Low-Frequency Temperature Spectra from a 444 Meter Tower[1]

R. CRAIG GOFF

National Severe Storms Laboratory, NOAA, Norman, Okla. 73069

CLAUDE E. DUCHON

Dept. of Meteorology, University of Oklahoma, Norman 73069

2 July 1973 and 8 January 1974

ABSTRACT

Temperature spectra at three levels in the planetary boundary layer covering a range of periods from about 5 hr to 35 days are presented. Apart from the diurnal and semidiurnal oscillations, there are two identifiable period lengths of interest. One extends from about 3 to 7 days, the other from 7 to 20 days. Comparisons are made between these spectra and spectra from other investigators.

1. Introduction

From 9 December 1966 to 31 May 1967 temperature data were collected from the 444 m National Severe Storms Laboratory (NSSL) meteorological tower facility located 6 n mi north of Oklahoma City.[2] Eulerian temperature variance spectra have been computed for three tower levels, with the spectral range extending from a period of a few hours to periods greater than 35 days. Systematic variations with height and frequency are observed in the spectra.

The temperature probes were Yellow Spring Instrument Company resistance-type thermistors protected in aspirated shields. Two independent electrical circuits relayed temperature signals to the recording equipment. Circuitry details and data processing are discussed by Carter (1970) and by Goff and Hudson (1972).

Data were recorded on strip charts and hand digitized at 1-hr intervals (5-min means centered at each hour). Spectra for the nearly 6-month sample were computed for three levels on the NSSL tower: 2, 90 and 444 m. Some scattered missing data points were assigned values by linear interpolation during steady-state conditions or by fitting a polynomial determined from hourly mean temperatures for the month during unsteady periods (i.e., morning or evening transition). No end point discontinuities occurred when the latter technique was used. One-day segments of the 6-month record were sampled at 10-sec intervals to test for aliasing. Their spectra show that aliasing is of no concern in the analysis that follows.

A seasonal trend as well as high-frequency "noise" are present at each of the three levels. The 2 m data are most affected by these low-frequency and high-frequency fluctuations. The band-pass filter shown in Fig. 1 is composed of two normal smoothing functions (see Holloway, 1958) designed to eliminate these unwanted oscillations. Limits of the 63% response are 4.8 hr and 37.5 days.

Fourier variance density spectra were calculated from the filtered data, then smoothed with a 3-point filter using weights 0.25, 0.50, 0.25 (the effective bandwidth becoming 0.000638 cycle hr^{-1}), and then the product of the variance density and frequency computed. Plotting this product versus logarithm of frequency results in an equal-area representation that allows comparison of variance at different scales.

2. Periodic fluctuations

The observations at each level in Fig. 2 show a sharp peak in variance at the 24-hr period, with the magnitude decreasing dramatically with height. On account of the spectral smoothing mentioned earlier, the total variance at the 24-hr period must necessarily also in-

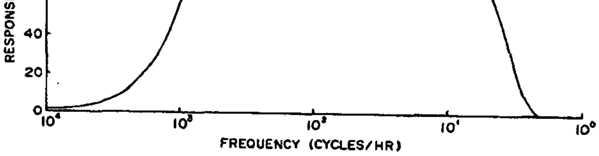

FIG. 1. Band-pass filter for spectra.

---

[1] The data collection program for this study was partially funded by the National Aeronautics and Space Administration.

[2] The tower is the television transmitter for WKY-TV (Oklahoma Broadcasting Company).

