GBT MEMO 126

The Statistics of Wind Speed near the GBT

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1 Introduction.

The wind causes antenna pointing errors and reduces antenna efficiency by deforming the reflector surface. A recent analysis of the GBT (GBT Memo 119, Norrod 1995) indicates that the surface rms attributable to wind is slightly more than 9 mils (0.2 mm) when the wind speed is six meters per second gusting to seven meters per second. In addition to similar estimates of surface rms as a function of wind speed, one would like to know what fraction of the time does the wind speed exceed a certain value. For the purposes of scheduling high frequency observations, one would also like to know both the time of year and the time of day when the wind speed is typically the smallest. In this memorandum I attempt to answer these questions with an analysis of wind speed data which have been collected in Green Bank.

2 Data Acquisition and Analysis.

The wind speed data were taken with two anemometers located on a tower in an open field. The tower is south and west of the GBT at a distance of about 1500 feet. The heights of the anemometers are 90 feet and 158 feet above grade. The anemometers were calibrated before they were installed on the tower. Data from the anemometer located at 90-feet were recorded from February 1991 until June 1994 when it was struck by lightning. This anemometer was just recently returned to service. Data from the anemometer located at 158 feet have been recorded since December 1991. The data are collected as part of routine interferometer operations at the interferometer control building.

The wind speed measured at each anemometer is sampled about once every second. Wind direction is not recorded. Individual data points are not time-tagged, but are binned into histograms. The histograms have 25 bins spread over a range of 100 miles per hour (mph) in wind speed, giving a bin resolution of four mph. The data are accumulated in a single histogram for 15 minutes. Each 15-minute histogram is tagged with both the day of the year and the time of day, and then stored on computer disk for off-line analysis. A differential wind speed is computed in real time by subtracting the wind speed at 90 feet from that at 158 feet. The differential wind speed is also stored in 15-minute histograms. The bin resolution of the difference histograms is one mph.

Single histograms (probability distributions) of wind speed at both 158 feet and at 90 feet were constructed by combining all of the appropriate 15-minute histograms. Cumulative distributions were then computed from the histograms. Histograms were also constructed for months of the year and specific times of day using the time-tag information. In order to make some type of quantitative comparison of histograms, a pseudo-mean, $< v >$, and a pseudo-variance, σ_{v}^2, were computed for each histogram. Hereafter, these quantities shall be referred to as the mean and the variance, and are defined by

$$< v >= \frac{1}{N} \sum_{i=1}^{M} N_i \bar{v}_i \tag{1}$$

$$\sigma_{\mathrm{v}}^2 = \frac{1}{N} \sum_{i=1}^{M} N_i \bar{v}_i^2 - < v >^2 \tag{2}$$

where N is the total number of samples in a histogram, $M = 25$ is the number of bins in the histogram, N_i is the number of samples in a given bin, and $\bar{v}_i = (2, 6, 10 \ldots 98)$ is the bin average.

3 Results.

Figures 1a and 1b are, respectively, the probability and cumulative distributions of the wind speed measured at a height of 158 feet. The ordinates of the figures are in units of percent of the total number of samples. The mean of the probability distribution is 6.3 mph, and the standard deviation is 4.3 mph. The cumulative distribution indicates that 97.2 percent of the samples have values less than 16 mph (7.2 meters per second). The distributions of wind speed at 90 feet (Figures 2a and 2b) are similar in appearance to those in Figure 1. The mean and standard deviation of wind speed at 90 feet are 5.4 mph and 3.8 mph, respectively. 98.6 percent of the samples in the distribution have values less than 16 mph.

