JPL PUBLICATION 81-17

Wind Speed Statistics for Goldstone, California, Anemometer Sites

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The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

ABSTRACT

The results of an exploratory wind survey at the JPL Goldstone, California, antenna complex are summarized statistically for possible application to future windmill designs. Data were collected at six locations from a total of ten anemometers. Statistics include means, standard deviations, cubes, pattern factors, correlation coefficients, and exponents for power law profile of wind speed. Curves presented include mean monthly wind speeds, moving averages, and diurnal variation patterns. Results indicate that three of the locations have sufficiently strong winds to justify consideration as candidate windmill sites.

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SECTION I

INTRODUCTION

This report represents the results of an exploratory wind survey at the JPL Goldstone, California, antenna complex to determine statistics of wind speed characteristics for possible application to future windmill designs. Goldstone wind speeds were examined previously for windmill applications in Wind Power Prediction Models.[1] In that report, Goldstone wind records were taken primarily from sets of data recorded from 1966 to 1968 at the Mars antenna location. Five additional locations were identified for consideration as possible windmill sites, and a few days of wind speed data for these locations were also analyzed (October 1974 through March 1975). This report covers data that were obtained from continuing measurements made in the period from October 1974 through August 1976 at anemometer towers at the same six locations, shown in Figure 1-1.

The six tower locations are listed below:

(1) The Mars tower (Sites 1 and 2) is near the center of a relatively flat area of several hundred meters (minimum dimension). The data for the 100-foot anemometer here were chosen as a reference for comparison of wind speeds at other sites because of the substantial amount of wind data available from earlier measurements at this anemometer height. Although this area is readily accessible and could accommodate a large number of windmills, the anticipated moderate wind speeds and the proximity to the Mars antenna are major disadvantages for using this location as a candidate windmill site.

(2) The Billboard Hill tower (Sites 3 and 4) was recommended by personnel who, as the result of several years of observation, believe this to be the windiest place in the complex.

(3) The WV tower (Sites 5 and 6) is near the center of a broad, flat area which would be suitable logistically for the placement of a large number of windmills.

(4) The Airport tower (Site 7) is located in an area similar to the WV tower, with equivalent logistical advantages.

(5) The Western Ridge tower (Sites 8 and 9) is on a crest thought to be perpendicular to the direction of the stronger local winds and was selected in anticipation of high wind speeds enhanced by a ridge effect.

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[1] Wind Power Prediction Models, Technical Memorandum 33-802, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 15, 1976.

(6) The Echo tower (Site 10) is near the Echo antenna and was selected for the expected combination of reasonably high wind speeds and logistic feasibility for windmill construction.

Except for the Mars site, the towers were at locations where windmills would not interfere with radar beams from existing antennas.

The basic component of the Goldstone wind measuring system, designed and installed by Meteorological Research, Inc. (MRI), includes an MRI Model 1091-3 Chart Recorder and an MRI Model 1022 Wind Set. One or two Wind Sets, which consist of a 3-cup anemometer and a wind vane, were installed on each tower. Table 1-1 lists the anemometer site numbers, the anemometer heights, as well as the tower locations and numbers.

For each anemometer, the instantaneous wind speeds recorded on the strip charts were reduced by hand to average hourly wind speed by estimating the mean of a 10-minute interval centered on each hour. The hourly data were then coded and processed by digital computer to compute the statistics analyzed in this report.

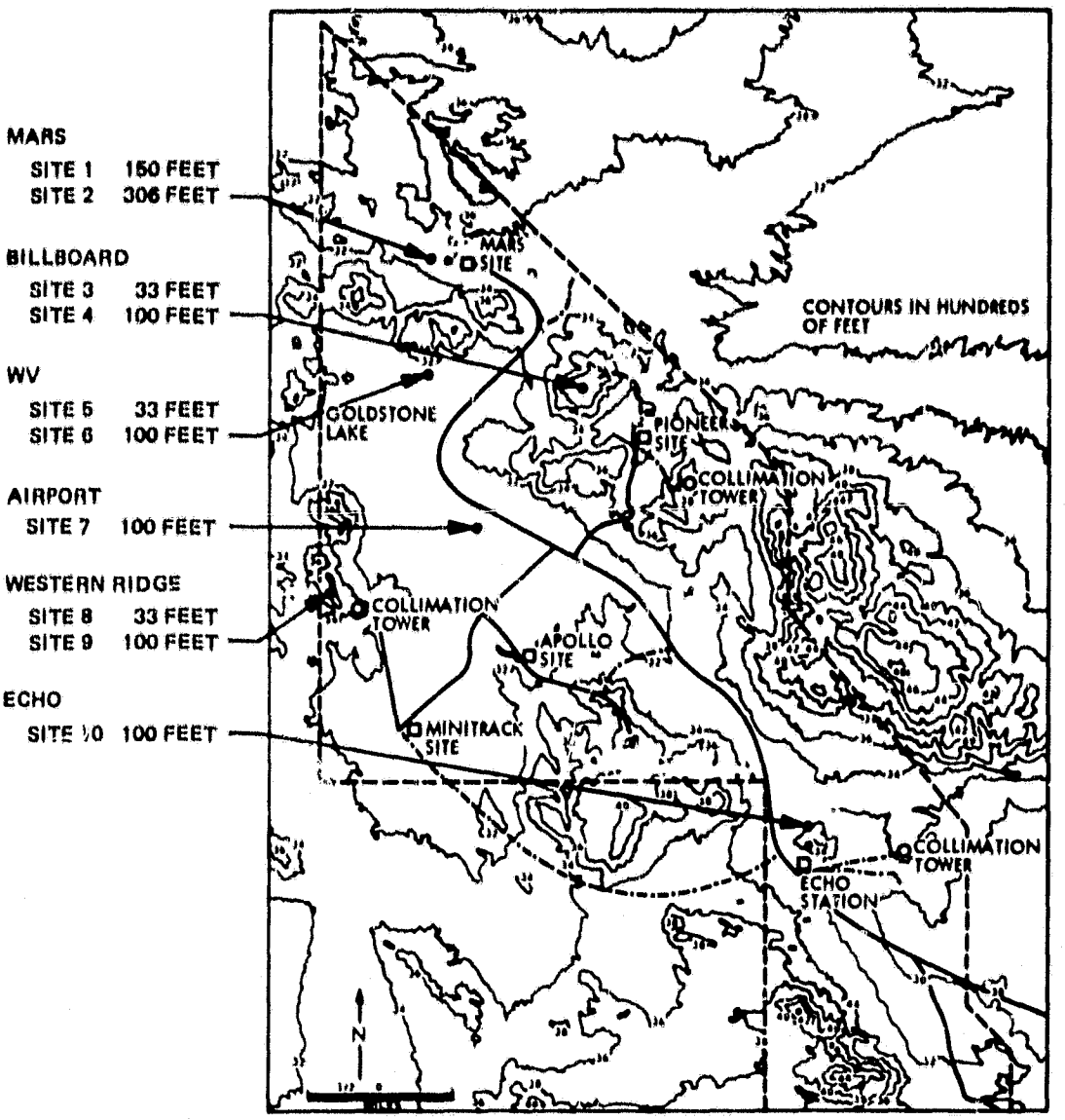


Figure 1-1. Geographic Location of the Goldstone Anemometer Sites

Table 1-1. Anemometer Locations

Anemometer			Tower	
Number	Height, feet	Elevation Above Mean Sea Level, feet	Location	Number
1[a]	150	3280	Mars	1
2	306			
3	33	4108	Billboard Hill	2
4	100			
5	33	3045	WV	3
6	100			
7	100	3020	Airport	4
8	33	3430	Western Ridge	5
9	100			
10	100	3574	Echo	6

[a]Reference anemometer.

SECTION II

PLOTS OF MONTHLY WIND SPEED VARIATIONS

Each curve in Figures 2-1 through 2-31 is the result of plotting period averages of mean hourly wind speed for a given month. Means of a period, generally 6-hour intervals, were used to "smooth" the curve so that up to five curves could be plotted on the same graph. For the last 3 months (June through August 1976), only the anemometers at Sites 6 and 10 recorded data; means of 4-hour intervals, therefore, provided sufficiently distinct curves. If, during a given interval, there were one or more hours with no observed speed, the mean speed of the remaining hours was used instead. If no data were available during the entire interval, a negative number was plotted.

The period averages were plotted opposite the first hour of the given interval; for example, for 6-hour means, the mean speed of hours 1 through 6 was plotted opposite hour 1, and the mean of hours 7 through 12 plotted opposite hour 7. The labels on each curve indicate the site number and mark the beginning interval of each day. Since some records included a considerable amount of missing data, only those sites with more than 500 observations (approximately two-thirds of all possible observations in a month) were selected to be plotted. The only exception to this criterion for plotting is Site 1, which is included in each figure as the reference anemometer.

Statistics for each site are included at the top of each figure. All of the available hourly data points (N) at each site were used to calculate mean monthly wind speed, the standard deviation (SIGMA), and the cube root of the expected cubed speed (CREC) given by:

$$\text{CREC} = \left(\frac{1}{N} \sum_{i=1}^{N} X_i^3 \right)^{1/3} \qquad (1)$$

where X_i is the mean hourly speed at the site.

The curves in these figures indicate similar relationships of wind speed versus time between all sites, particularly those at the same location. Those sites located on hilltops or ridges have higher monthly means than those at lower elevations, and each site has a large standard deviation relative to the mean.

When comparing curves before January 28, 1976 with those after that date, it is necessary to consider the changes in the upper limit of speeds recorded. Prior to this date, the full range of the strip charts was 50 mph and all offscale speeds were coded as missing data. After that date, the scale was revised to include speeds up to 100 mph. Consequently, peak speeds of the windier months before February 1976 may underestimate true means, particularly at the windier sites.