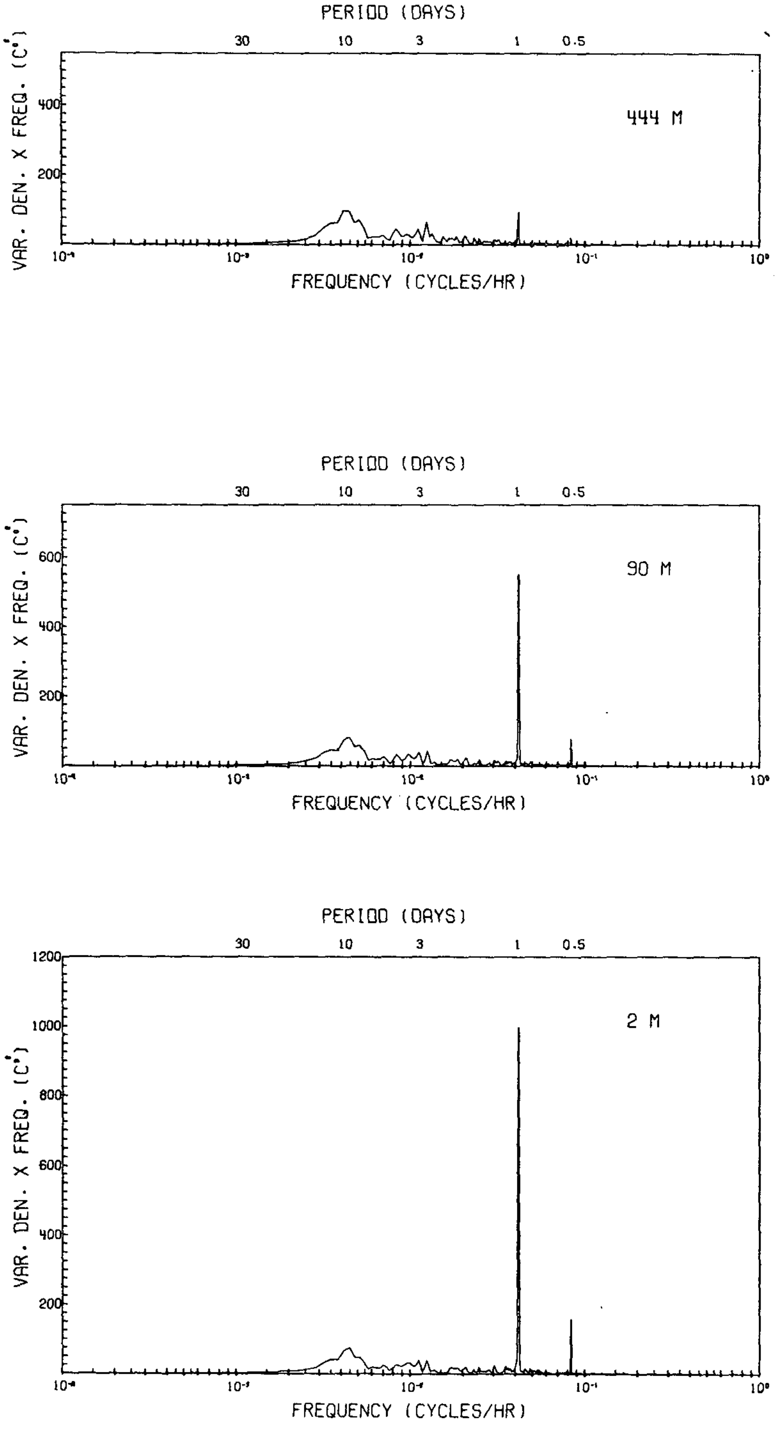

FIG. 2. Temperature spectra in the planetary boundary layer at 2, 90 and 444 m.

clude the two adjacent variances. If the total variance of each diurnal wave is equated to the variance of a sinusoid, the diurnal temperature amplitudes become 4.1C, 3.0C and 1.3C at 2, 90 and 444 m, respectively. The smaller but distinct peaks at the 12-hr periods correspond to semi-diurnal amplitudes 1.2C, 0.8C and 0.4C, again decreasing with increasing height.

There is a noteworthy contrast between the average diurnal vertical temperature variation in the tower layer and the average diurnal vertical wind variation observed by Crawford and Hudson (1973). For example, the amplitude of the diurnal wind speed oscillation at 444 m is three times that at 7 m, corresponding to level 6 and the surface level, respectively, in Fig. 3.