A single histogram of differential wind speed (Figure 3) was also computed by combining all of the appropriate 15-minute histograms. Figure 3 indicates that the wind speed at 158 feet is typically about one mph greater than the speed at 90 feet. A significant fraction of these samples have values less zero, implying that the wind speed is not always greater at the higher elevation. The dashed line in the histogram reflects the uncertainity in how these data were binned at the time they were recorded. The data with values between plus and minus one were assigned to the central bin. Thus the central bin originally had a resolution of two mph instead of one mph like the other bins in the histogram. To display a more realistic histogram of differential wind speed, the central bin was divided into two subbins of one mph resolution. The number of samples, N_{0-1}, possessing wind speeds in the range $0 \leq v < 1$ mph was estimated with

$$N_{0-1} = N_{\mathrm{c}} \frac{N_{v \geq 1}}{N - N_{\mathrm{c}}} \tag{3}$$

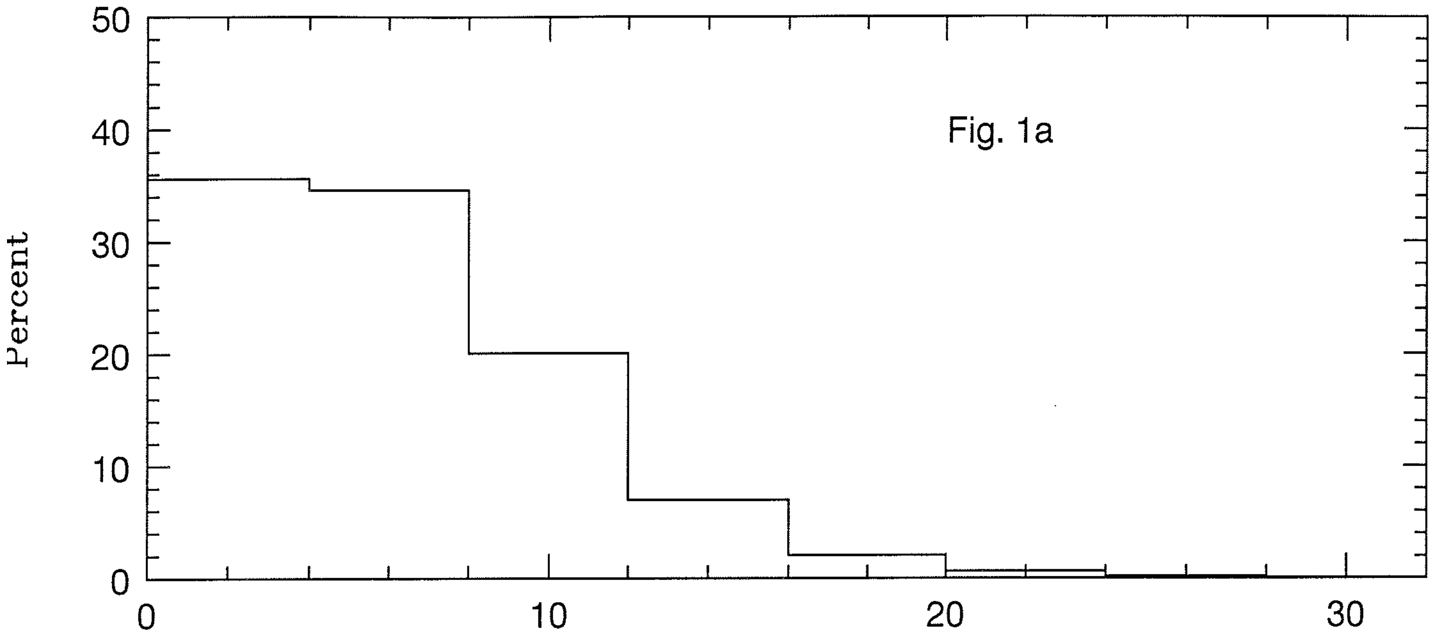
where N_{c} is the number of samples in the central bin and $N_{v \geq 1}$ is the number of samples with wind speeds greater than or equal to one mph. The number of samples possessing wind speeds in the range $-1 \leq v < 0$ was estimated in a similar way.

