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3.7.2 THE FREQUENCY SPECTRUM OF C_n^2 FROM MST RADAR DATA

G. D. Nastrom

Control Data Corporation
Minneapolis, MN 55440

INTRODUCTION

In a recent study (NASTROM et al., 1986), the variability of the refractivity turbulence structure constant, C_n^2, was examined using observations from the ST/MST radars at Poker Flat, Alaska, and Platteville, Colorado. Variations of C^2 with height, season, and weather conditions were examined. Also, the autocorrelation function and the frequency distribution of C_n^2 were studied, and it was shown that C_n^2 follows a log-normal frequency distribution. The interested reader is referred to that paper for details. One of the more tentative results given in that paper is a first look at the spectrum of log C_n^2 as a function of frequency at Poker Flat. This spectrum, shown in Figure 1, appears to obey a power law relation with frequency, $P(F) \sim F^k$, with k near -5/3 at periods between about 4 hours and 6 days, and with k near -1 at shorter periods. Power law behavior of a spectrum often helps us to infer the underlying dynamics which give rise to this spectrum, and it is thus of some concern to establish further confidence in the spectral shape. For example, is the shape displayed in Figure 1 representative of other altitudes or locations, and does it change with season or background weather conditions. The purpose of this contribution is to address these questions.

SPECTRAL ANALYSIS RESULTS

Figure 2 shows the spectra of C_n^2 in the troposphere at Poker Flat (8.2 km) and Platteville (7.3 km) over the range of periods from about 9 minutes to 24 hours. These results are based on a larger data set than that used in Figure 1 as indicated by N in the figure. N is the number of 9-hour or 36-hour data segments used to estimate the spectrum. The lag correlation method was used. The lines with slopes -5/3 and -1 have been added at the same coordinates as in Figure 1 to aid comparison. At both stations in Figure 2, the spectral shape is approximately the same as in Figure 1, with a change in slope found near the 2-4 hour period. The spectral amplitude at Platteville is higher than that at Poker Flat at periods less than about 2 hours. Note that all spectra show a markedly decreased slope at periods less than about 15 minutes. As discussed by NASTROM et al. (1986), this behavior may be due to noise or aliasing, or may arise from reduced spectral fidelity due to occasional gaps in the data (BAER and TRIBBIA, 1976).

Figure 3 shows the spectra at Poker Flat at 12.5 km for periods from about 9 minutes to 6 hours for summer (May-August) and winter (October-April). There is no obvious change with season, except that the spectral amplitude appears slightly higher in summer than in winter.

The results in Figures 1-3 strongly suggest that the shape of the spectrum of log C_n^2 is fairly universal, and shows little dependence on season, location, or across the tropopause. As a check on possible synoptic weather dependence, the mean spectrum was formed for the 97 cases when the background wind speed near the tropopause was in excess of 21 m/s^{-1}. The results, not shown, are nearly identical to the winter results in Figure 3 and show that strong background wind does not distort the spectrum.

The -1 slope region of the spectrum was not anticipated, and warrants further attention. Current theories of gravity wave motions and quasi-two-