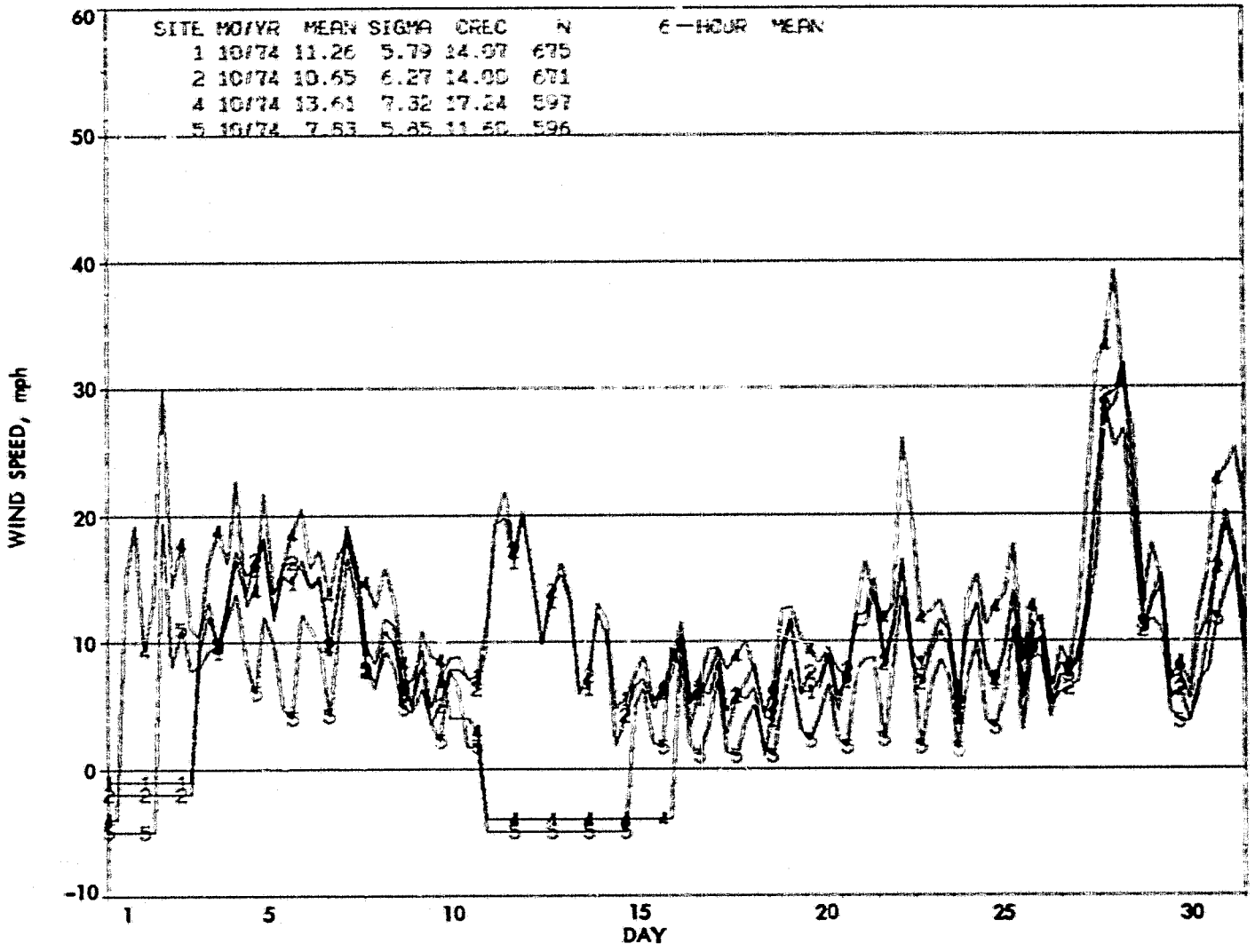


Figure 2-1. Monthly Wind Speeds for October 1974: Sites 1, 2, 4, and 5

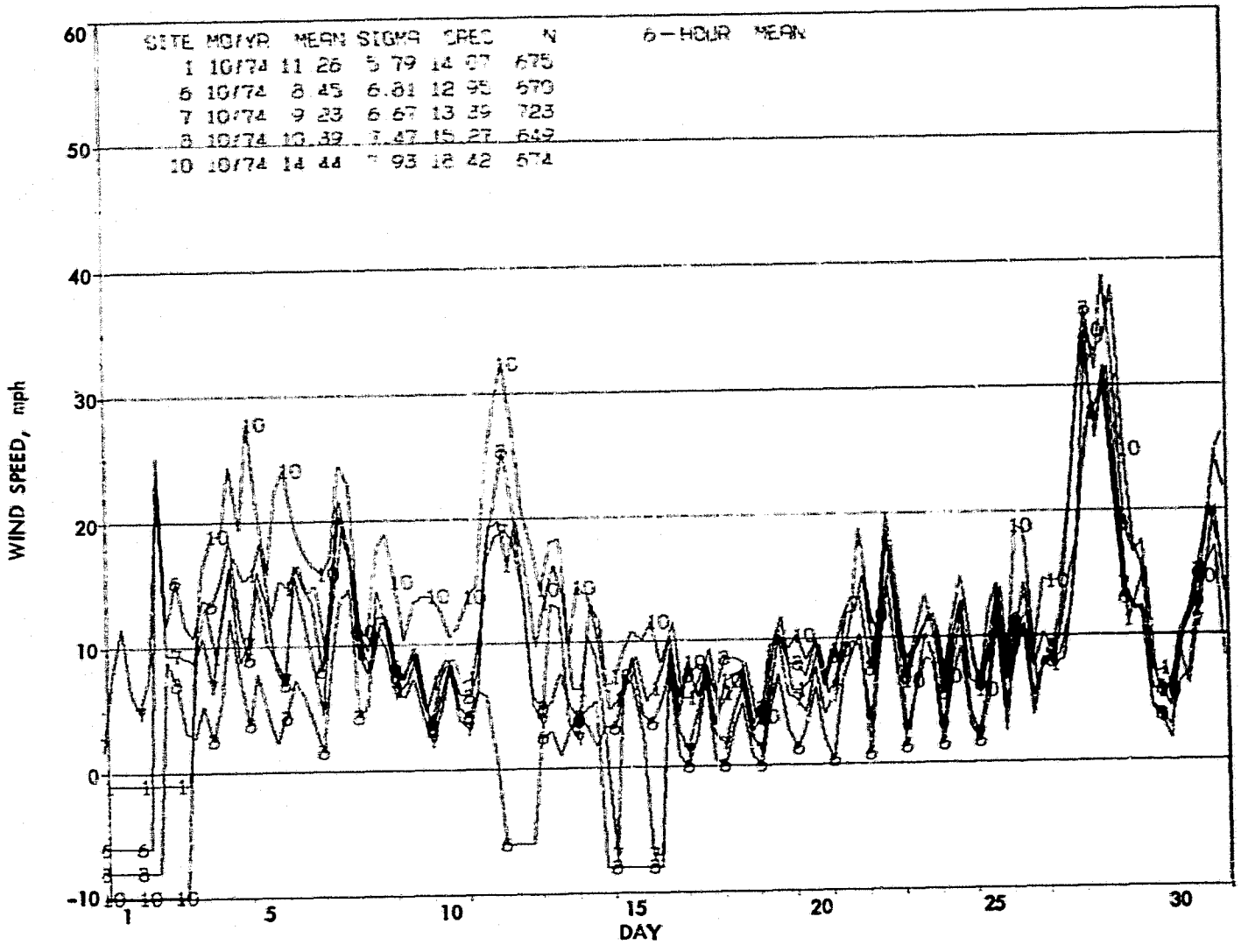


Figure 2-2. Monthly Wind Speeds for October 1974: Sites 1, 6, 7, 8, and 10

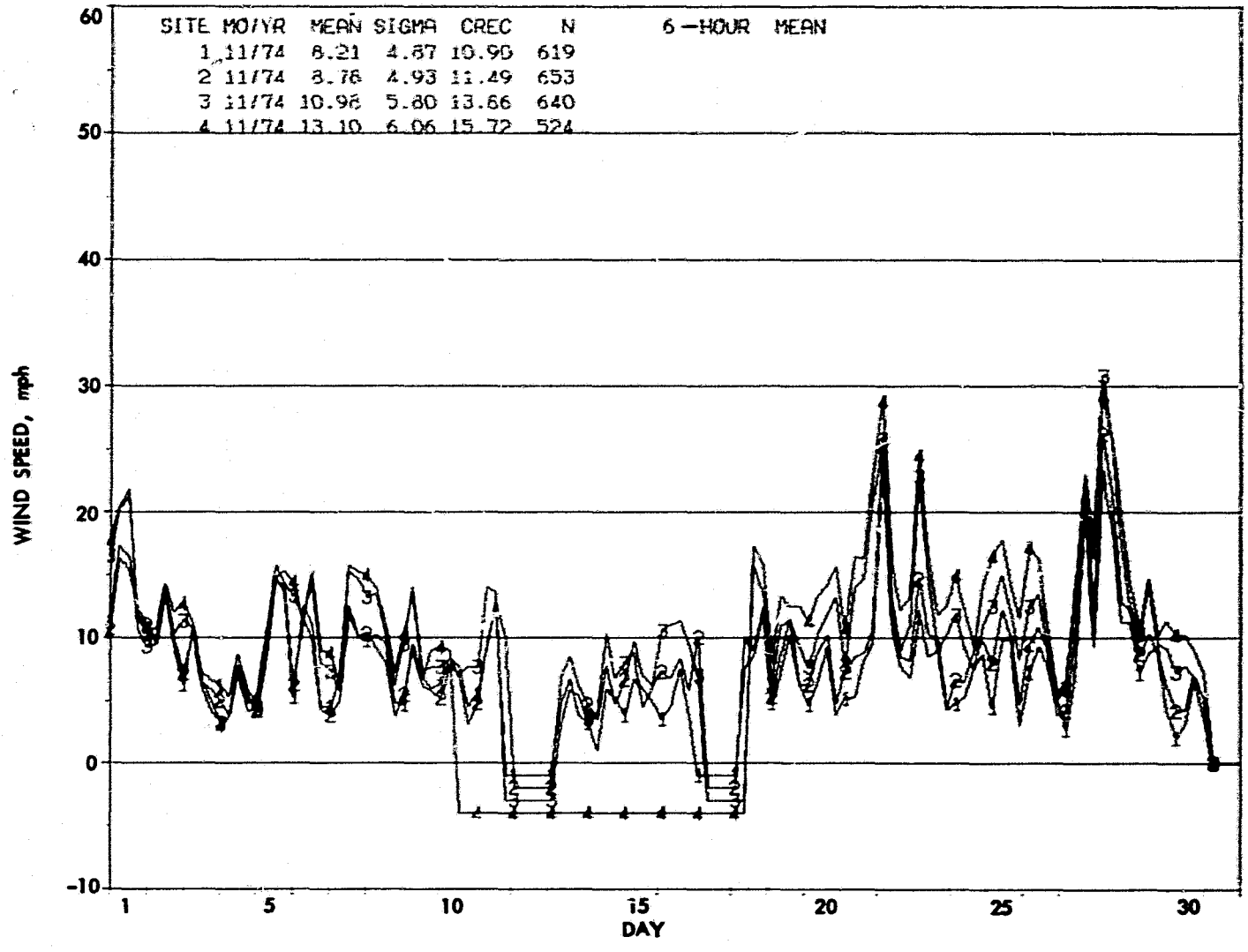


Figure 2-3. Monthly Wind Speeds for November 1974: Sites 1, 2, 3, and 4

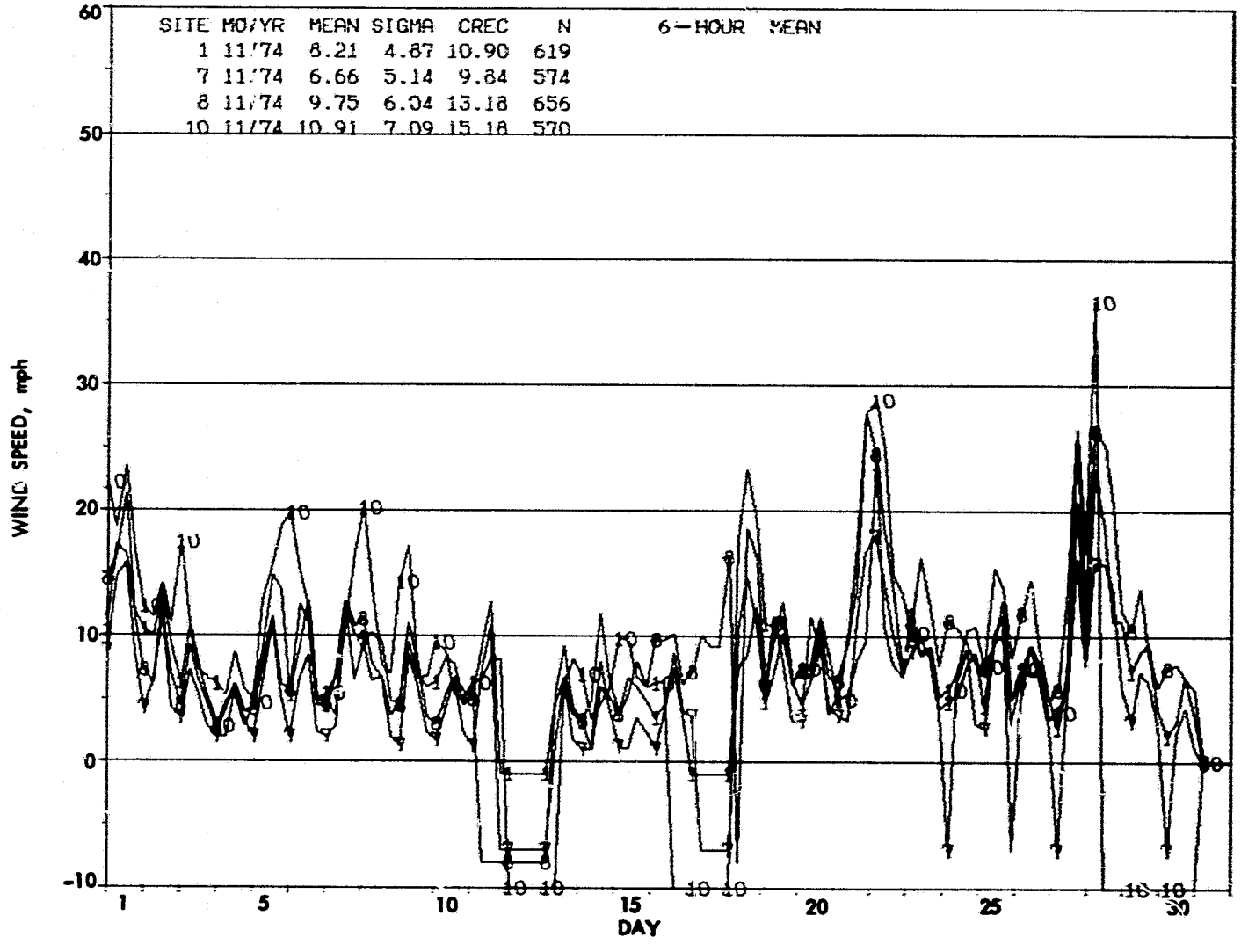


Figure 2-4. Monthly Wind Speeds for November 1974: Sites 1, 7, 8, and 10

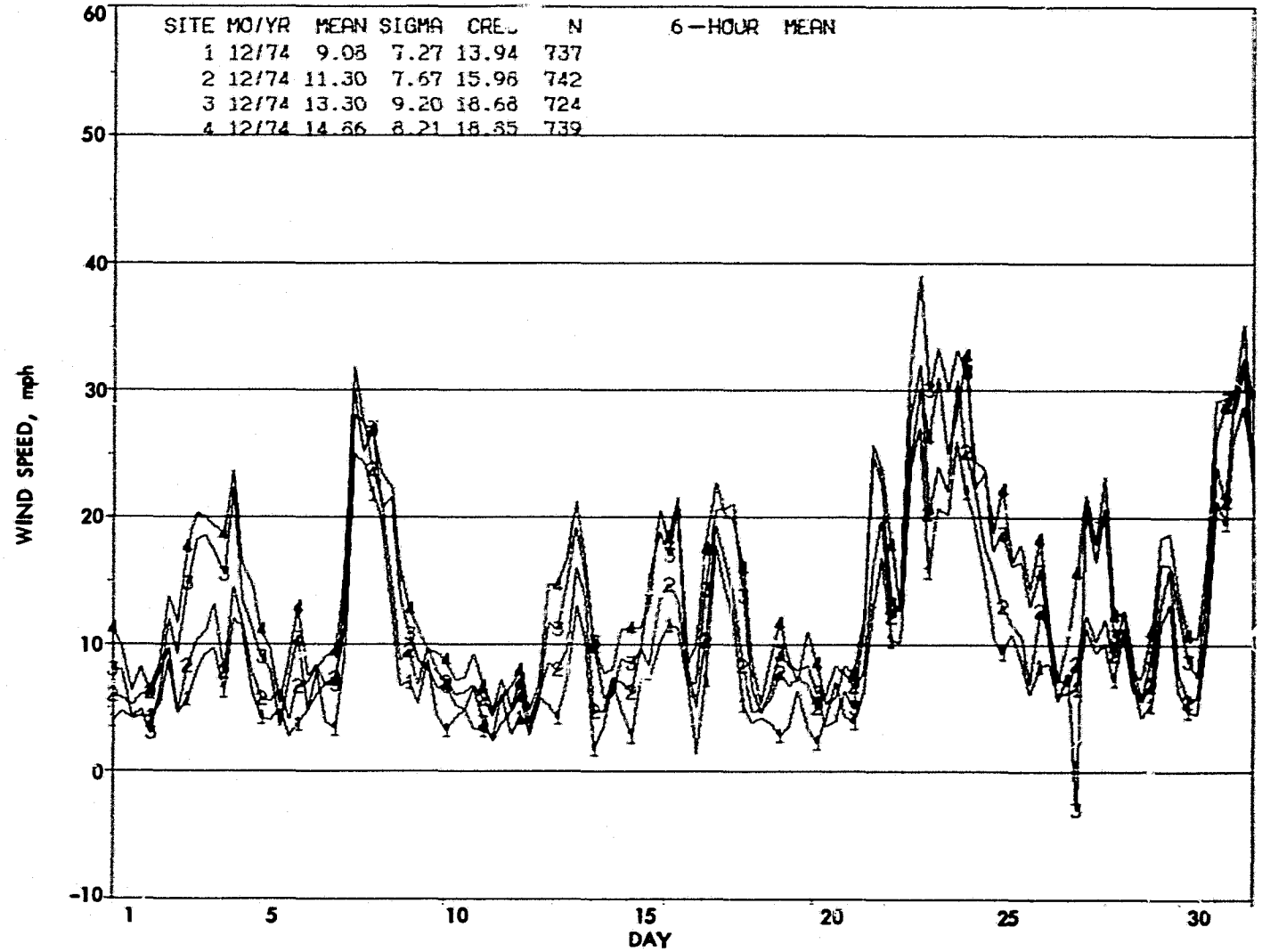


Figure 2-5. Monthly Wind Speeds for December 1974: Sites 1, 2, 3, and 4

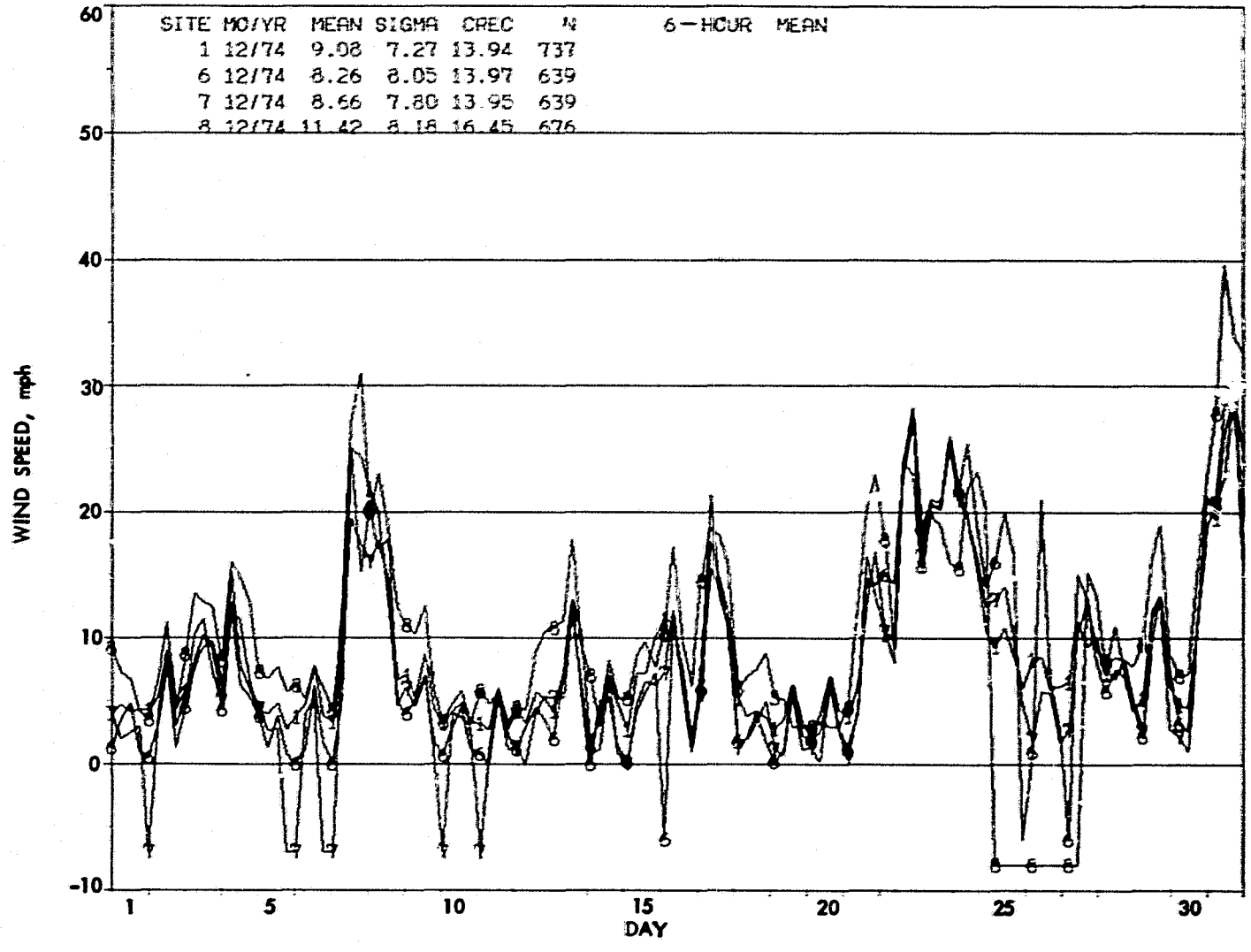


Figure 2-6. Monthly Wind Speeds for December 1974: Sites 1, 6, 7, and 8

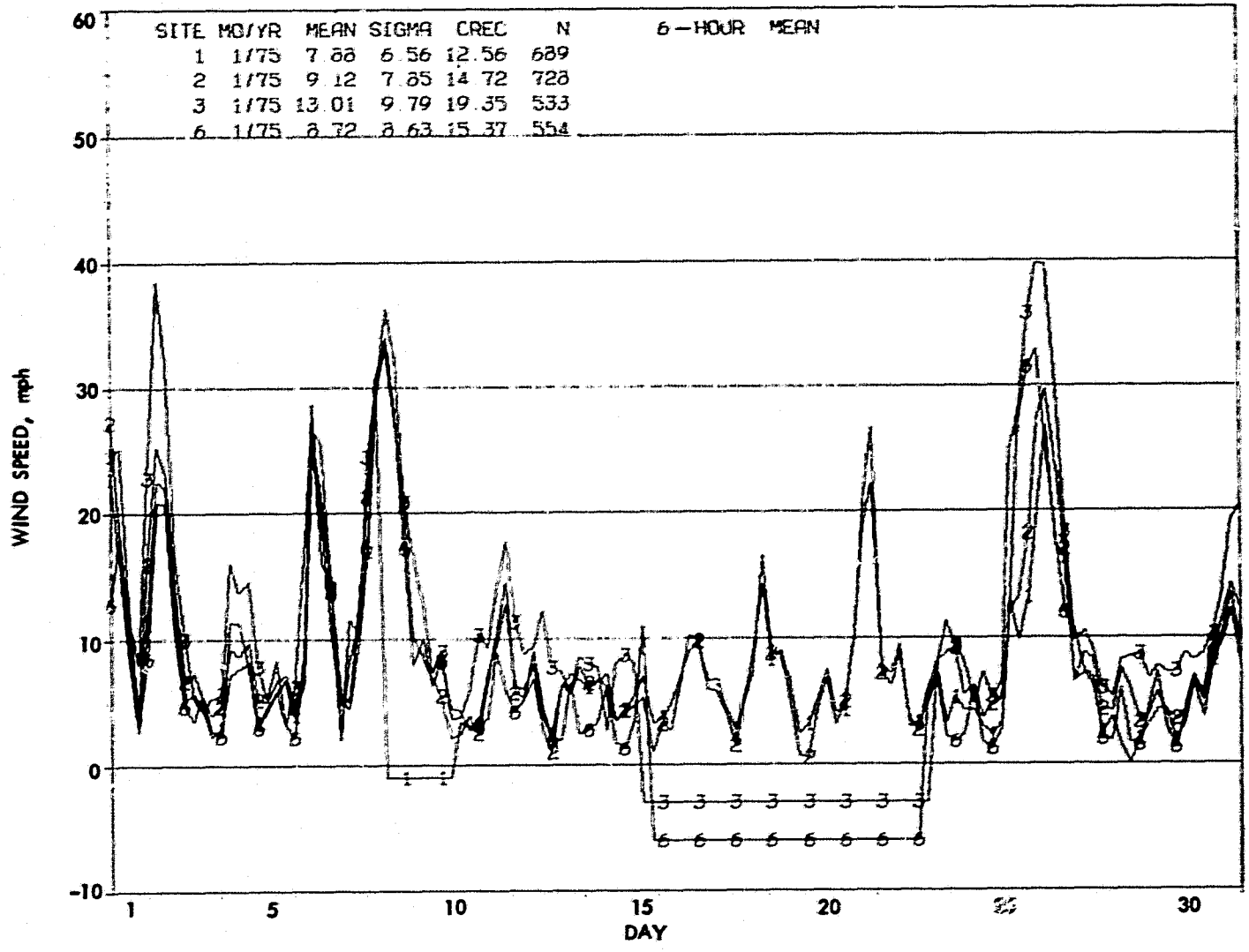


