce a single

[3]On leave from the Max-Planck-Institut fur Aeronomie, Katlenburg-Lindau, West Germany.

C-4

spectrum characteristic of the troposphere and lower stratosphere. The result is shown in Figure 1. The spectrum shows a characteristic power law close to -0.80.

Separate average spectra were also calculated for the troposphere only, for the height range around the tropopause, and for the lower stratosphere up to 18 km. The average tropospheric frequency spectrum is very similar in terms of power level and spectral slope to the average spectrum for the entire height range. However the spectra in the tropopause region and lower stratosphere both show a considerably shallower slope near -0.2. RASTOGI and BEMRA (1985) have found a similar result for the frequency spectra of the horizontal velocities based on data from the Poker Flat radar, namely that the spectral slope decreases near the tropopause.

## 4. INERTIAL WAVES

The vertical velocity/frequency spectrum in the tropopause region shows a very pronounced peak at a period near 14 hrs, close to the inertial period. Such a peak is not evident in either of the other two height ranges. The wave structure is clearly evident in the reflectivity data as well (not shown) and the phase propagation indicates a wave source in the vicinity of the tropopause.

Although the peak is close to the inertial period, the actual wave period must be slightly smaller since a purely inertial wave would not be propagating vertically. Also, there would be no vertical velocity perturbation associated with a wave characterized by the inertial period.

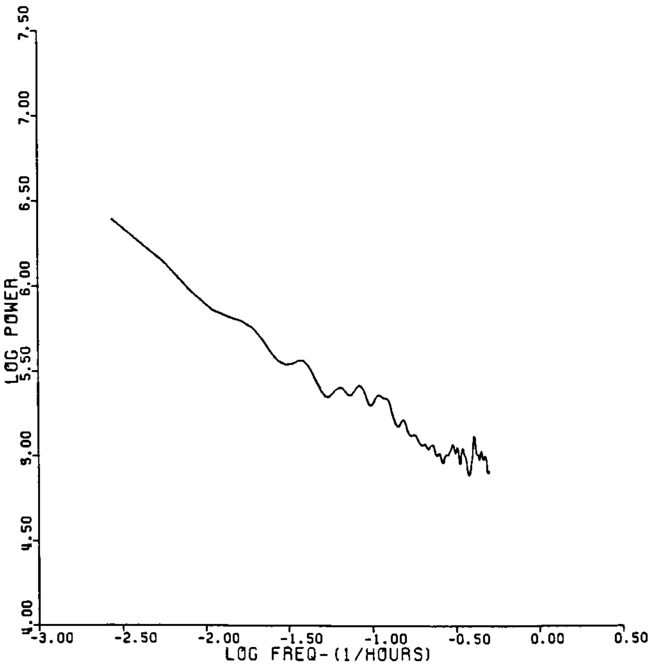


Figure 1. Average of log power spectrum for the atmosphere to 70 mb.

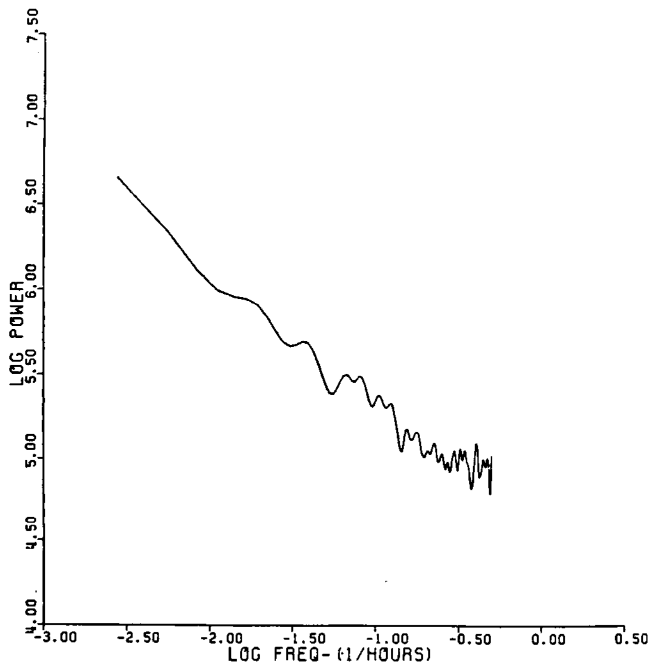


Figure 2. Average of log power spectrum for the troposphere to 230 mb.