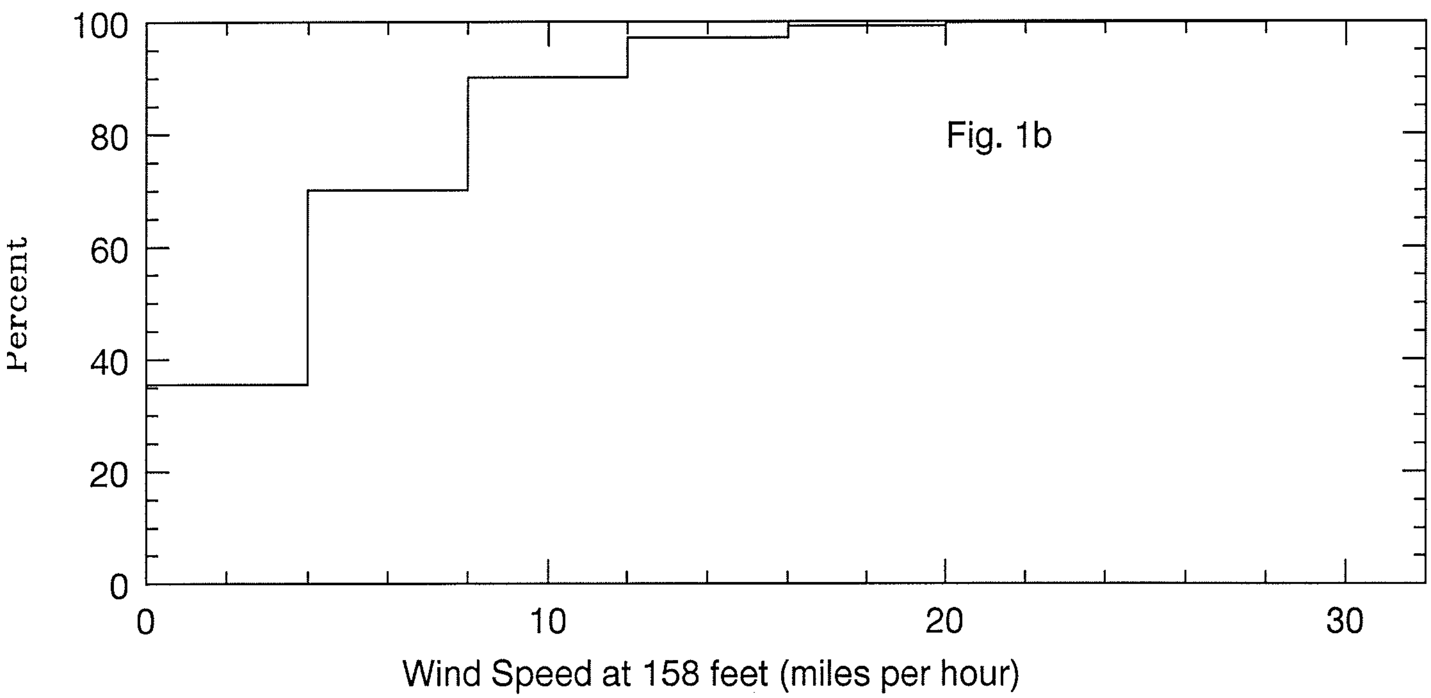
Figure 4 shows the mean and standard deviation of wind speed at 158 feet computed for each month of the year. The mean and standard deviation computed from the entire data set are shown by the horizontal lines in the figure for comparison. A similar plot is shown for the wind speed at 90 feet in Figure 5. In both cases, the wind speed is typically greatest in the month of March. The wind speed is typically at its lowest value in August. The mean and standard deviation of wind speed appear to be correlated, implying that fluctuations in wind speed are greatest when the wind speed is large.

Figure 6 shows the mean and standard deviation of wind speed at 158 feet as a function of the time of day. The mean wind speed is roughly constant at about 4.8 mph from local midnight (05:00 UT) to local sunrise (11:00 - 12:00 UT). The peak in the mean wind speed is 9.0 mph and occurs early in the afternoon (19:00 UT).

4 Conclusions.

The results of this analysis are about what one would expect. The wind speed near the GBT is typically low and usually increases with increasing elevation. Fluctuations in wind speed appear to be greatest when the wind speed is large. High frequency observations should be scheduled from local midnight to local sunrise to minimize the impact of wind upon antenna pointing and efficiency. On the basis of wind speed alone, the best winter months for high frequency observing are December and January.