Figure 2-7. Monthly Wind Speeds for January 1975: Sites 1, 2, 3, and 6

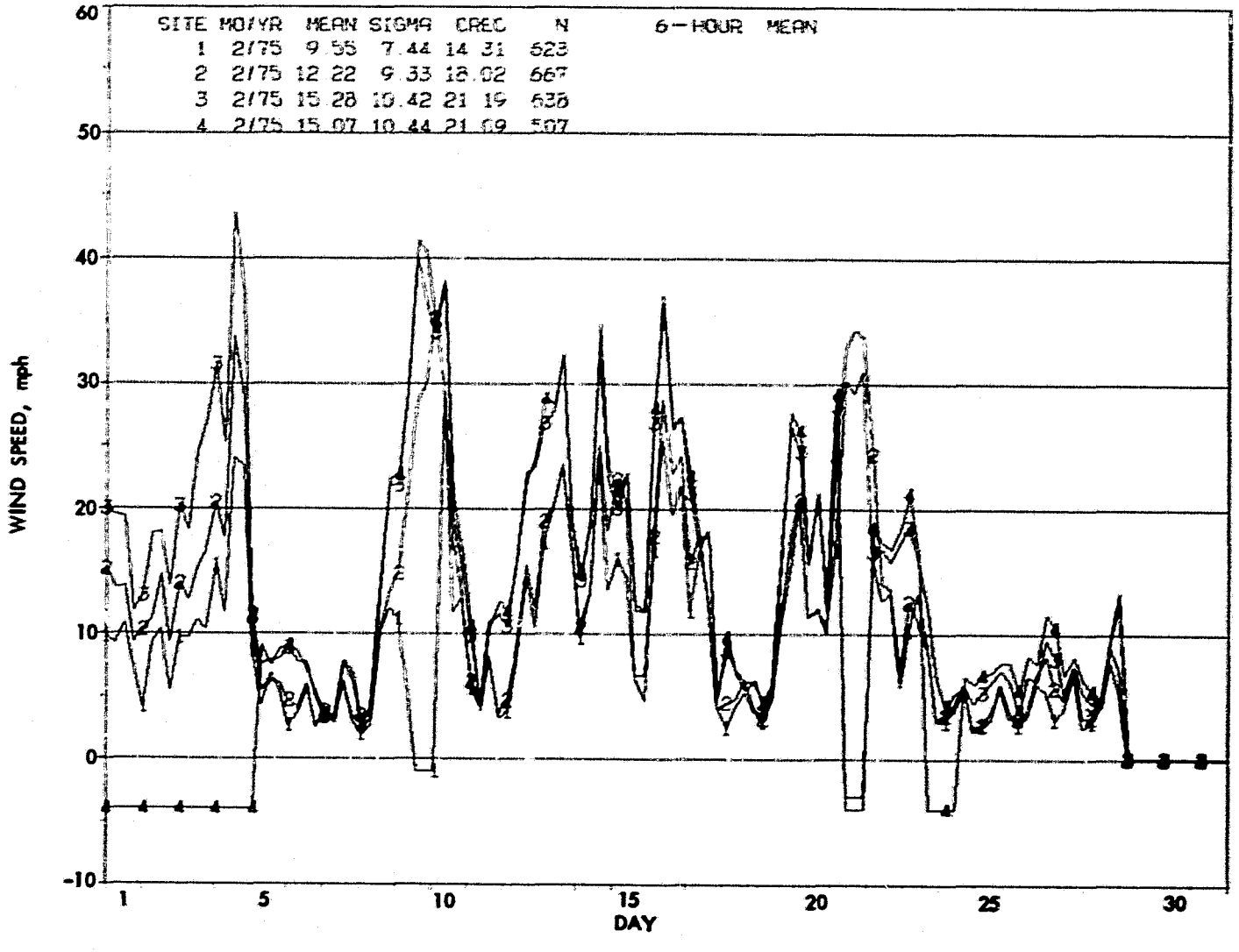


Figure 2-8. Monthly Wind Speeds for February 1975: Sites 1, 2, 3, and 4

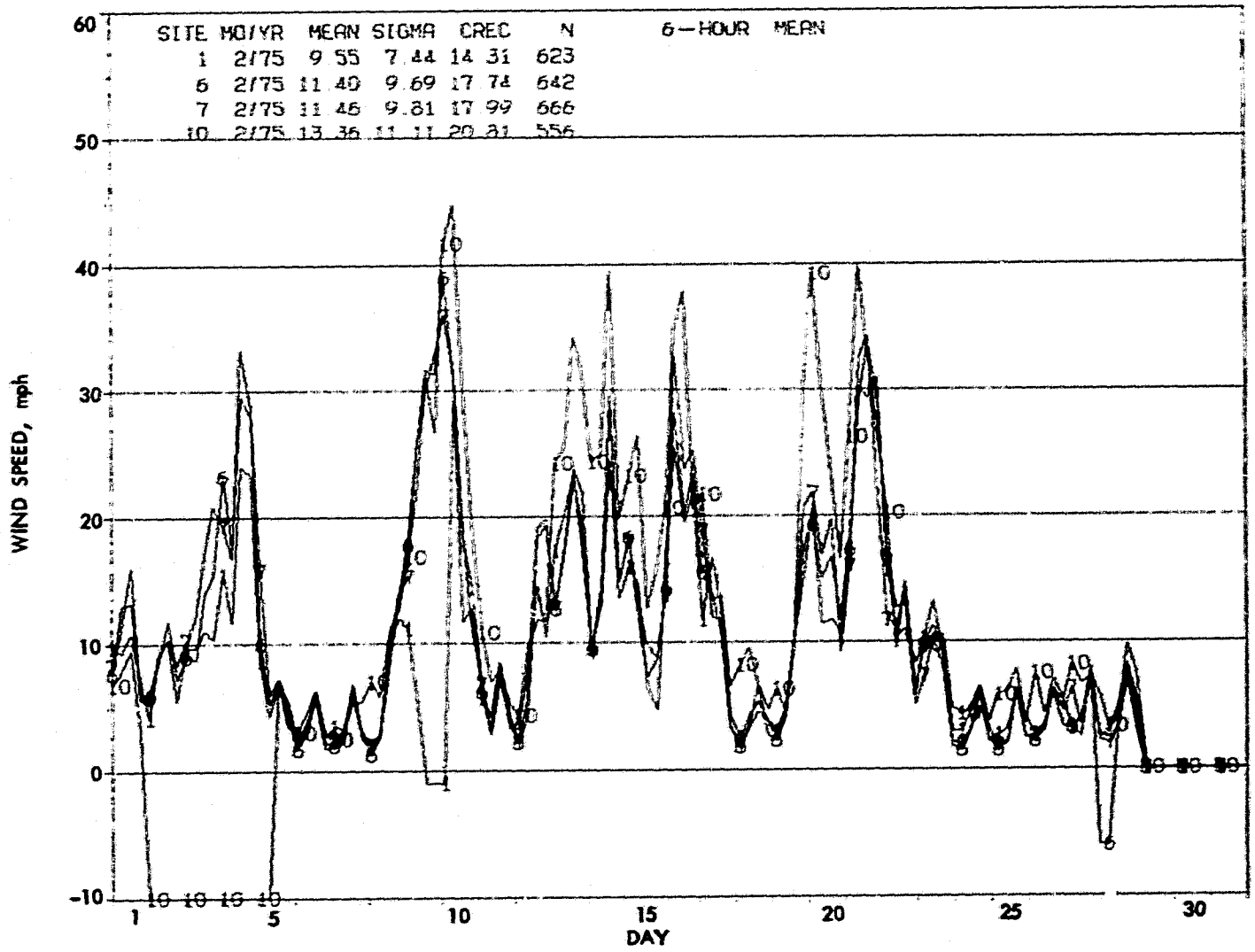


Figure 2-9. Monthly Wind Speeds for February 1975: Sites 1, 6, 7, and 10

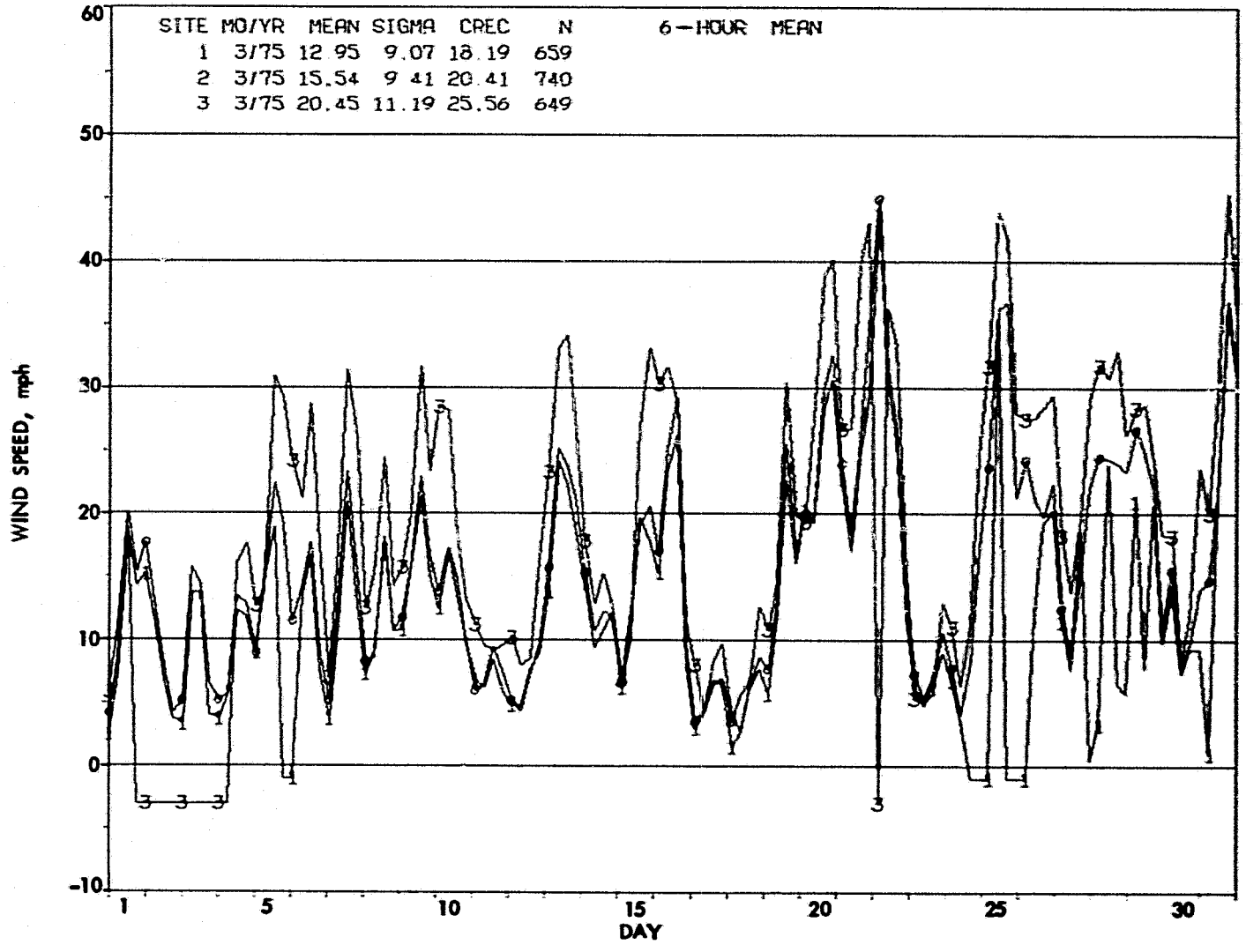


Figure 2-10. Monthly Wind Speeds for March 1975: Sites 1, 2, and 3

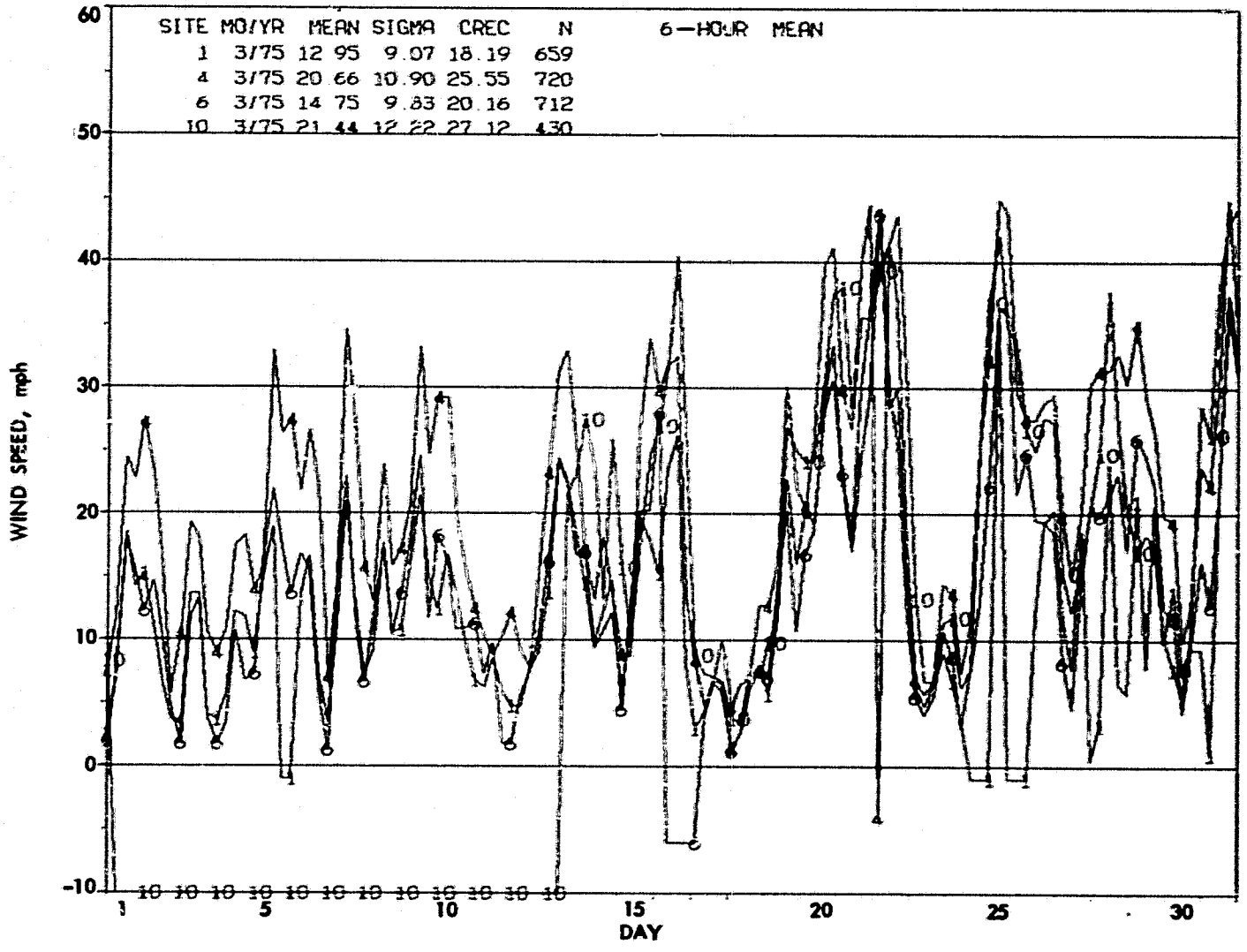


Figure 2-11. Monthly Wind Speeds for March 1975: Sites 1, 4, 6, and 10

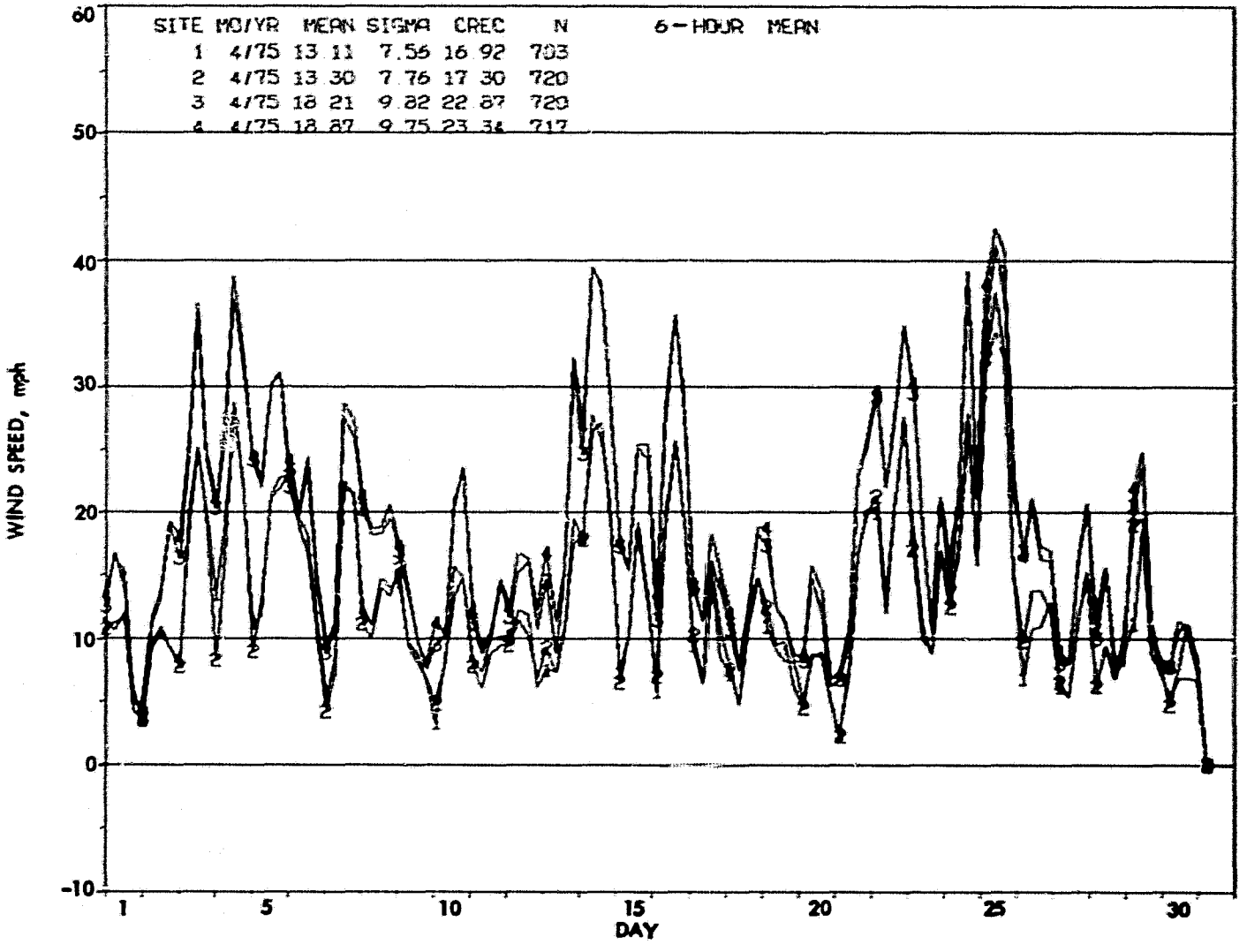


Figure 2-12. Monthly Wind Speeds for April 1975: Sites 1, 2, 3, and 4

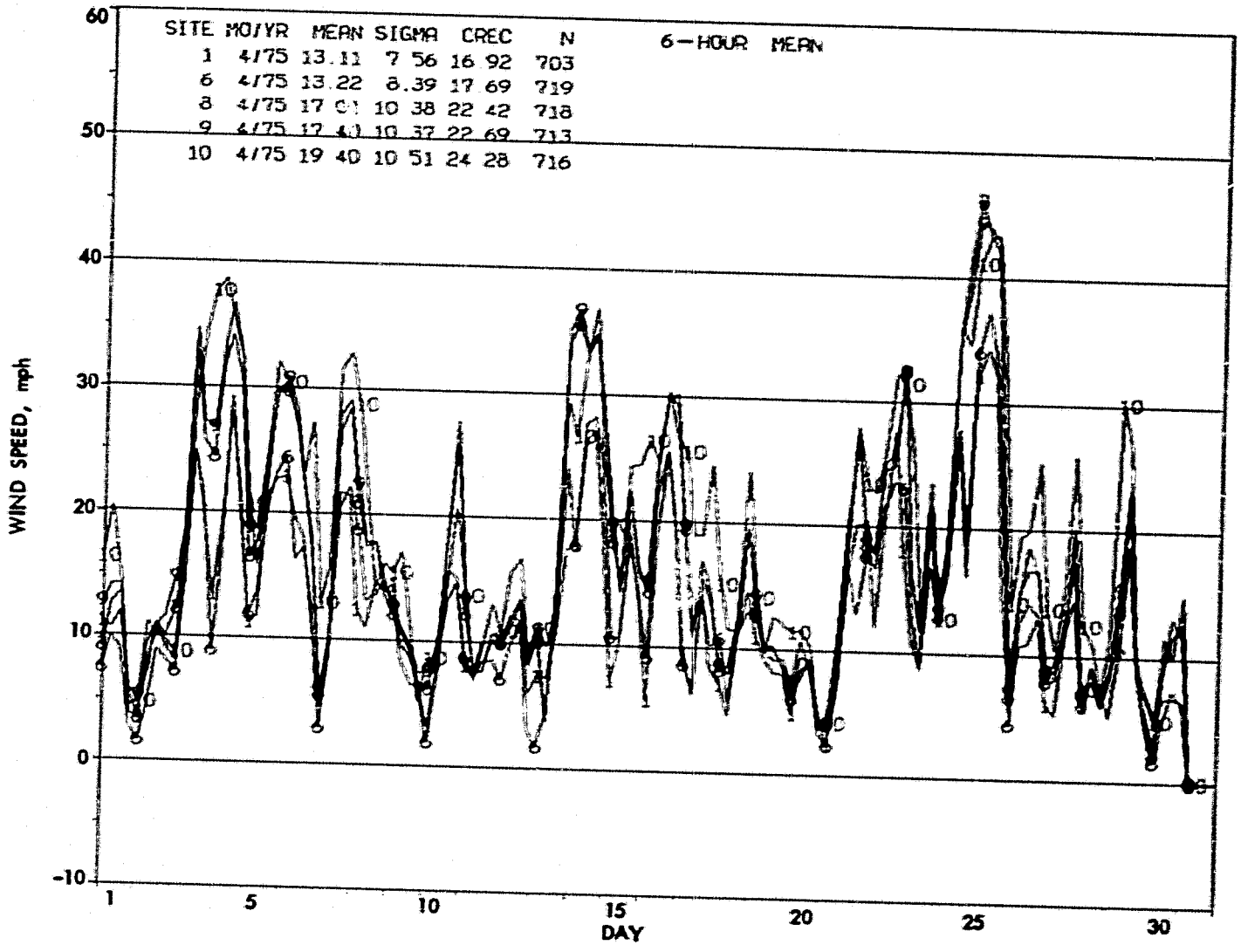