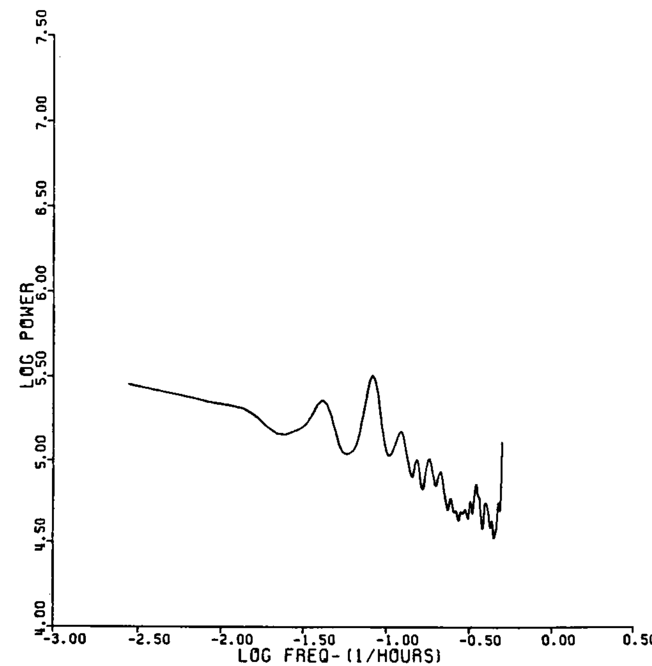


Figure 3. Average of log power spectrum around the tropopause at 230 mb.

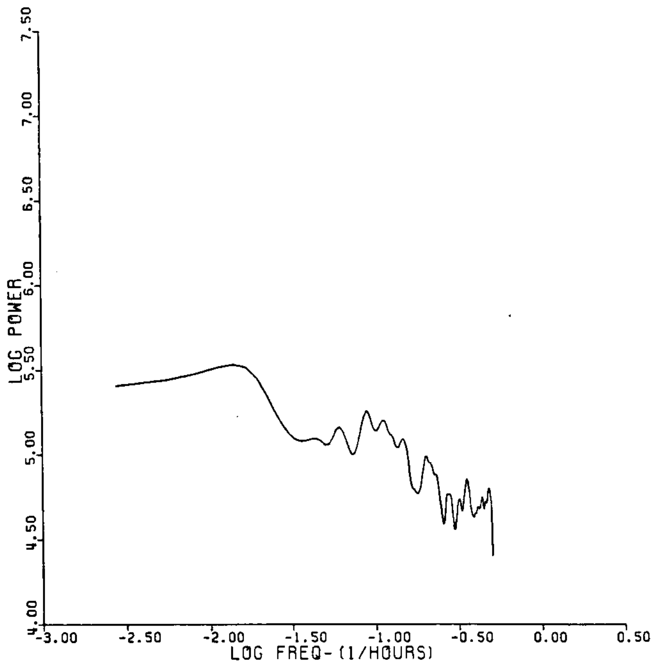


Figure 4. Average of log power spectrum for the stratosphere to 100 mb.

5. VERTICAL WAVE NUMBER SPECTRA

The 300-m height resolution of the data set is sufficient to produce meaningful vertical wave number spectra. The spectrum for each profile was calculated, and the average is shown in Figure 5. The spectral slope is close to -3/2 but much shallower than the slope of -5/2 expected from the GARRETT and MUNK (1975) predictions.