50
40
30
20
10
0
Percent
0
10
20
30
Fig. 1a


100
80
60
40
20
0
Percent
0
10
20
30
Fig. 1b
Wind Speed at 158 feet (miles per hour)

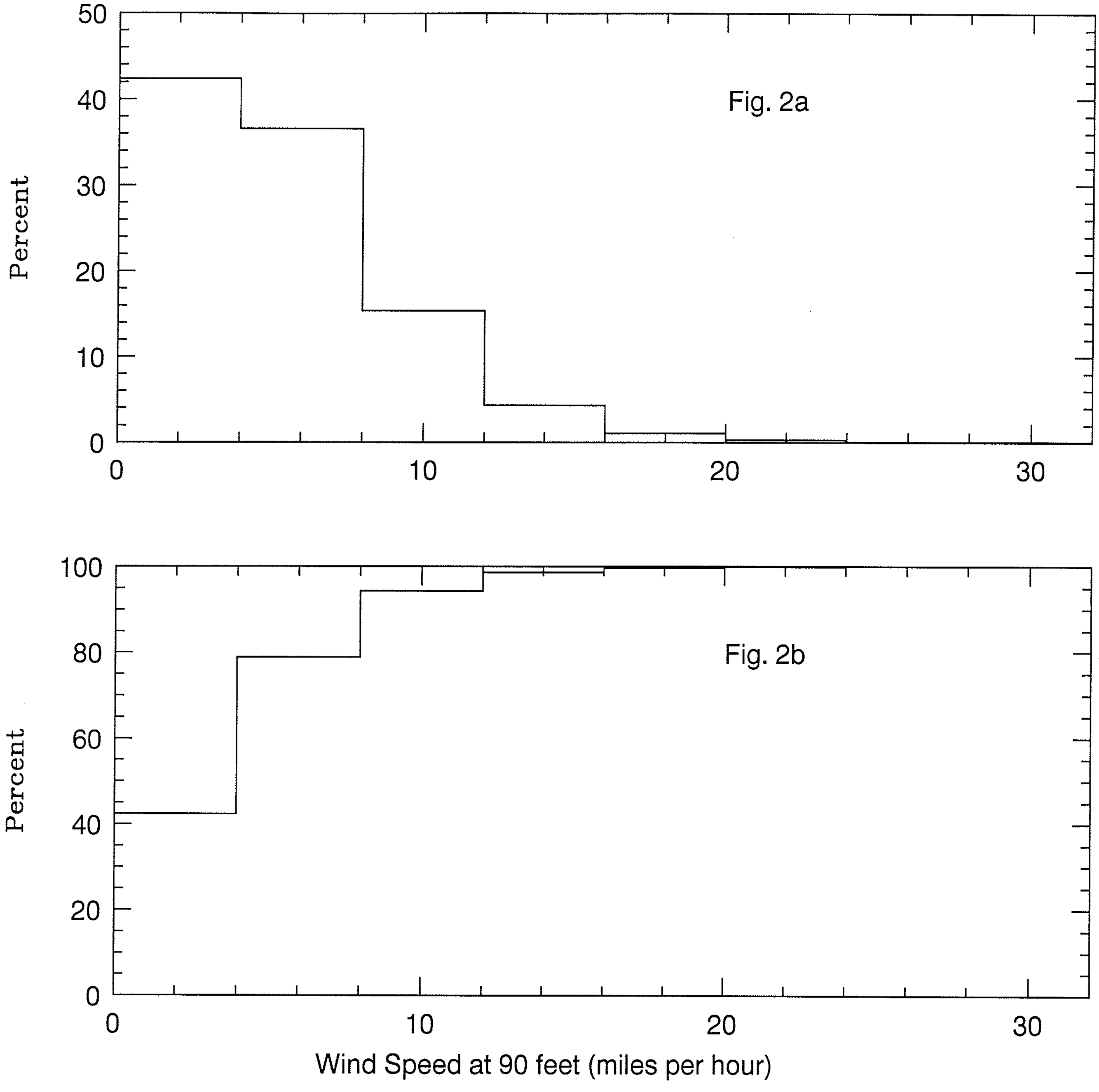


Fig. 2a
Percent
0
10
20
30
40
50
0
10
20
30
Fig. 2b
Percent
0
20
40
60
80
100
0
10
20
30
Wind Speed at 90 feet (miles per hour)