Figure 2-13. Monthly Wind Speeds for April 1975: Sites 1, 6, 8, 9, and 10

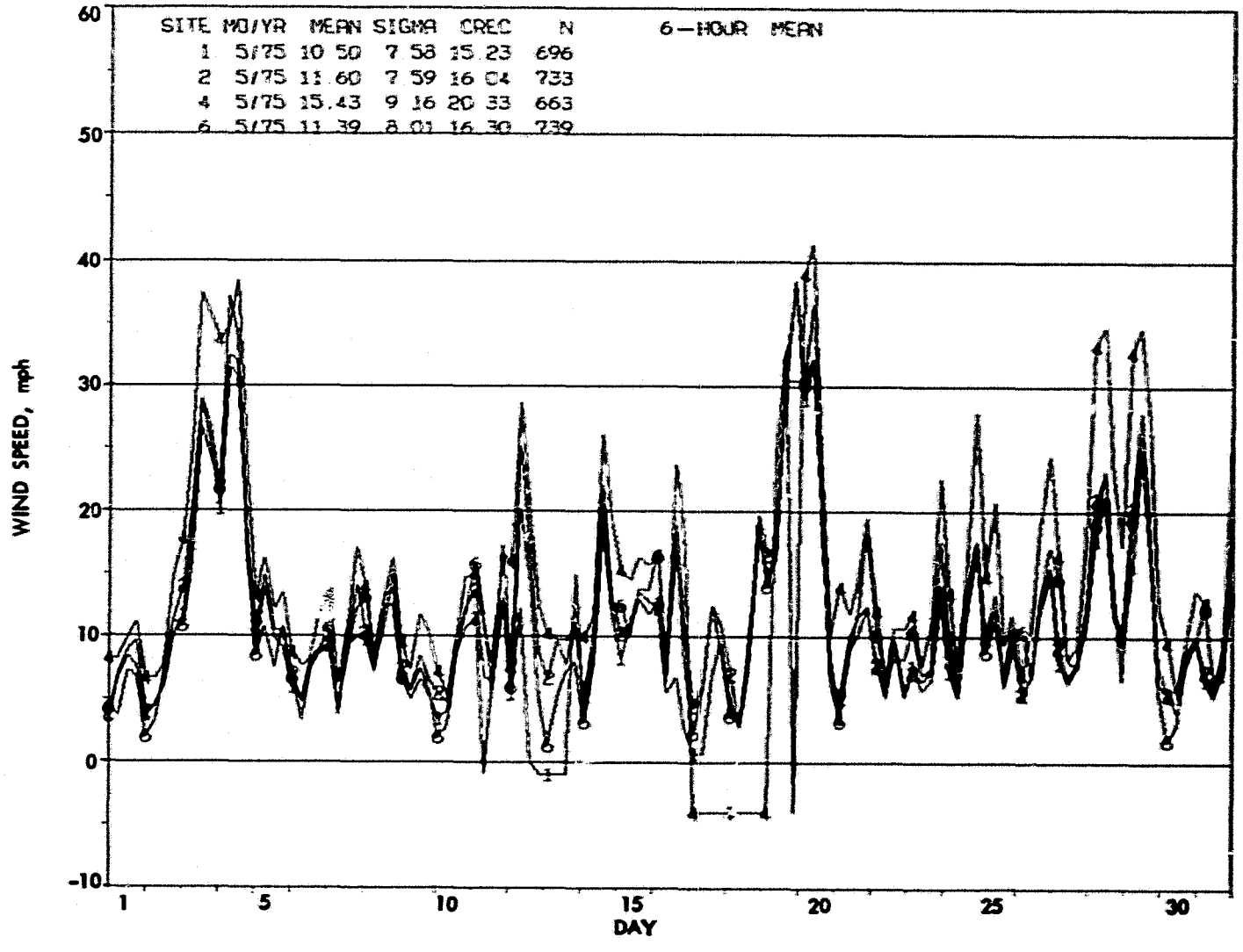


Figure 2-14. Monthly Wind Speeds for May 1975: Sites 1, 2, 4, and 6

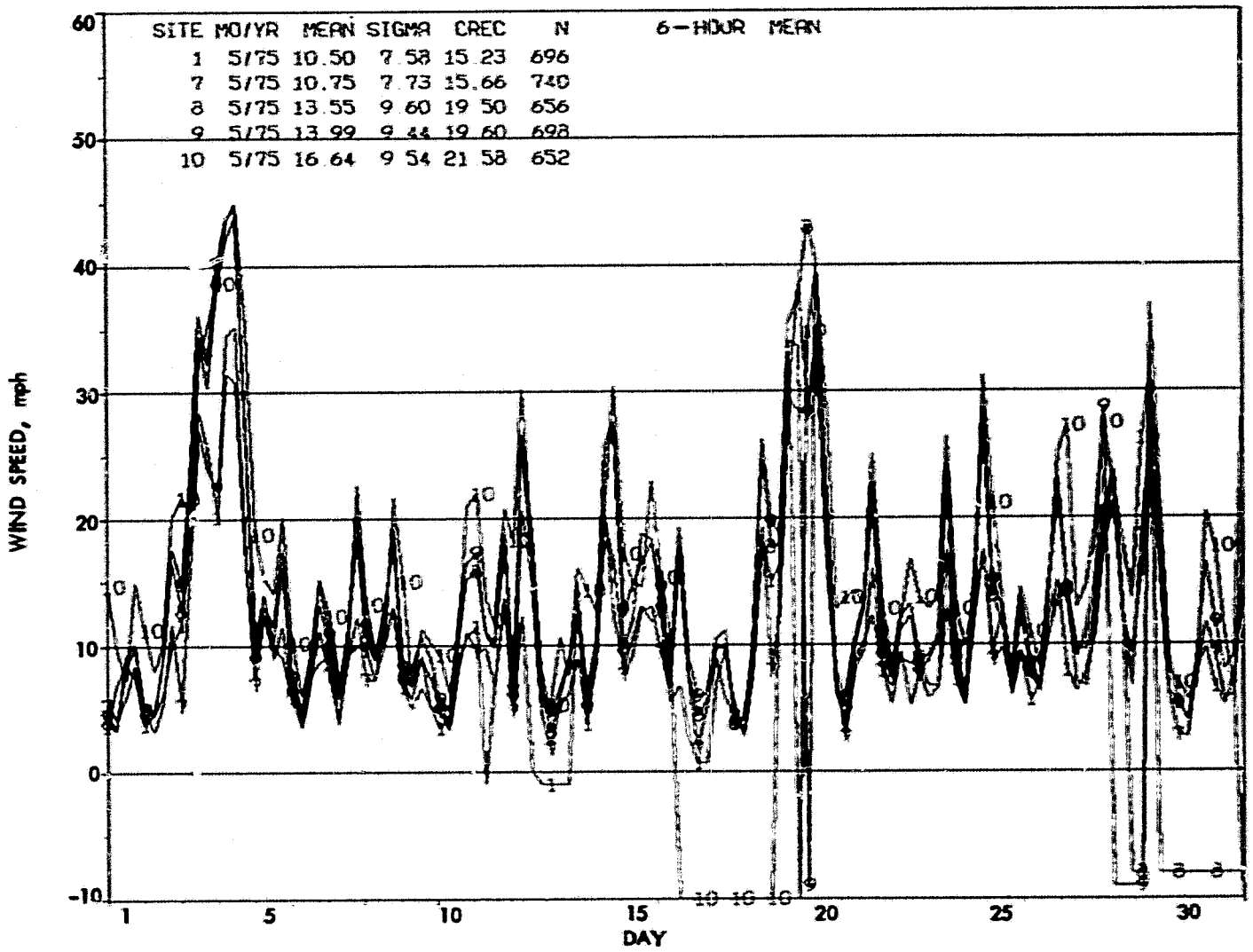


Figure 2-15. Monthly Wind Speeds for May 1975: Sites 1, 7, 8, 9, and 10

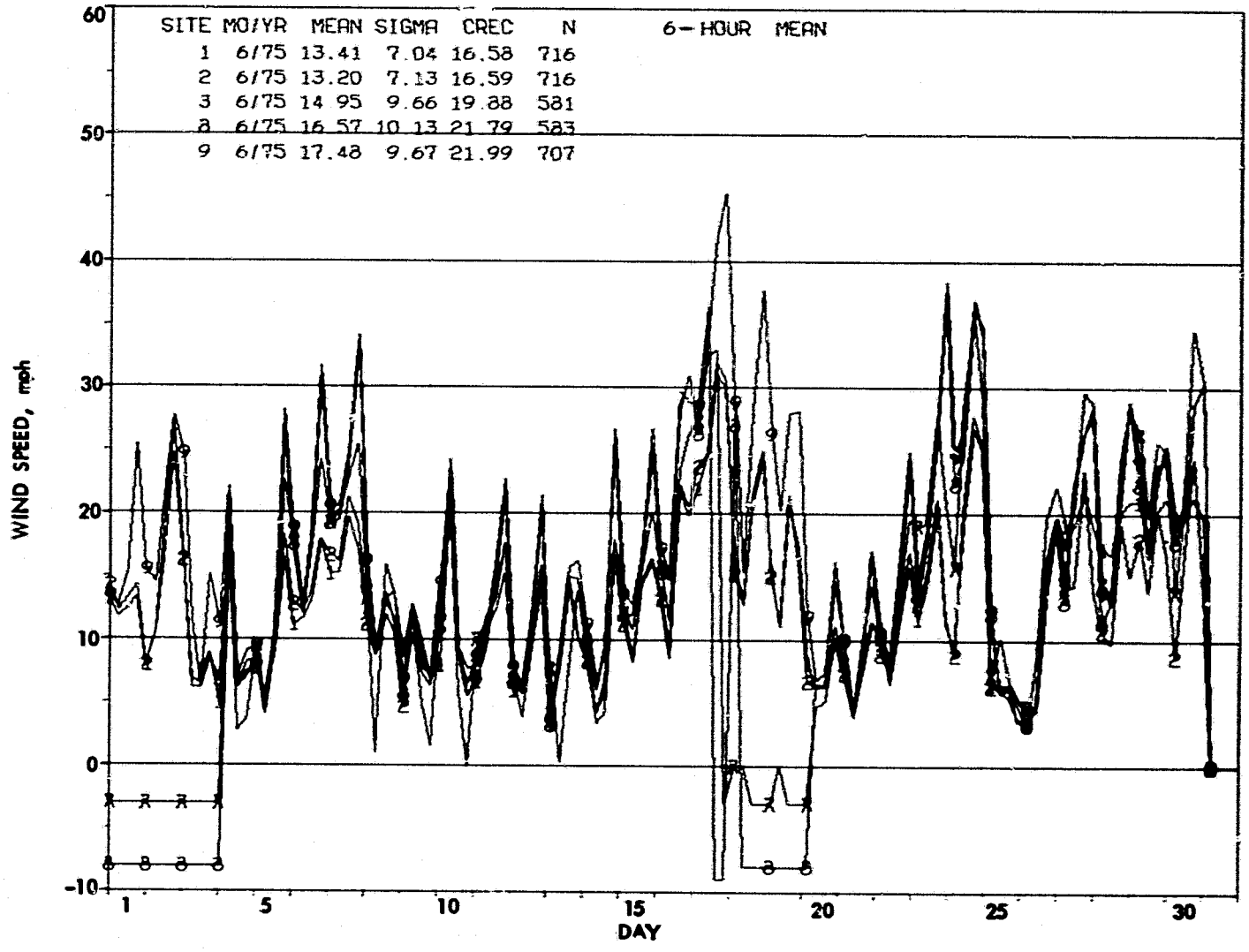


Figure 2-16. Monthly Wind Speeds for June 1975: Sites 1, 2, 3, 8, and 9

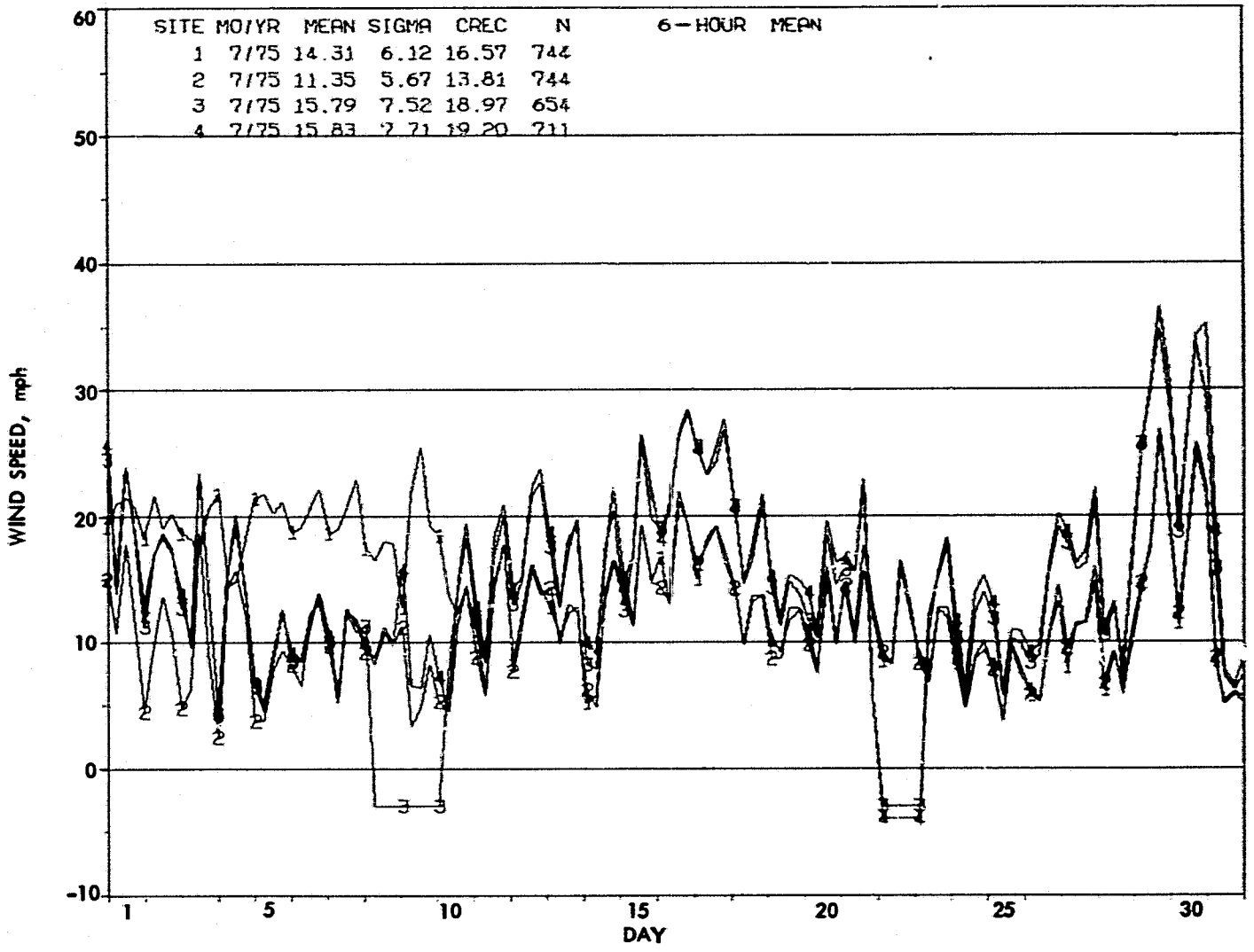


Figure 2-17. Monthly Wind Speeds for July 1975: Sites 1, 2, 3, and 4

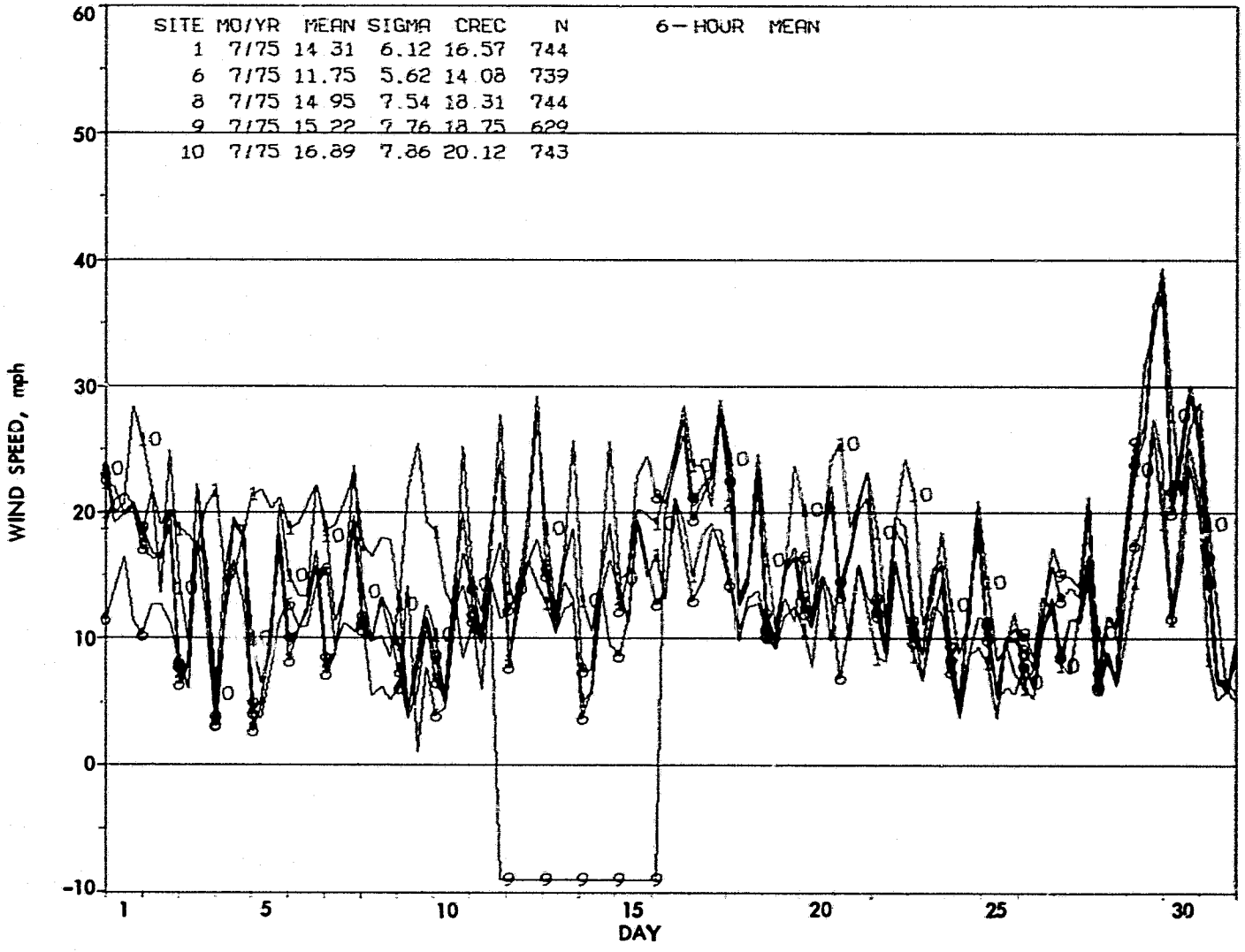


Figure 2-18. Monthly Wind Speeds for July 1975: Sites 1, 6, 8, 9, and 10

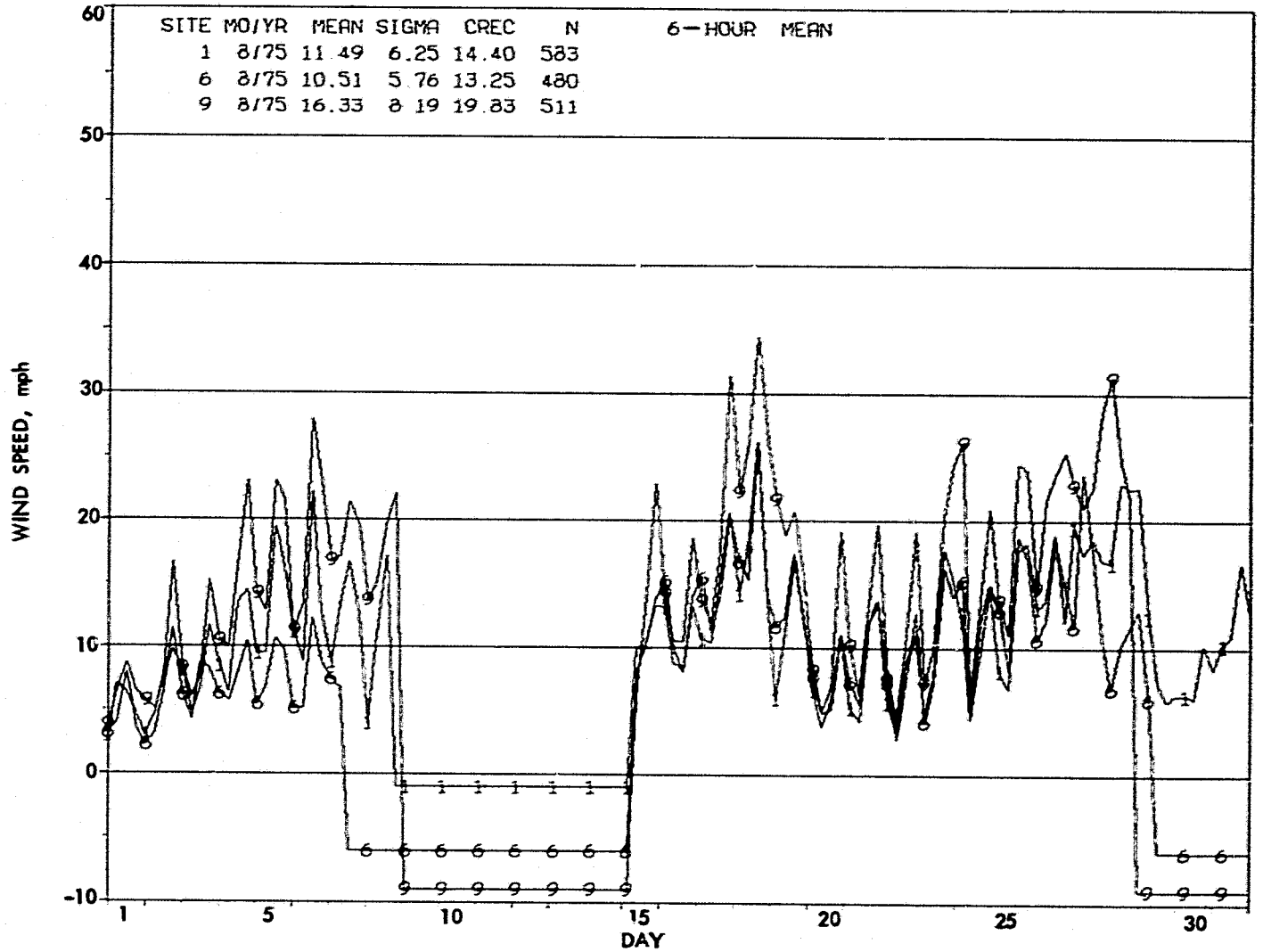


Figure 2-19. Monthly Wind Speeds for August 1975: Sites 1, 6, and 9