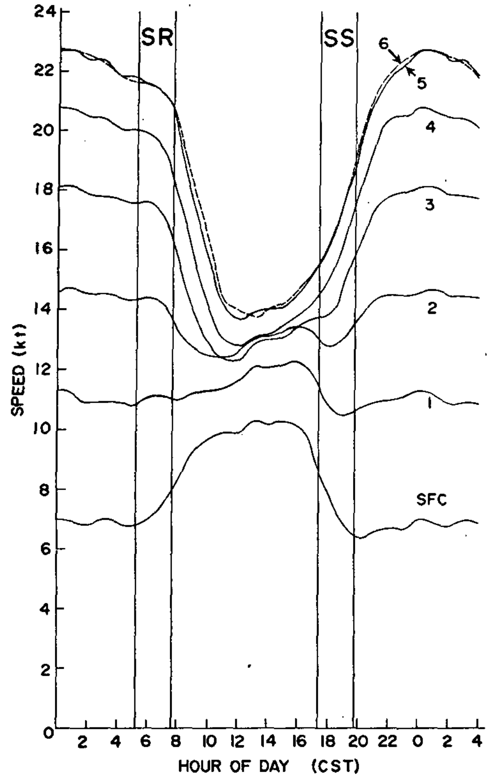

FIG. 3. Diurnal variation of mean wind speeds on an annual basis. Sunrise and sunset are indicated by vertical lines (from Crawford and Hudson, 1973).

The temperature data show exactly the opposite behavior. Of course, the diminution of the diurnal temperature oscillation with height is because both the daytime net absorption and nighttime net emission of radiation are maximum at the surface. The diurnal wind speed variation in the lower levels is primarily a consequence of the daily fluctuation in the magnitude of the downward transport of horizontal momentum. At the upper levels this fluctuation is greatly overshadowed by what appears to be the low-level jet phenomenon (Blackadar, 1957; Gerhardt, 1962), a diurnal wind feature not significantly affecting the amplitude of the temperature wave.

3. Aperiodic fluctuations

As can be seen at all levels in Fig. 2 there is one period range from about 7 to 20 days (0.006 to 0.002 cycles hr^{-1}) displaying increasing variance from both ends to a maximum at approximately 10 days (0.004 cycle hr^{-1}) and another period range from 3 to 7 days (0.014 to 0.006 cycle hr^{-1}). In contrast to the former period range, the variance is lower and its distribution flatter. The variance at 444 m is noticeably larger than that at 2 and 90 m, the variance at the latter two levels differing little from each other. In concordance with Kolesnikova and Monin (1965), we shall refer to the period ranges, respectively, as the planetary scale, associated with Rossby-type waves, and the synoptic scale, associated with the passage of frontal systems.

In contrast to the results of the above authors and also Griffith *et al.* (1956), there is larger variance at the planetary scale compared with the synoptic scale. One explanation for this difference may be the reduction in the number of frontal passages, especially in the spring months in Oklahoma (35N) compared with Pennsylvania (41N) and the USSR stations (48 and 54N). In addition, these references cite a synoptic maximum near a period of 4 days. The gradual reduction in the occurrence of frontal passages in Oklahoma would spread their variance over a broad period length. Finally, the peak in variance around 10 days is also present in the spectra shown by Griffith *et al.* (1956).

4. Concluding remarks

In Oklahoma, for heights up to at least 450 m, the diurnal amplitudes of temperature and wind speed vary inversely with height. Temperature spectra in the period range 3 to 7 days do not show a 4-day peak found in data from higher latitudes. On the other hand, a peak in the variance spectra around 10 days is in agreement with the results from at least one other higher latitude station.

REFERENCES

Blackadar, A. K., 1957: Boundary layer wind maxima and their significance for the growth of nocturnal inversions. *Bull. Amer. Meteor. Soc.*, **38**, 283–290.

Carter, J. K., 1970: The meteorologically instrumented WKY-TV tower facility. ESSA Tech. Memo. ERL NSSL-50, 40 pp.

Crawford, K. C., and H. R. Hudson, 1973: The diurnal wind variation in the lowest 1500 ft in Central Oklahoma: June 1966–May 1967. *J. Appl. Meteor.*, **12**, 127–132.

Gerhardt, J. R., 1962: An example of a nocturnal low-level jet stream. *J. Atmos. Sci.*, **19**, 116–118.

Goff, R. C., and H. R. Hudson, 1972: The thermal structure of the lowest half kilometer in Central Oklahoma: December 9, 1966–May 31, 1967. NOAA Tech. Memo. ERL NSSL-58, 53 pp.

Griffith, H. L., H. A. Panofsky and I. van der Hoven, 1956: Power spectrum analysis over large ranges of frequency. *J. Meteor.*, **13**, 279–282.

Holloway, J. L., 1958: Smoothing and filtering of time series and space fields. *Advances in Geophysics*, Vol. 4, New York, Academic Press, 351–389.

Kolesnikova, V. N., and A. S. Monin, 1965: Spectra of meteorological field fluctuations. *Izv. Atmos. Oceanic Phys.*, **1**, 653–669.