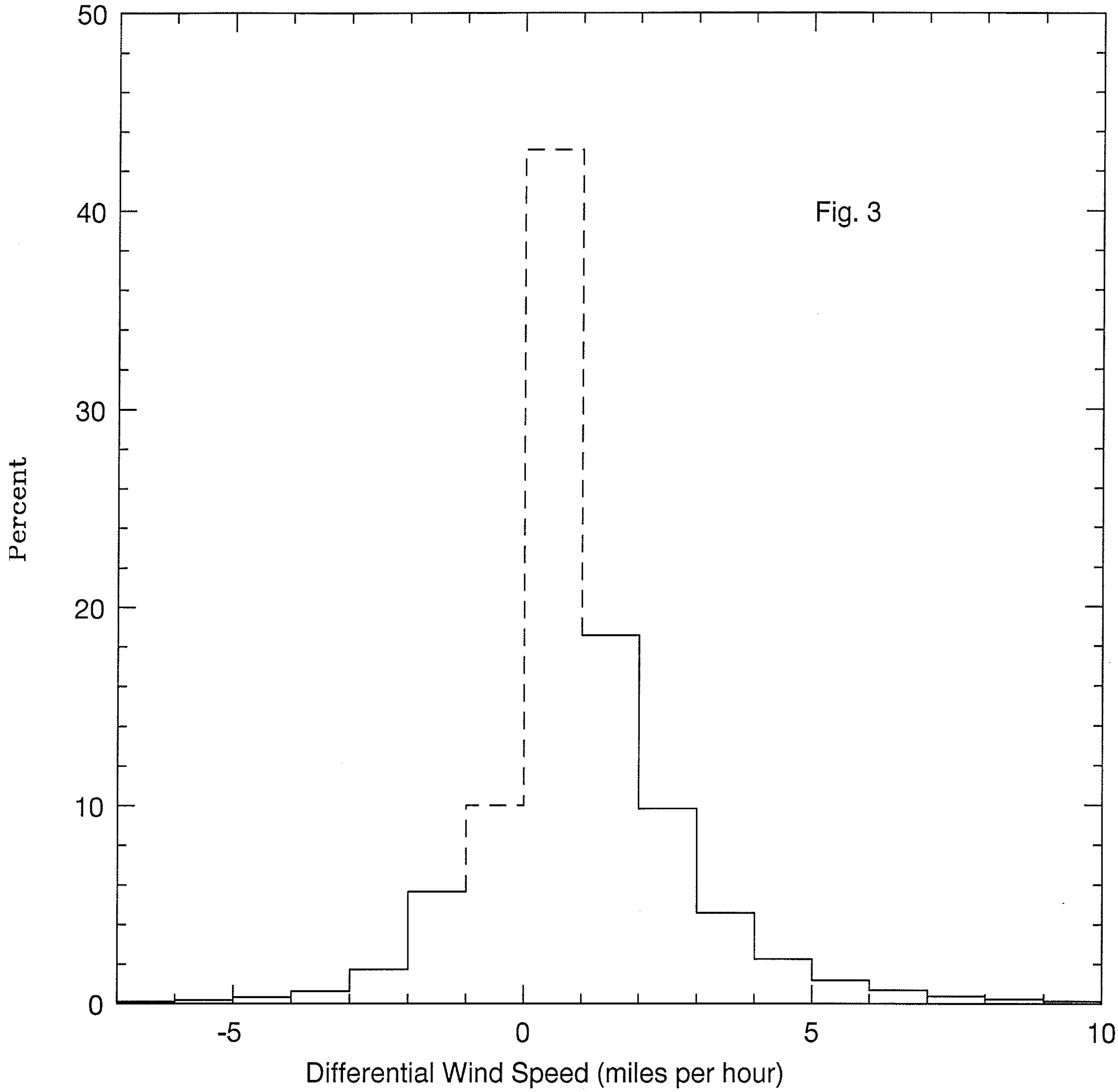


Fig. 3
Percent
50
40
30
20
10
0
-5
0
5
10
Differential Wind Speed (miles per hour)