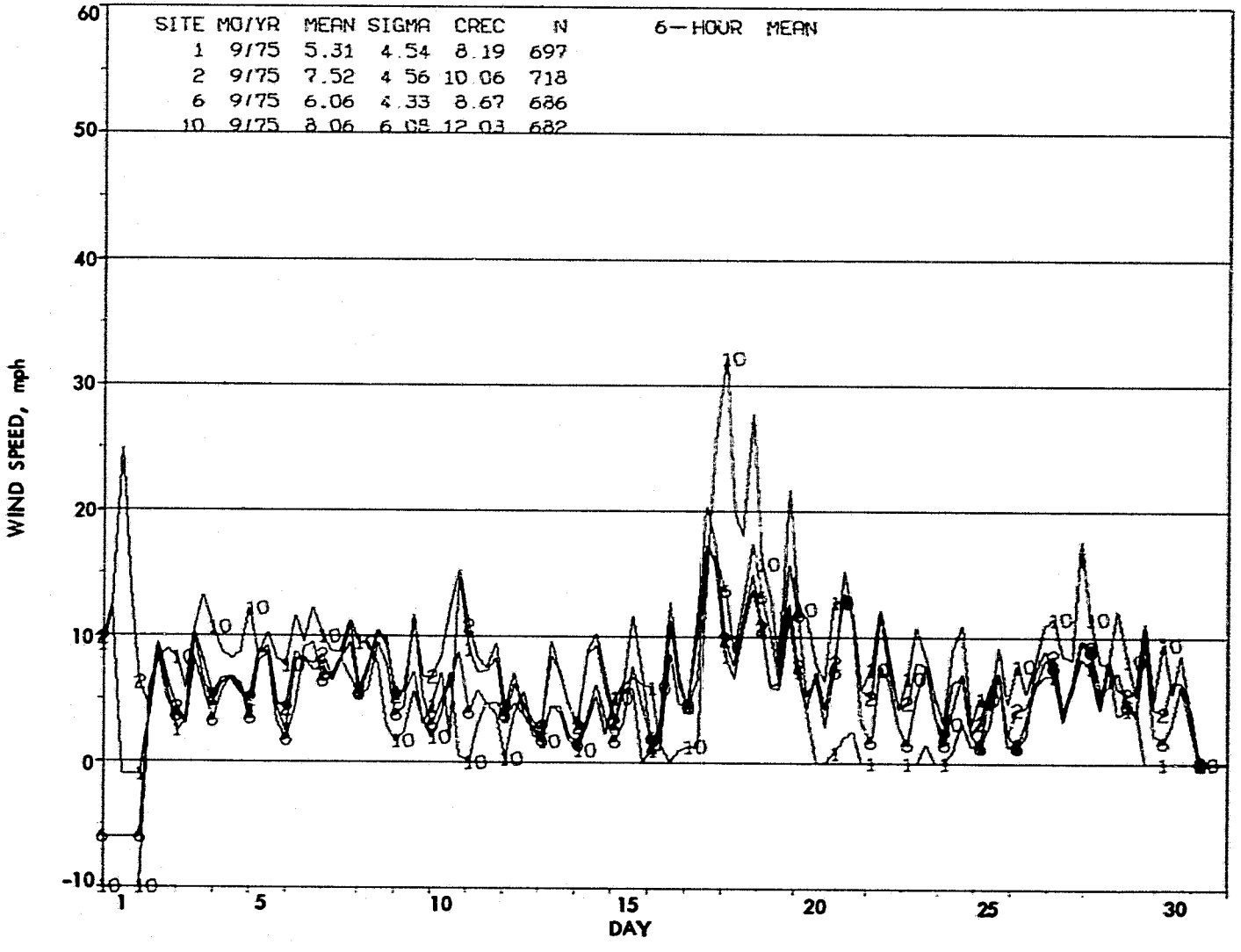


Figure 2-20. Monthly Wind Speeds for September 1975: Sites 1, 2, 6, and 10

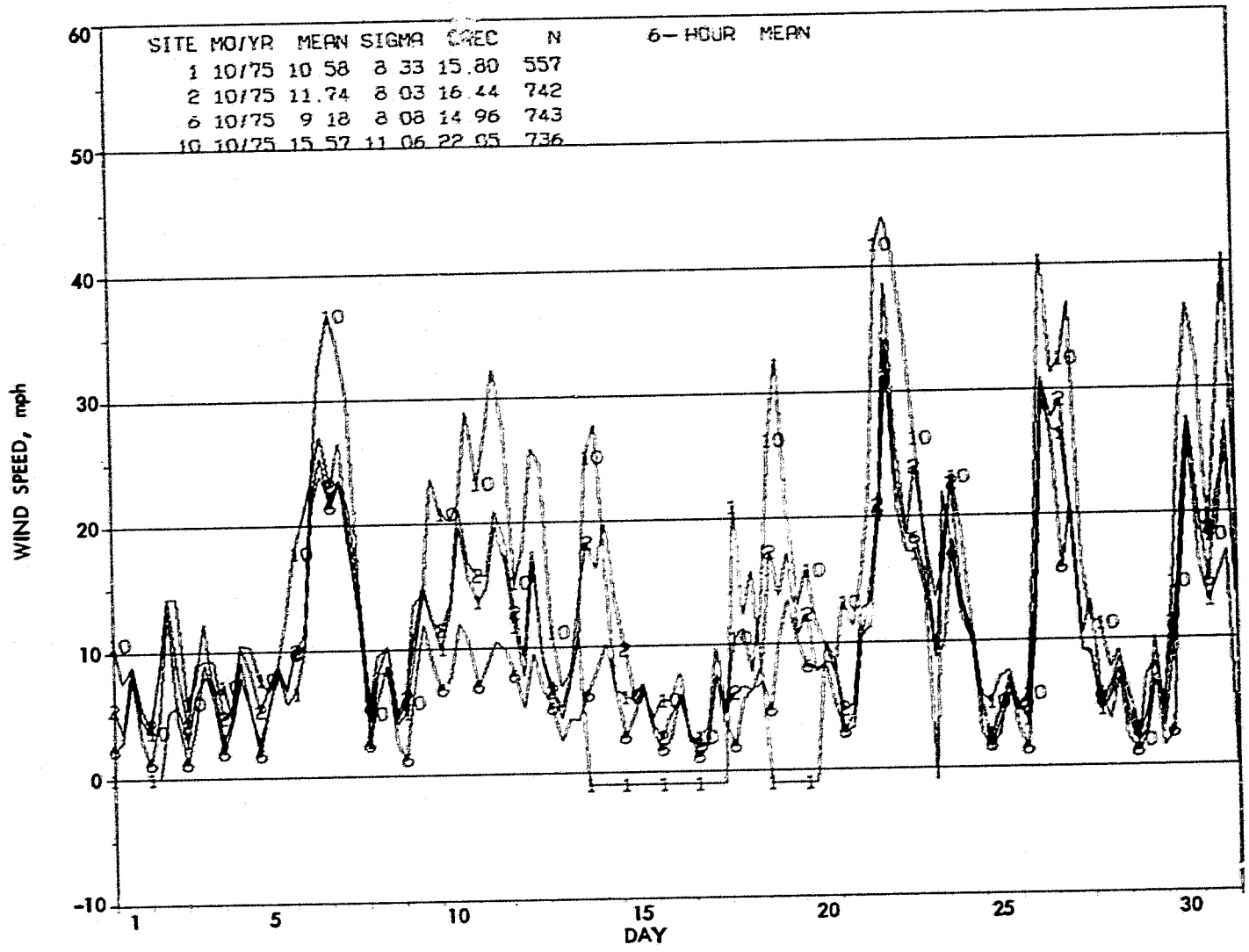


Figure 2-21. Monthly Wind Speeds for October 1975: Sites 1, 2, 6, and 10

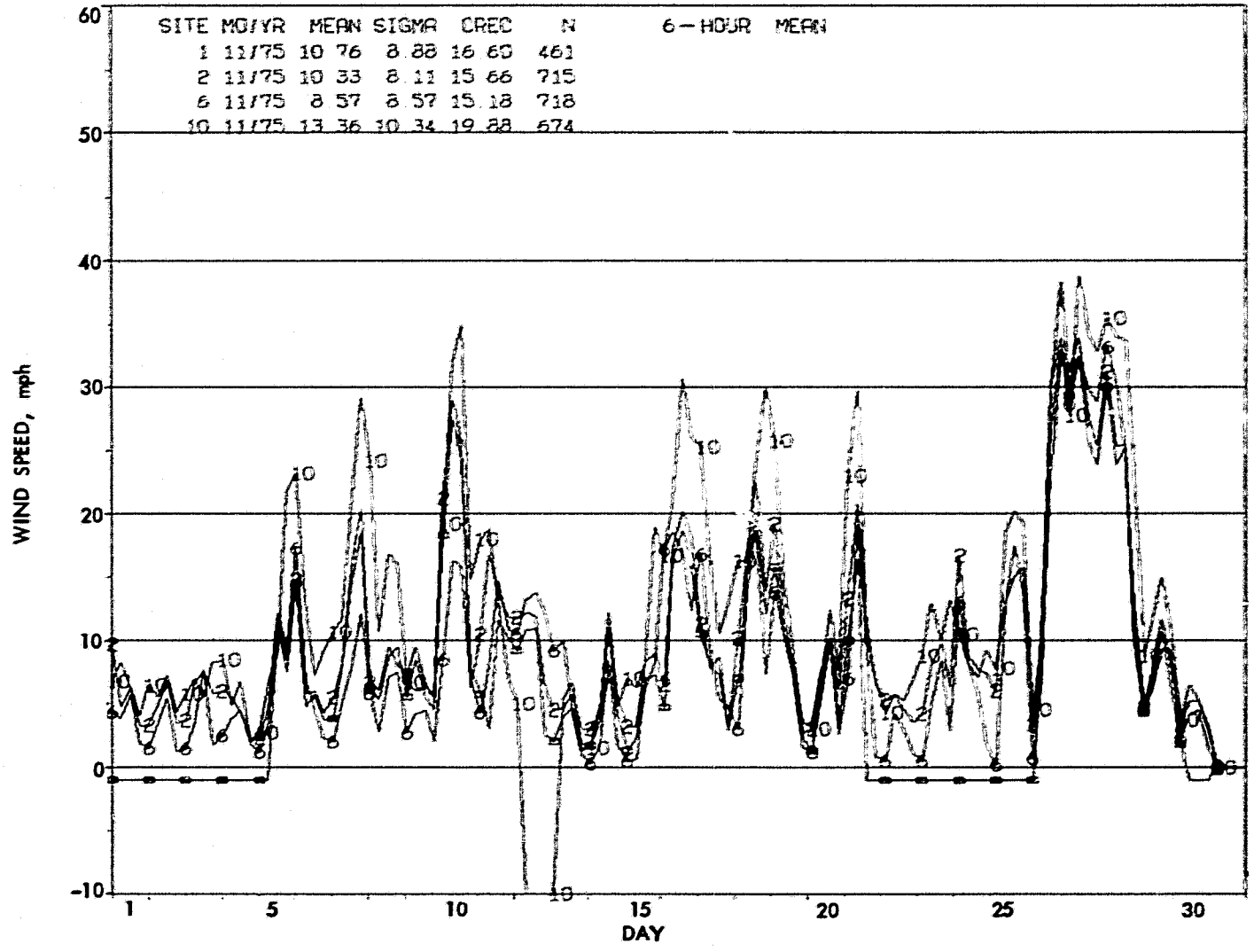


Figure 2-22. Monthly Wind Speeds for November 1975: Sites 1, 2, 6, and 10

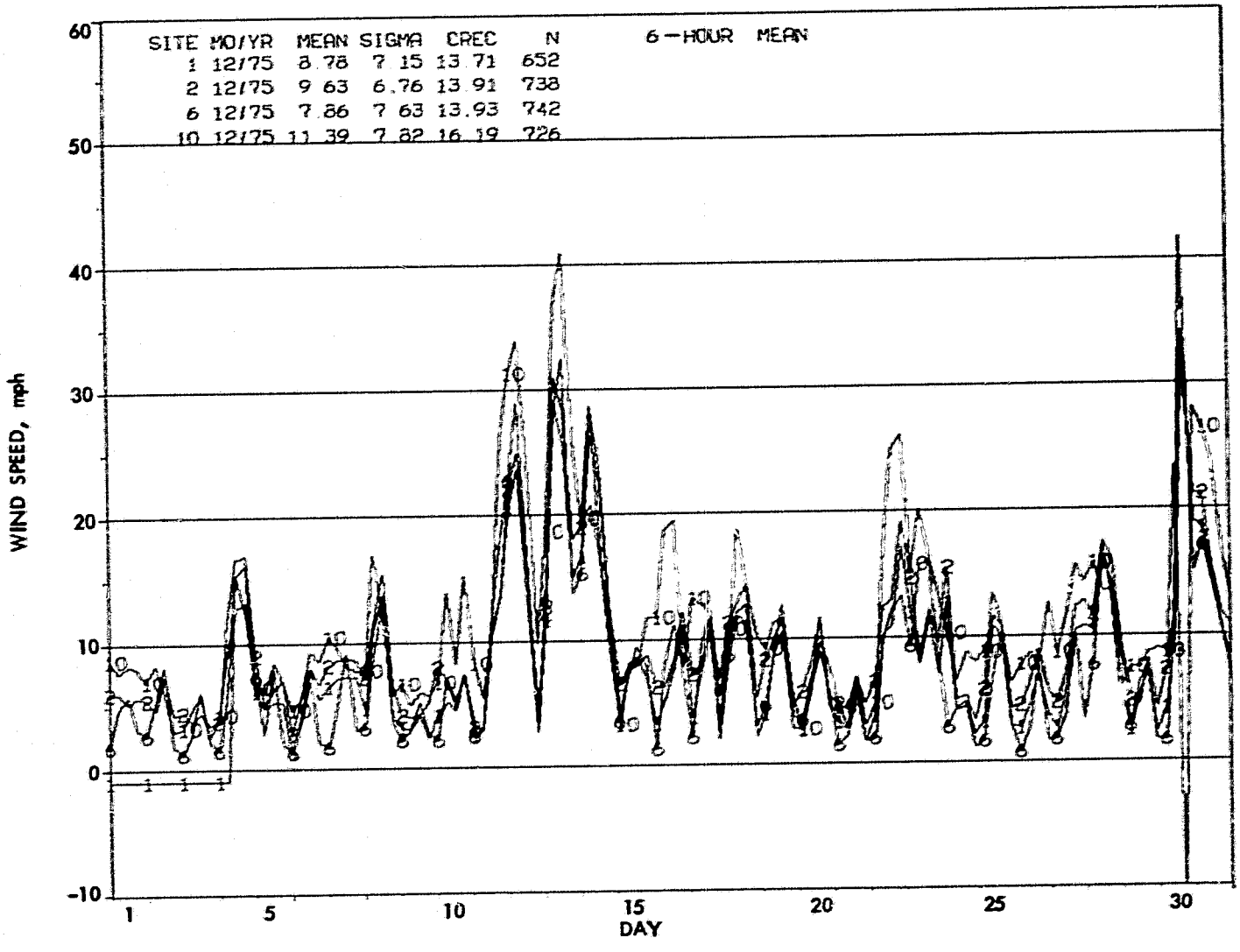


Figure 2-23. Monthly Wind Speeds for December 1975: Sites 1, 2, 6, and 10

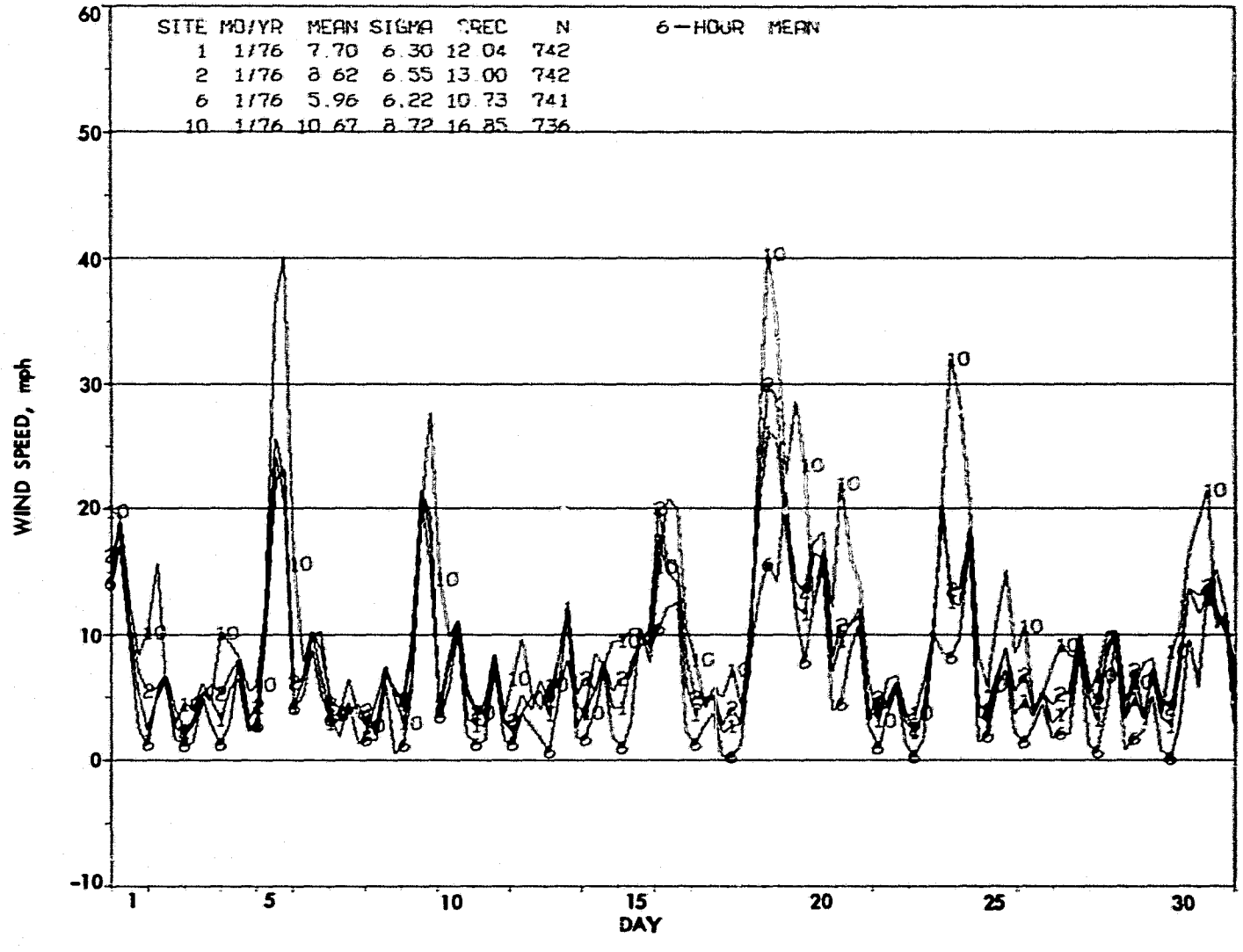


Figure 2-24. Monthly Wind Speeds for January 1976: Sites 1, 2, 6, and 10

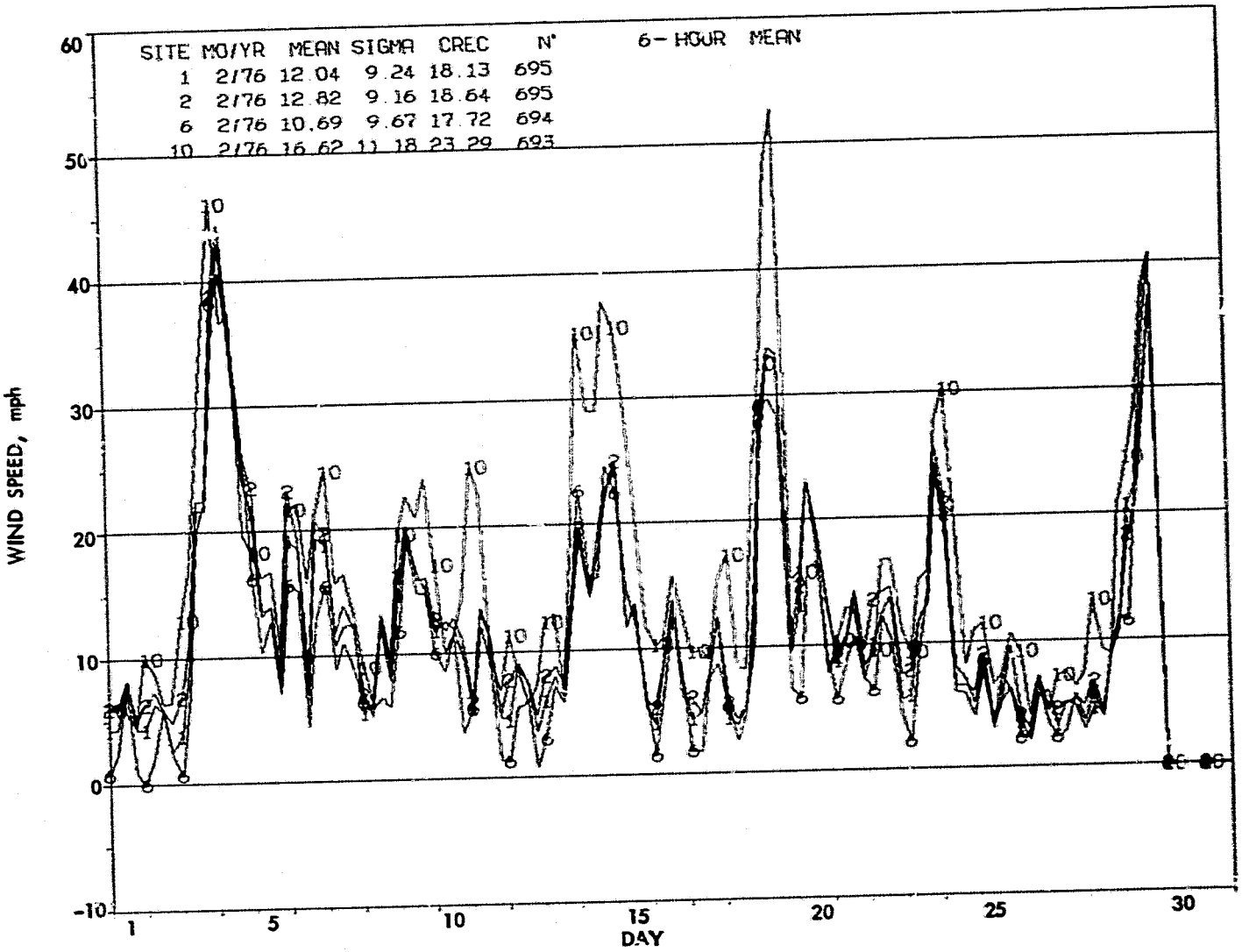


Figure 2-25. Monthly Wind Speeds for February 1976: Sites 1, 2, 6, and 10

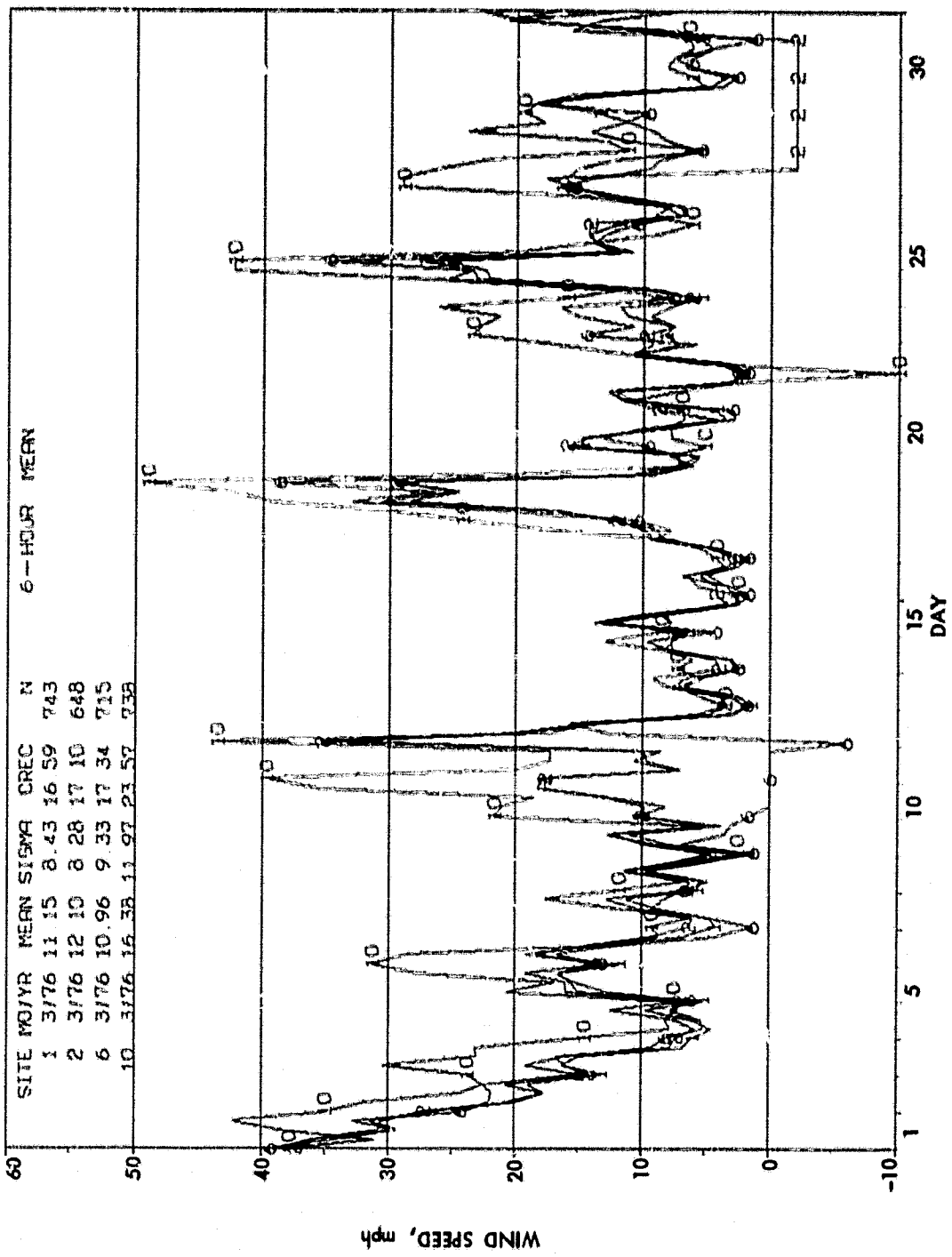