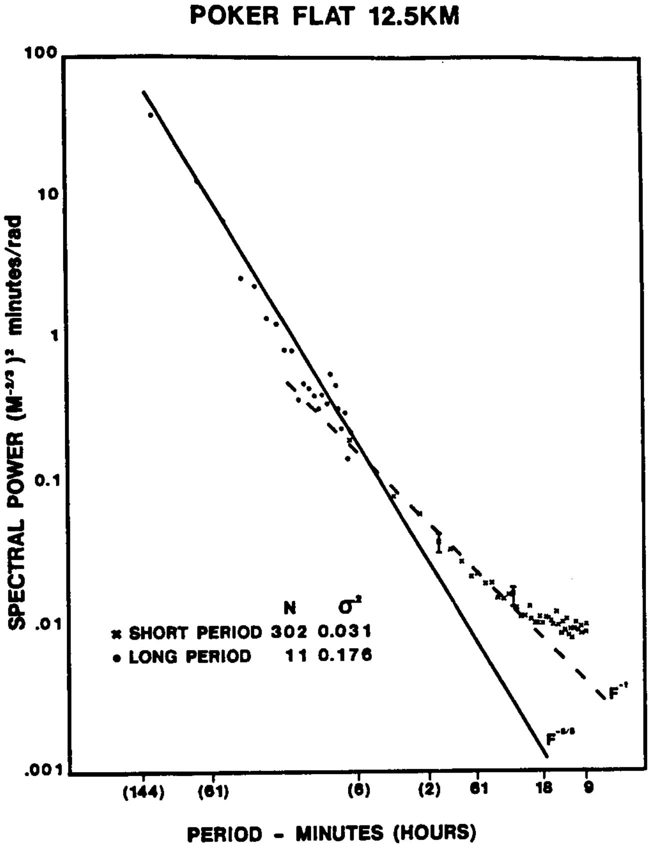
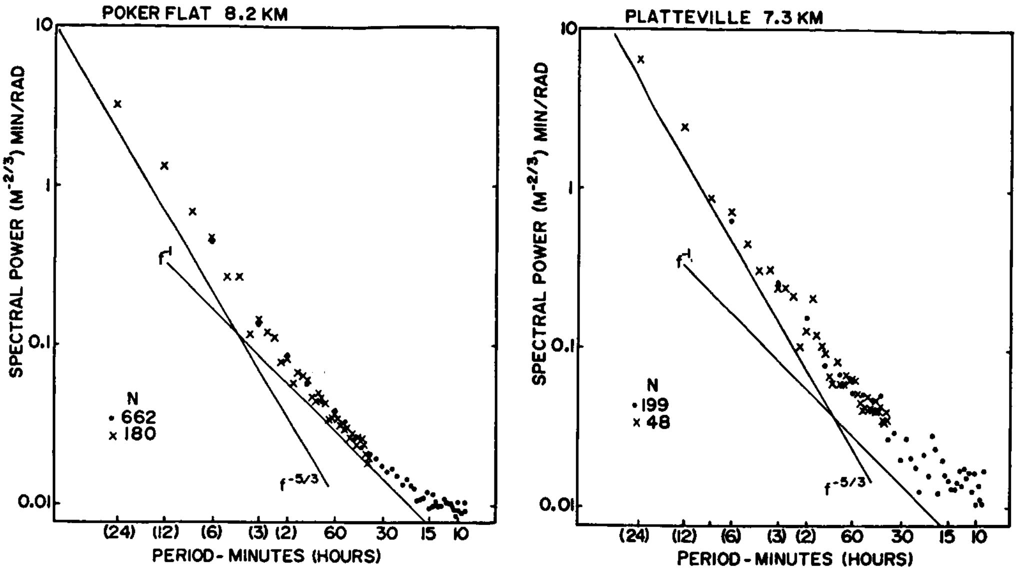


Figure 1. The variance power spectrum of log C_n^2 at 12.5 km at Poker Flat (NASTROM et al., 1985).

dimensional turbulence do not predict a -1 slope region. However, due to its robust statistical character and firm observational basis, it cannot be ignored. Beside the present results, a -1 slope region was noted by BALSLEY and CARTER (1982) in the spectrum of radial velocities. Also, a -1 slope region was found by NASTROM and GAGE (1983) in the wave number spectrum of winds encountered by airplanes during and immediately after encounters with moderate turbulence. HARRINGTON and HEDDINGHAUS (1974) noted a -1 slope in winds near the surface at periods below about 2 hours. Finally, the spectrum of ozone in the upper troposphere shows a -1 slope region at wavelengths less than about 100 km as found by NASTROM et al. (1985), and as shown in detail in Figure 4. These results are based on data collected during GASP from aircraft and represent the average spectrum over N flight segments, where N is given in the figure. Mean ozone values less than 150 ppbv or so are typical of the troposphere.

DISCUSSION

In summary, the shape of the frequency spectrum of log C_n^2 is fairly universal; showing a -5/3 slope region at long periods and a -1 slope region at periods below 4 hours or so. Other meteorological data have also shown a -1



a)

b)

Figure 2. Power spectrum of log C_n^2 (a) Poker Flat at 8.2 km, (b) Platteville at 7.3 km.

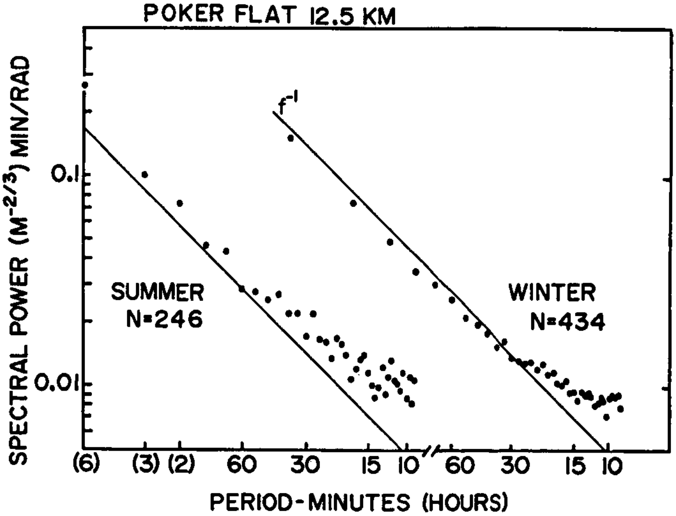


Figure 3. Power spectrum of log C_n^2 at 12.5 km at Poker Flat during summer (May-August) and winter (October-April), over the range of periods from about 9 minutes to 6 hours.