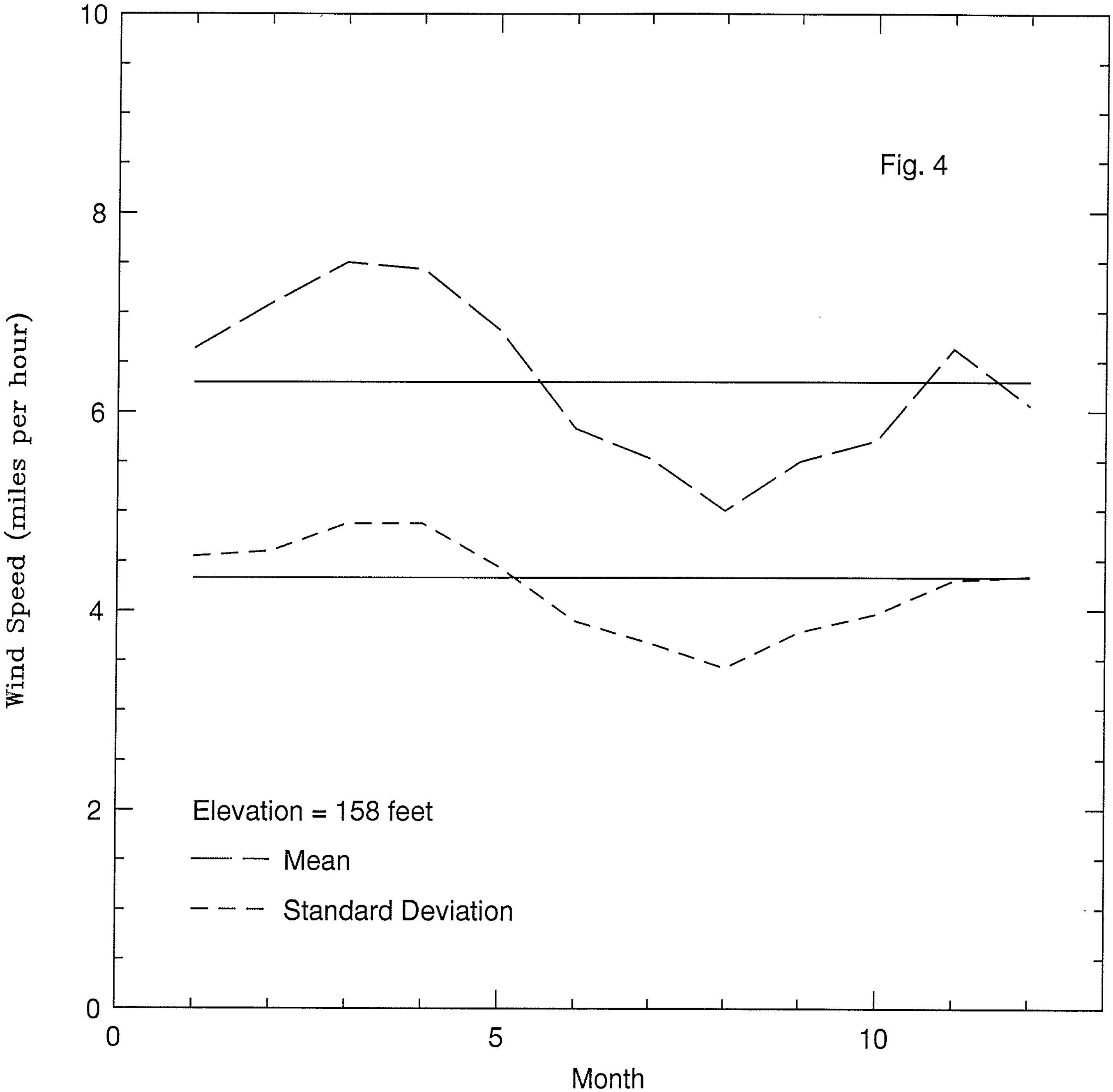


Fig. 4
Wind Speed (miles per hour)
Month
Elevation = 158 feet
Mean
Standard Deviation
0
2
4
6
8
10
0
5
10