Figure 2-26. Monthly Wind Speeds for March 1976: Sites 1, 2, 6, and 10

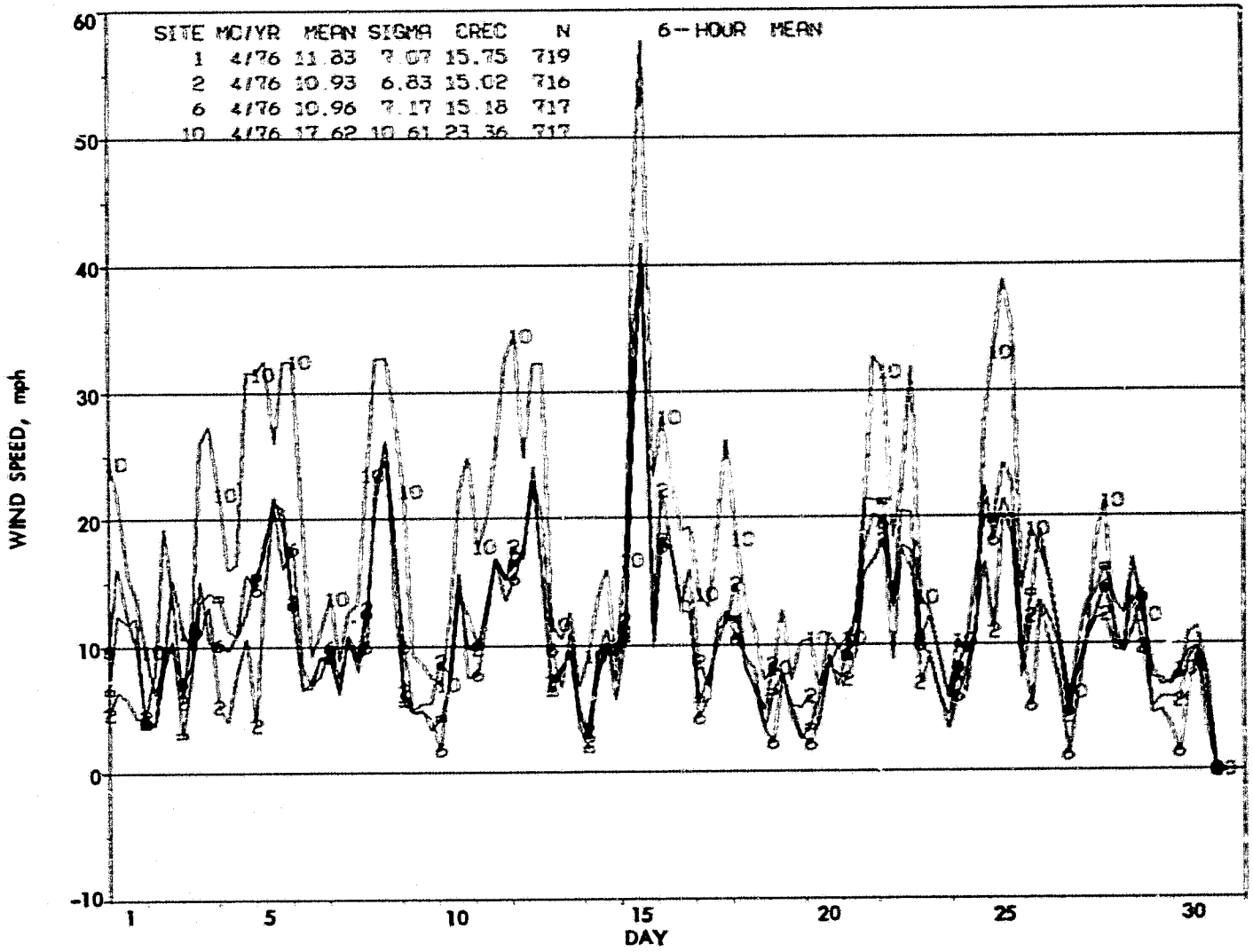


Figure 2-27. Monthly Wind Speeds for April 1976: Sites 1, 2, 6, and 10

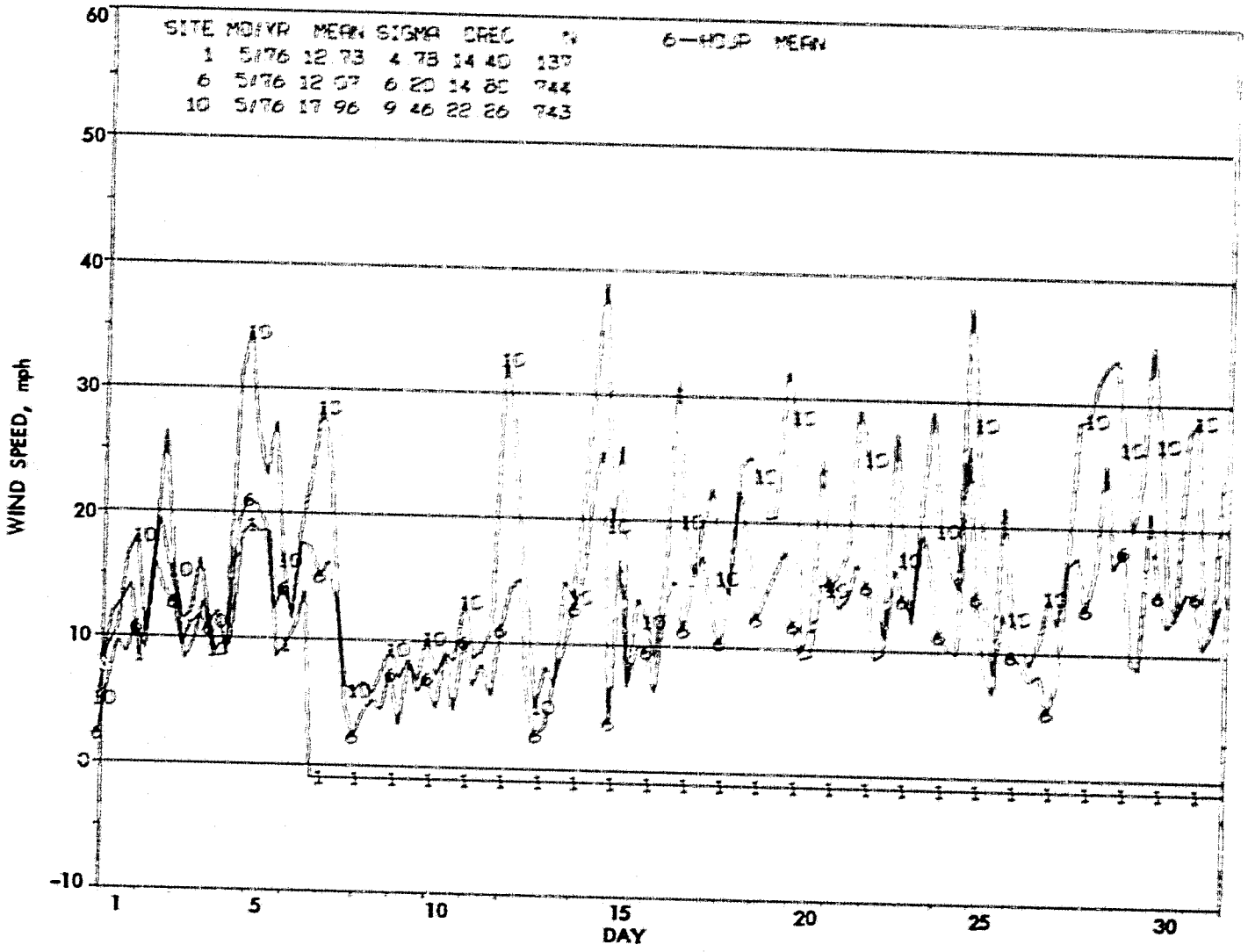


Figure 2-28. Monthly Wind Speeds for May 1976: Sites 1, 6, and 10

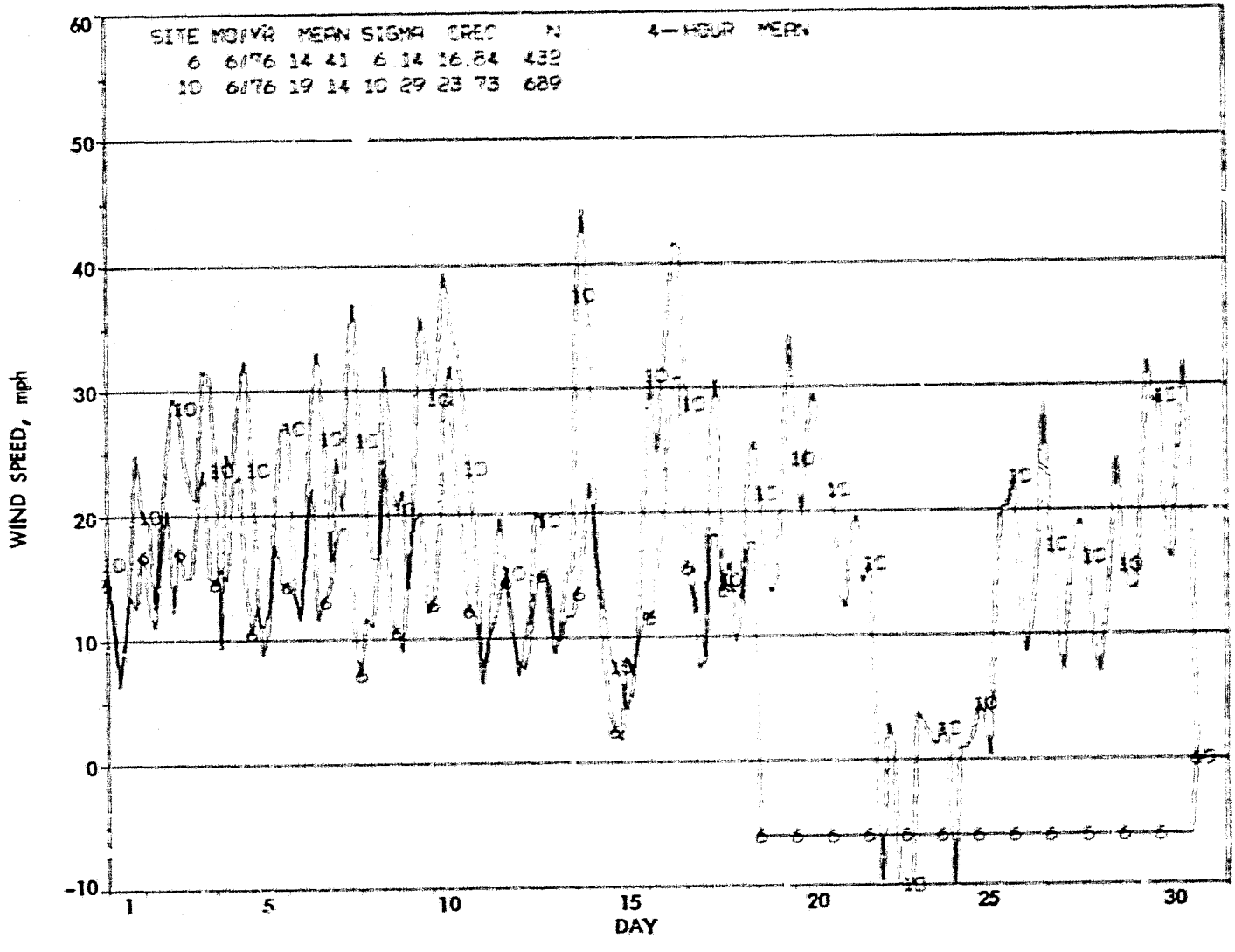


Figure 2-29. Monthly Wind Speeds for June 1976: Sites 6 and 10

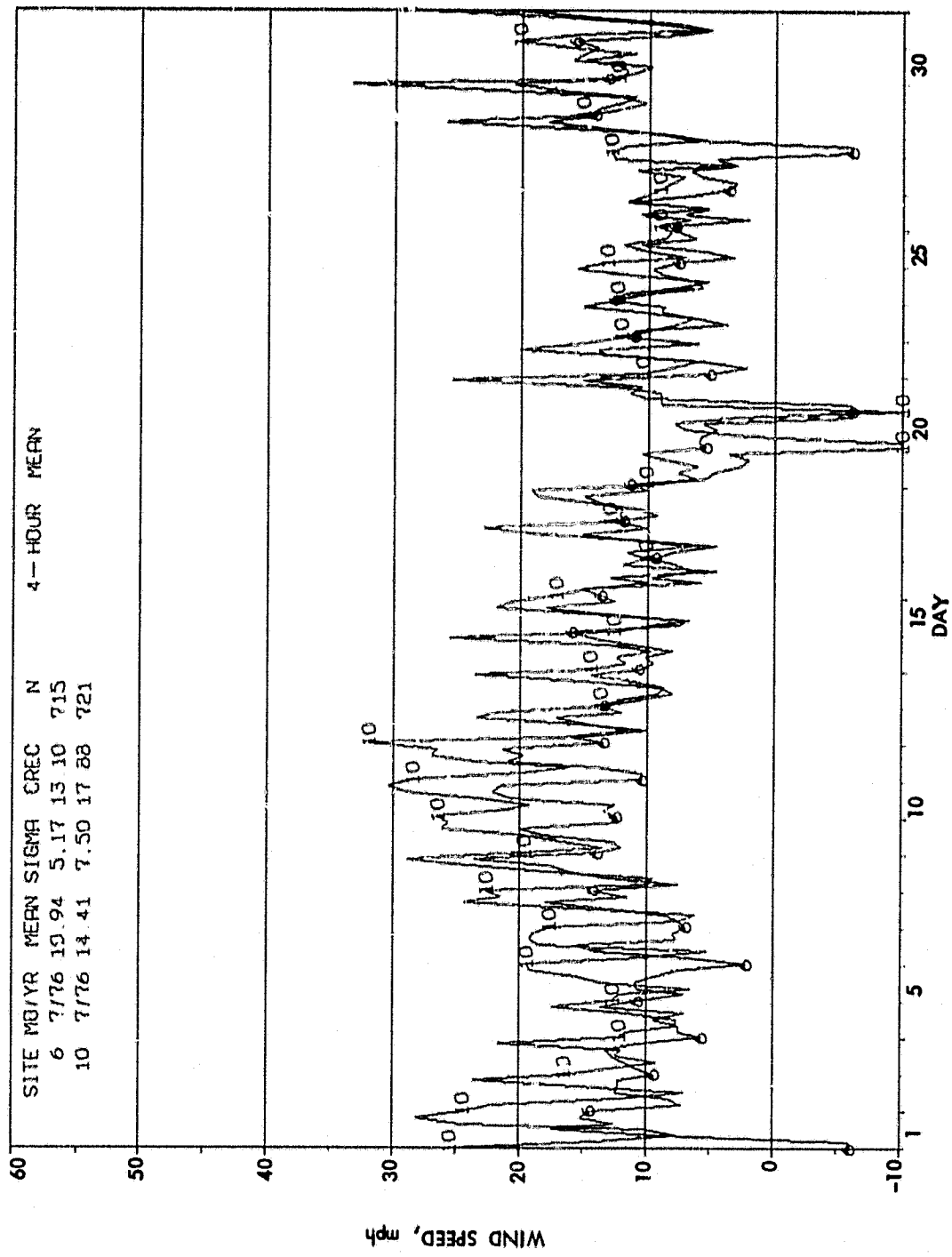


Figure 2-30. Monthly Wind Speeds for July 1976: Sites 6 and 10

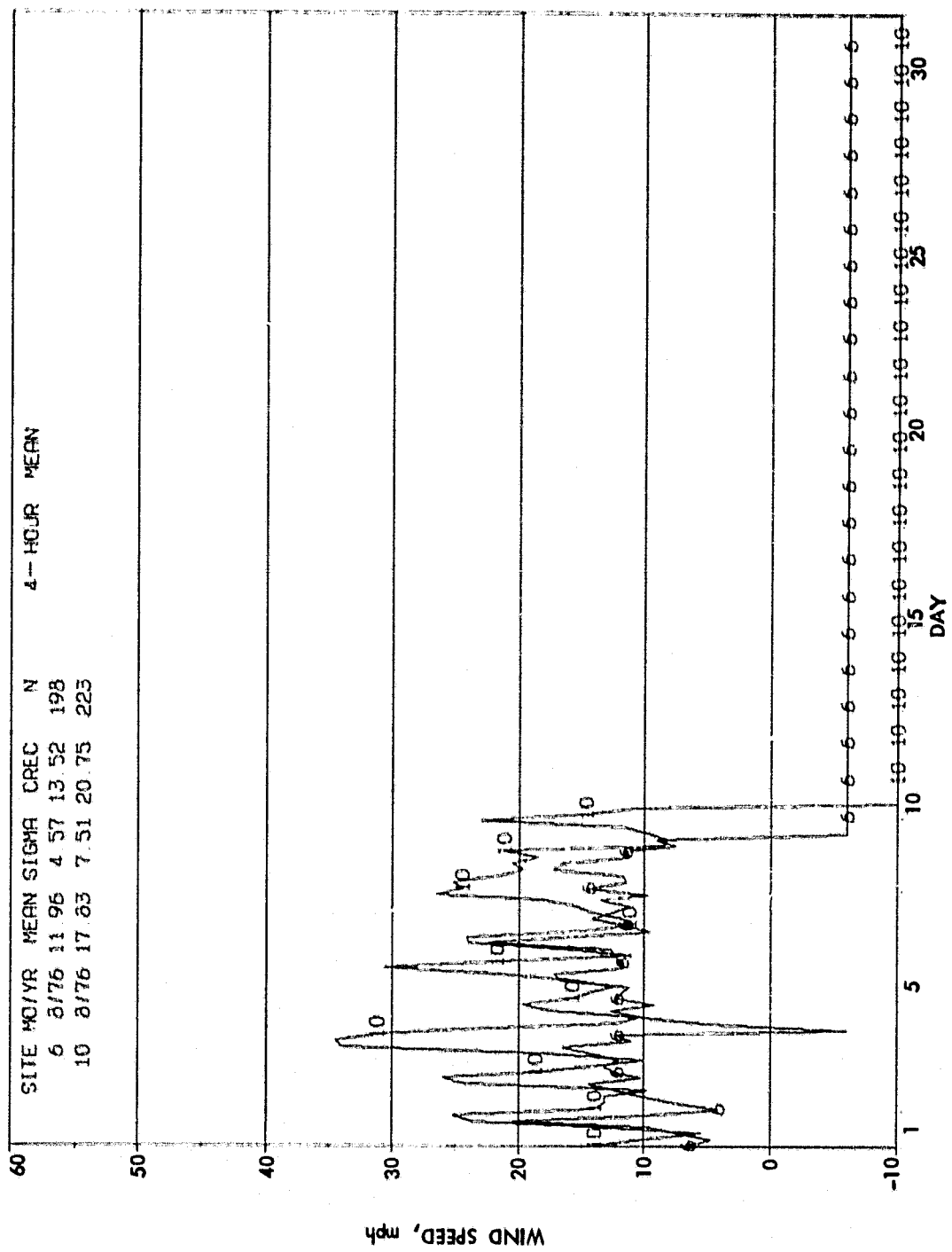


Figure 2-31. Monthly Wind Speeds for August 1976: Sites 6 and 10

SECTION III

COMPARATIVE SITE STATISTICS

To relate wind speeds at the various sites, comparative statistics were calculated using Site 1 as a reference site. Table 3-1 summarizes the number of hours, N', during which wind speed was recorded at Site 1 and at each of the remaining sites. The total number of observations for each month at Site 1 is given in the right-hand column ("Site 1 TOTAL"), and summaries for the entire period of record are given in the bottom row ("CUMULATIVE"). These values of N' are used in calculating statistics for Tables 3-2 through 3-7. Where less than 100 matching observations were recorded for a given month, N' and all corresponding comparative statistics are indicated by asterisks. All available matching observations, however, are included in calculations of cumulative statistics.