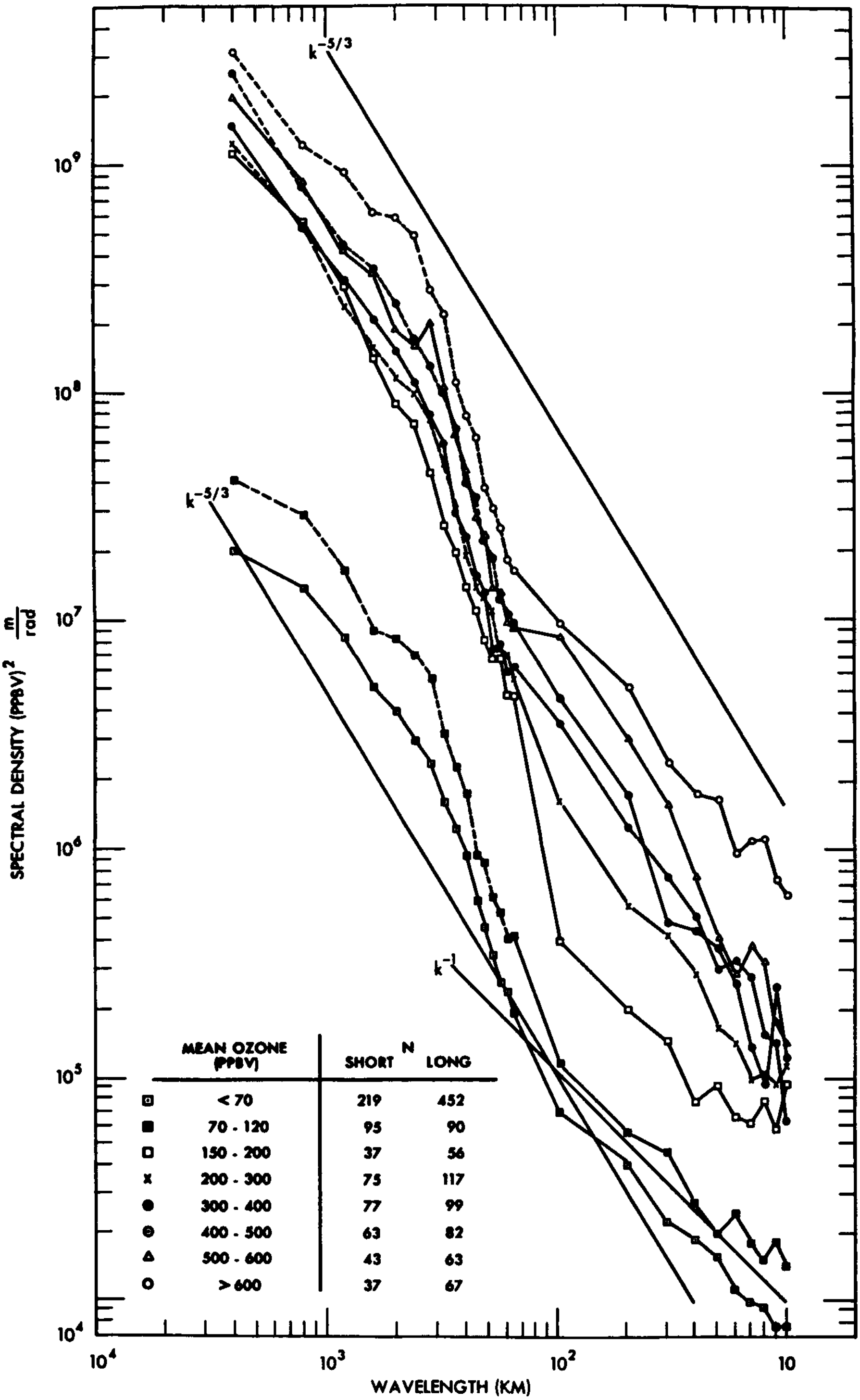


Figure 4. Power spectra of ozone from aircraft observations made during GASP, grouped according to the mean ozone along each flight segment.

slope region, indicating this signature is not specific to C_n^2. The -1 slope region is not anticipated by current theories. Important clues toward understanding it may be that it is associated with rather high levels of turbulence in the airplane wind data, and is the most apparent in ozone near the tropopause where folding processes may contribute significantly to the variance of ozone. LILLY (1983) predicted that two-dimensional decay spectra propagate in wave number space with the wave number and amplitude of the spectral peak following an approximately k^{-1} curve. When many such events are superposed, it is presumed that the net spectrum follows $k^{-5/3}$. However, it may turn out that when intense individual events are combined, as done here, the average spectrum retains a k^{-1} dependence. This issue will clearly require more attention in the future.

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