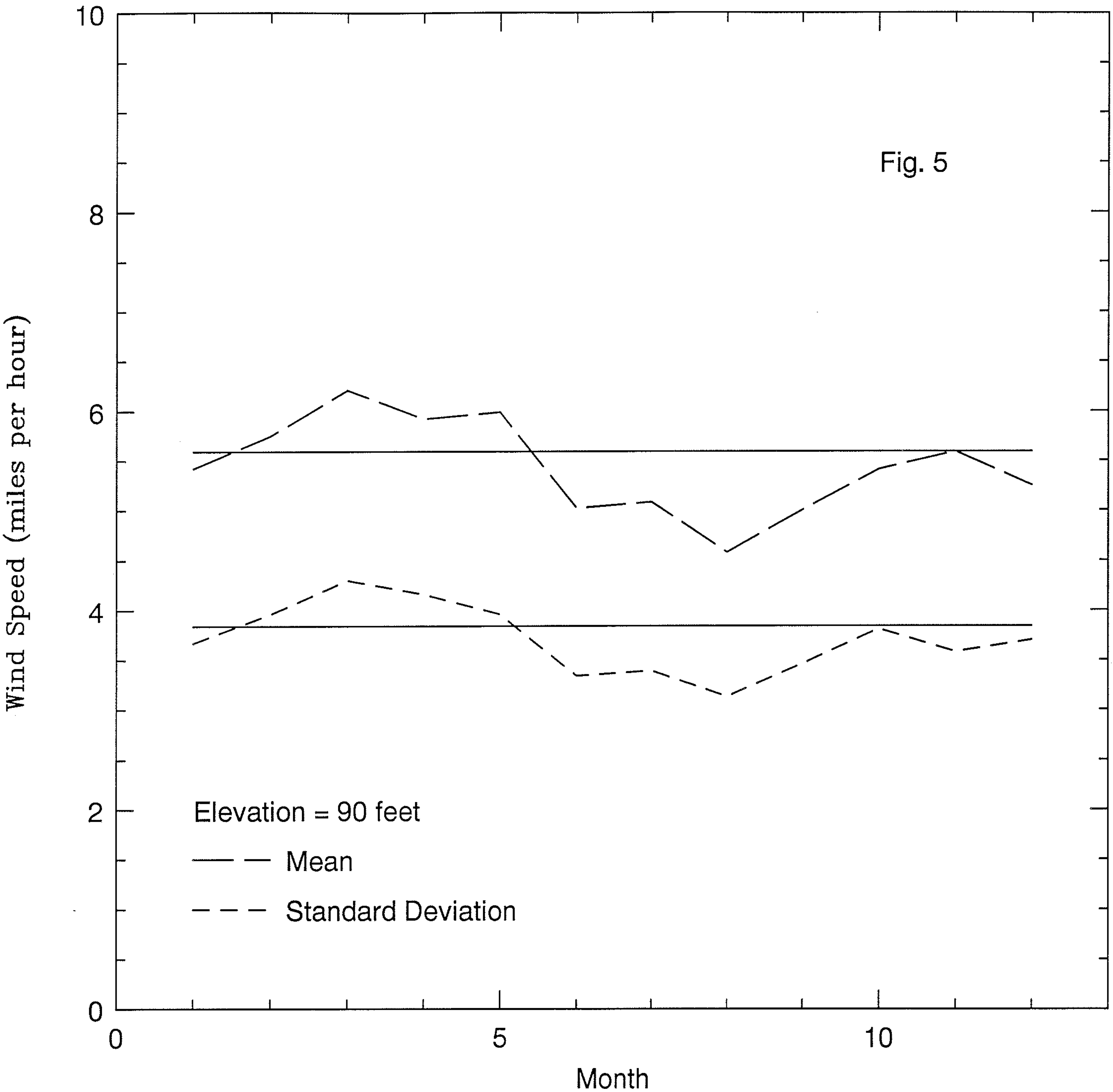
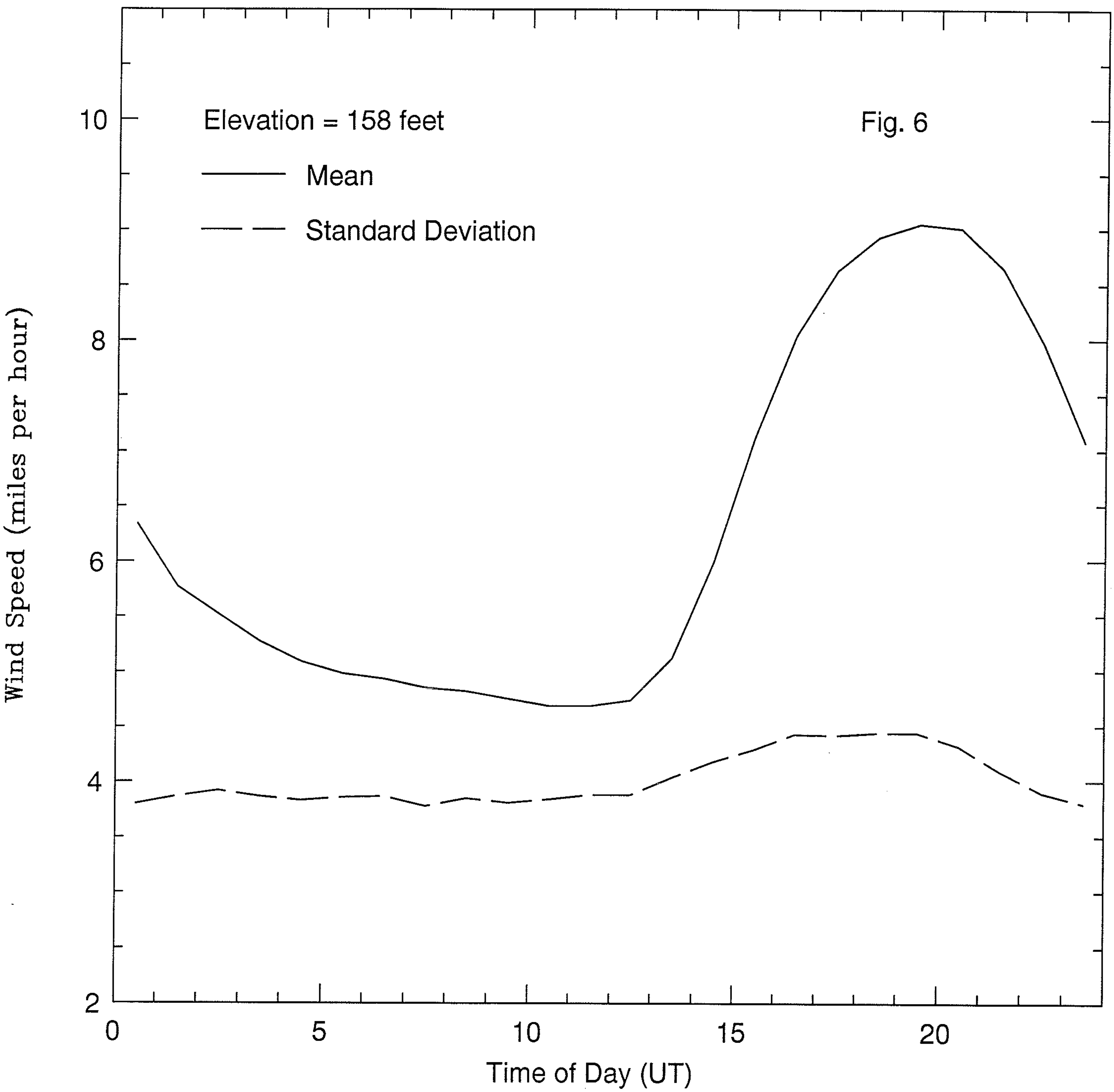


Fig. 5
Elevation = 90 feet
Mean
Standard Deviation
Wind Speed (miles per hour)
Month
0
2
4
6
8
10
0
5
10


Elevation = 158 feet
Fig. 6
Mean
Standard Deviation
Wind Speed (miles per hour)
Time of Day (UT)
10
8
6
4
2
0
5
10
15
20