DISCUSSION

Our analysis of an extensive 15-day data set obtained with the SOUSY VHF radar has shown the slope of the vertical wave number spectrum of the vertical velocity to be close to -1.5, in agreement with the results of LARSEN et al. (1985) based on data from Arecibo, Puerto Rico. Also, the slope near -1 inferred by LARSEN et al. (1985) and BALSLEY and CARTER (1982) for the frequency spectrum of the vertical velocity at periods less than 1 hr has been shown to be characteristic of the vertical velocities in the troposphere out to periods of several days. However, the slope of the vertical velocity spectrum as a function of frequency is shallower near the tropopause and in the lower stratosphere.

There has been considerable discussion in the recent literature about the roles of gravity waves and two-dimensional turbulence in explaining the observed power spectra at scales characteristic of the mesoscale (GAGE, 1979; VANZANDT, 1982; LILLY, 1983; LARSEN et al., 1985). The observed vertical velocity spectral slopes may provide an impetus to further theoretical development of the various ideas. The observed slopes do not agree with the predictions of the GARRETT and MUNK (1975) spectrum which lead to a slope of

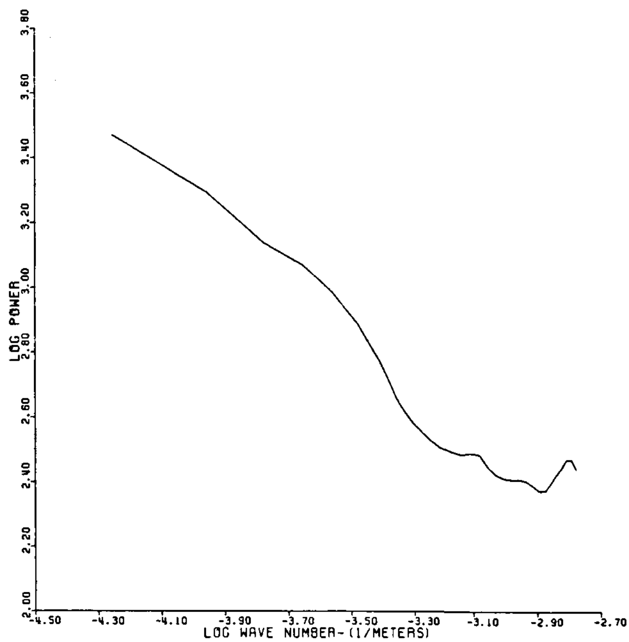


Figure 5. Average of log power spectrum for the atmosphere to 70 mb.

zero or +1/3 for the vertical velocity as a function of frequency and a slope of −5/2 for the vertical velocity as a function of vertical wave number. Since the theory for quasi-two-dimensional turbulence has not been developed sufficiently to include the effects of vertical velocities, no comparison can be made with the observations.

REFERENCES


Balsley, B. B., and D. A. Carter (1982), The spectrum of atmospheric velocity fluctuations at 8 km and 86 km, Geophys. Res. Lett., 9, 465-468.

Gage, K. S. (1979), Evidence for a $k^{-5/3}$ law inertial range in mesoscale two-dimensional turbulence, J. Atmos. Sci., 36, 1950-1954.

Garrett, C., and W. Munk (1975), Space-time scales of internal waves: A progress report, J. Geophys. Res., 80, 291-297.

Larsen, M. F., R. F. Woodman, T. Sato, and M. K. Davis (1985), Power spectra of vertical velocities in the troposphere and lower stratosphere observed at Arecibo, Puerto Rico, submitted to J. Atmos. Sci..

Lilly, D. K. (1983), Stratified turbulence and the mesoscale variability of the atmosphere, J. Atmos. Sci., 40, 749-761.

Rastogi, P. K., and R. S. Bemra (1985), Preliminary report on the analysis of 40 days of Poker Flat ST data for January and June 1984, Report WGR-85-3, Department of Electrical Engineering and Applied Physics, Case Western Reserve University, Cleveland, Ohio.

Singleton, R. C. (1967), On computing the fast Fourier transform, Commun, ACM, 10, 647-654.

VanZandt, T. E. (1982), A universal spectrum of buoyancy waves in the atmosphere, Geophys. Res. Lett., 9, 575-578.