Table 3-2 gives the ratios of the monthly mean at Sites 2 through 10 to the mean at Site 1 for matching sets of data. The ratio, R_j, was calculated as:

$$R_j = \sum_{i=1}^{N'} Y_{ji} \Big/ \sum_{i=1}^{N'} X_i \qquad (2)$$

where j is the site number, Y_{ji} is the mean hourly speed at Site j, X_i is the speed at Site 1 for that same hour, and N' is the number of hours with data at both sites (from Table 3-1). Ratios of all available matching data are given in the bottom row. The right-hand column provides monthly mean speeds at Site 1 using all available data at that site. Where the number of paired speeds in a given month is the same as all observations at Site 1, the mean at Site j can be found by multiplying the mean speed at Site 1 by the appropriate ratio.

Anemometers at approximately the same elevation as Site 1 (Sites 6 and 7) have cumulative ratios of approximately 1.0. Those anemometers at higher elevations (Sites 3, 4, 8, 9, and 10) have slightly higher cumulative ratios, ranging from 1.34 to 1.43. Site 5 has relatively low wind speeds during October and the first half of November 1974, but it would be inappropriate to characterize wind speed at Site 5 based on less than 2 months of data.

Site 2, 156 feet above Site 1, occasionally has a monthly ratio less than Site 1, with a particularly small ratio in July. Inspection of the plot of 6-hour means (Figure 2-17) raises the possibility of errors in data collection. Means at Site 1 for the first 10 days of July are roughly 10 mph greater than those at the remaining sites, during daily maxima as well as minima. After July 10, the date when the strip charts were changed, the means of Site 1 more clearly resemble those of Site 2. Additionally, displacement of Site 1 means occurs from the beginning of this particular strip chart, June 26 (Figure 2-16). Removal of the questionable data increases the June ratio from 0.98 to

1.04 and July's ratio to 0.99. The possibility of error in the data for these 2 months must be considered when analyzing the statistics in the following tables.

Table 3-3 summarizes the ratios of cubed speeds, R_c, at Sites 2 through 10 to the cubed speed at Site 1, where R_c for Site j is given by:

$$R_{cj} = \sum_{i=1}^{N'} Y_{ji}^3 \Big/ \sum_{i=1}^{N'} X_i^3 \qquad (3)$$

The last column contains the cube root of the mean cubed speed, CREC, at Site 1 using all available data. Where the number of paired observations is equal to all available data at Site 1, the mean cubed speed at Sites 2 through 10 can be calculated by cubing CREC and multiplying it by the appropriate ratio.

As in Table 3-2, the cumulative cubed speeds at Sites 6 and 7 are approximately the same as at Site 1, although there can be considerable variability in the monthly ratios. Cubed speeds at Site 2 are consistently higher than those at Site 1. The remaining sites have cubed speeds about 2.5 times greater than those at Site 1; monthly ratios of these sites exhibit great fluctuations, as exemplified by the range of ratios at Site 10, 1.79 to 5.43.

Tables 3-4 and 3-5, showing the mean square speed at Site 1 and the mean cross-product of speeds at Site 1 and Sites 2 through 10, provide the terms for the denominator and numerator of the slope, B, of the best fit line passing through the origin. The slope, B, for Site j is computed as:

$$B_j = \sum_{i=1}^{N'} X_i Y_{ji} \Big/ \sum_{i=1}^{N'} X_i^2 \qquad (4)$$

The mean square cross-product is obtained by dividing the numerator of Eq.(4) by N'. The mean square speed is similarly obtained from the denominator. Slopes of the best fit line, shown in Table 3-6, are approximately 1.0 at lower anemometer heights and 1.25 at higher heights. The slopes are similar to, although almost always smaller than, the corresponding ratios of means.

Table 3-7 gives the correlation coefficient, r, which is calculated for Site j as follows:

$$r_j = N_j \Big/ D_j \qquad (5)$$

where

$$N_j = \left(\frac{1}{N'} \sum_{i=1}^{N'} X_i Y_{ji}\right) - \left(\frac{1}{N'} \sum_{i=1}^{N'} X_i\right)\left(\frac{1}{N'} \sum_{i=1}^{N'} Y_{ji}\right)$$

and

$$D_j = \left[\frac{1}{N'}\sum_{i=1}^{N'} X_i^2 - \left(\frac{1}{N'}\sum_{i=1}^{N'} X_i\right)^2\right]^{1/2}\left[\frac{1}{N'}\sum_{i=1}^{N'} Y_{ji}^2 - \left(\frac{1}{N'}\sum_{i=1}^{N'} Y_{ji}\right)^2\right]^{1/2}$$

The weak correlations of all sites in July increase after removing the questionable 2-week period in July from all data sets; the correlation coefficient for Site 2, for example, increases from 0.45 to 0.91. The strongest correlation with Site 1 is at Site 2 (156 feet above Site 1 on the same tower). Correlations with the remaining sites decrease with increasing distance from Site 1. At locations with two anemometers, correlation with Site 1 is strongest for the lower anemometer.

Table 3-1. Number of Data Points for Matching Hours, N[1]

SITE	2	3	4	5	6	7	8	9	10	SITE 1 TOTAL
1974										
OCT	667	412	543	565	640	655	624	359	667	675
NOV	618	611	499	295	470	559	599	*****	541	619
DEC	735	717	732	*****	634	637	669	411	*****	737
1975										
JAN	678	486	373	*****	503	347	165	202	200	689
FEB	623	605	474	*****	595	619	*****	283	518	623
MAR	657	572	644	*****	627	102	143	135	368	659
APR	703	703	700	*****	702	340	701	696	699	703
MAY	695	354	622	*****	695	695	613	656	608	696
JUN	716	580	422	*****	429	*****	562	706	285	716
JUL	744	654	711	*****	739	*****	744	629	743	744
AUG	344	330	193	*****	480	*****	105	505	428	583
SEP	695	*****	*****	*****	685	*****	*****	*****	680	697
OCT	556	*****	*****	*****	556	*****	*****	*****	552	597
NOV	457	*****	*****	*****	460	*****	*****	*****	416	461
DEC	650	*****	*****	*****	651	*****	*****	*****	636	652
1976										
JAN	741	*****	*****	*****	740	*****	*****	*****	738	742
FEB	694	*****	*****	*****	694	*****	*****	*****	692	695
MAR	648	*****	*****	*****	714	*****	*****	*****	737	745
APR	716	*****	*****	*****	716	*****	*****	*****	716	719
MAY	*****	*****	*****	*****	137	*****	*****	*****	137	137
CUMULATIVE										
	12391	6024	5913	860	11867	4040	4948	4624	10416	12847

Table 3-2. Ratio of Means (Site j/Site 1)

SITE	2	3	4	5	6	7	8	9	10	SITE 1 MEAN
1974										
OCT	.94	1.23	1.21	.69	.75	.81	.91	1.11	1.30	11.26
NOV	1.09	1.35	1.50	.56	.70	.78	1.20	*****	1.35	8.21
DEC	1.25	1.50	1.64	*****	.88	.88	1.26	1.57	*****	9.08
1975										
JAN	1.12	1.61	1.80	*****	1.02	1.08	1.57	1.51	1.71	7.88
FEB	1.16	1.60	1.58	*****	1.06	1.10	*****	1.67	1.41	9.55
MAR	1.14	1.51	1.60	*****	1.07	.97	1.36	1.67	1.52	12.95
APR	1.02	1.39	1.45	*****	1.01	.99	1.30	1.33	1.47	13.11
MAY	1.13	1.36	1.51	*****	1.09	1.02	1.32	1.44	1.62	10.50
JUN	.98	1.14	1.32	*****	.95	*****	1.24	1.33	1.36	13.41
JUL	.79	1.12	1.09	*****	.82	*****	1.04	1.05	1.18	14.31
AUG	1.05	1.38	1.43	*****	.89	*****	1.25	1.40	1.57	11.49
SEP	1.36	*****	*****	*****	1.16	*****	*****	*****	1.56	5.31
OCT	1.14	*****	*****	*****	.91	*****	*****	*****	1.56	10.58
NOV	1.13	*****	*****	*****	.98	*****	*****	*****	1.52	10.76
DEC	1.17	*****	*****	*****	.95	*****	*****	*****	1.46	8.78
1976										
JAN	1.12	*****	*****	*****	.77	*****	*****	*****	1.42	7.70
FEB	1.06	*****	*****	*****	.89	*****	*****	*****	1.38	12.04
MAR	1.05	*****	*****	*****	1.01	*****	*****	*****	1.46	11.15
APR	.93	*****	*****	*****	.93	*****	*****	*****	1.89	11.83
MAY	*****	*****	*****	*****	.97	*****	*****	*****	1.33	12.73
CUMULATIVE										
	1.06	1.36	1.45	.65	.94	.98	1.19	1.34	1.43	10.56

Table 3-3. Ratio of Cubed Speeds (Site j/Site 1)

SITE	2	3	4	5	6	7	8	9	10	SITE 1 MEAN
1974										
OCT	.98	2.10	1.85	.53	.77	.83	1.22	1.94	2.41	14.07
NOV	1.21	2.10	2.63	.39	.61	.69	1.83	*****	2.83	10.90
DEC	1.52	2.61	2.49	*****	.92	.87	1.58	2.66	*****	13.94
1975										
JAN	1.47	3.53	4.00	*****	1.41	1.46	3.04	2.88	5.43	12.56
FEB	1.43	3.42	3.09	*****	1.37	1.60	*****	3.99	3.28	14.31
MAR	1.25	2.78	3.11	*****	1.16	.93	2.02	3.07	2.67	18.19
APR	1.06	2.45	2.70	*****	1.14	1.03	2.36	2.48	2.91	16.92
MAY	1.24	2.15	2.95	*****	1.19	1.04	2.24	2.92	3.26	15.23
JUN	1.00	1.85	2.35	*****	.91	*****	2.28	2.54	2.61	16.58
JUL	.55	1.54	1.51	*****	.62	*****	1.35	1.38	1.79	16.57
AUG	1.09	2.53	2.86	*****	.73	*****	2.21	2.55	3.11	14.40
SEP	1.55	*****	*****	*****	1.24	*****	*****	*****	3.44	8.19
OCT	1.20	*****	*****	*****	.99	*****	*****	*****	3.12	15.80
NOV	1.22	*****	*****	*****	1.09	*****	*****	*****	2.56	16.60
DEC	1.28	*****	*****	*****	1.18	*****	*****	*****	2.64	13.71
1976										
JAN	1.26	*****	*****	*****	.71	*****	*****	*****	3.01	12.04
FEB	1.08	*****	*****	*****	.93	*****	*****	*****	2.11	18.15
MAR	.99	*****	*****	*****	1.22	*****	*****	*****	2.85	16.59
APR	.87	*****	*****	*****	.96	*****	*****	*****	3.28	15.75
MAY	*****	*****	*****	*****	1.06	*****	*****	*****	3.07	14.40
CUMULATIVE	1.11	2.39	2.56	.51	1.01	1.07	1.92	2.45	2.73	15.13

Table 3-4. Mean Square Speed at Site 1 for Matching Hours at Sites 2 through 10

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	161.99	134.01	154.14	157.87	155.44	163.72	166.88	207.79	154.42	160.22
NOV	91.14	91.96	103.97	85.38	108.66	97.76	91.59	******	91.24	91.10
DEC	135.28	129.15	135.62	******	145.17	153.48	139.07	180.32	******	135.20
1975										
JAN	106.82	107.32	126.48	******	114.05	142.17	169.93	202.13	106.26	105.23
FEB	146.44	129.37	126.25	******	147.24	142.80	******	165.76	119.14	146.44
MAR	246.41	241.67	222.36	******	246.95	118.08	309.03	259.76	281.15	249.95
APR	229.12	229.12	224.93	******	229.30	229.47	226.16	223.80	227.92	229.12
MAY	164.44	164.68	153.80	******	167.33	167.87	161.46	141.04	157.95	167.66
JUN	229.20	220.45	234.78	******	234.62	******	229.03	219.05	253.19	229.20
JUL	242.30	237.90	247.81	******	241.55	******	242.30	249.85	242.54	242.30
AUG	182.12	149.12	145.72	******	178.58	******	74.86	174.79	148.62	171.02
SEP	48.60	******	******	******	47.35	******	******	******	46.39	48.88
OCT	181.63	******	******	******	181.63	******	******	******	176.90	181.32
NOV	184.14	******	******	******	195.03	******	******	******	197.74	194.63
DEC	123.10	******	******	******	125.36	******	******	******	107.01	120.14
1976										
JAN	99.09	******	******	******	99.25	******	******	******	93.62	98.99
FEB	230.52	******	******	******	230.48	******	******	******	230.86	230.43
MAR	209.75	******	******	******	186.00	******	******	******	196.97	195.42
APR	189.20	******	******	******	185.25	******	******	******	189.49	189.91
MAY	******	******	******	******	184.91	******	******	******	184.91	184.91
CUMULATIVE										
	168.32	170.11	176.15	133.01	169.67	153.50	182.55	201.60	166.07	168.40

Table 3-5. Mean Cross-Product for Matching Hours at Site 1

SITE	2	3	4	5	6	7	8	9	10
1974									
OCT	156.39	162.59	178.47	114.02	121.41	156.55	150.46	227.95	192.63
NOV	95.82	111.86	137.11	51.83	78.90	75.61	101.05	******	114.55
DEC	156.30	171.05	180.33	******	130.50	133.38	153.84	237.33	******
1975									
JAN	116.02	152.10	192.18	******	111.02	141.86	231.78	274.11	162.76
FEB	163.50	186.45	177.55	******	151.95	151.33	******	251.33	156.29
MAR	261.34	327.40	313.17	******	245.34	107.62	337.44	328.90	367.11
APR	230.45	302.48	307.86	******	228.18	216.52	284.25	287.51	309.31
MAY	175.08	206.68	213.87	******	170.34	160.31	198.55	188.21	222.91
JUN	222.85	249.92	247.43	******	211.31	******	277.81	279.87	296.49
JUL	178.20	243.86	245.70	******	179.84	******	230.35	236.58	257.09
AUG	186.58	195.63	198.59	******	147.62	******	91.27	228.41	204.73
SEP	51.75	******	******	******	42.89	******	******	******	49.89
OCT	190.32	******	******	******	161.02	******	******	******	244.90
NOV	197.79	******	******	******	184.38	******	******	******	257.89
DEC	134.62	******	******	******	117.88	******	******	******	131.59
1976									
JAN	106.51	******	******	******	79.17	******	******	******	118.35
FEB	257.27	******	******	******	210.98	******	******	******	282.36
MAR	209.73	******	******	******	185.75	******	******	******	262.62
APR	169.76	******	******	******	169.86	******	******	******	268.47
MAY	******	******	******	******	173.55	******	******	******	240.30
CUMULATIVE									
	169.54	213.61	226.94	92.69	154.55	141.21	203.62	248.87	212.93

Table 3-6. Slope of Best Fit Line Through Origin

SITE	2	3	4	5	6	7	8	9	10
1974									
OCT	.97	1.21	1.16	.72	.78	.83	.90	1.10	1.25
NOV	1.05	1.22	1.32	.61	.73	.77	1.10	*****	1.26
DEC	1.16	1.32	1.33	*****	.90	.87	1.11	1.32	*****
1975									
JAN	1.10	1.42	1.52	*****	.97	1.00	1.36	1.36	1.53
FEB	1.12	1.44	1.41	*****	1.03	1.06	*****	1.52	1.31
MAR	1.06	1.35	1.41	*****	.99	.91	1.09	1.27	1.31
APR	1.01	1.32	1.37	*****	1.00	.94	1.26	1.28	1.36
MAY	1.06	1.25	1.39	*****	1.02	.96	1.23	1.33	1.41
JUN	.97	1.13	1.27	*****	.90	*****	1.21	1.28	1.17
JUL	.74	1.03	.99	*****	.74	*****	.95	.95	1.06
AUG	1.02	1.31	1.36	*****	.83	*****	1.22	1.31	1.38
SEP	1.06	*****	*****	*****	.91	*****	*****	*****	1.08
OCT	1.05	*****	*****	*****	.89	*****	*****	*****	1.38
NOV	1.07	*****	*****	*****	.95	*****	*****	*****	1.30
DEC	1.09	*****	*****	*****	.94	*****	*****	*****	1.23
1976									
JAN	1.07	*****	*****	*****	.80	*****	*****	*****	1.26
FEB	1.03	*****	*****	*****	.92	*****	*****	*****	1.22
MAR	1.00	*****	*****	*****	1.00	*****	*****	*****	1.33
APR	.90	*****	*****	*****	.92	*****	*****	*****	1.40
MAY	*****	*****	*****	*****	.94	*****	*****	*****	1.30
CUMULATIVE	1.01	1.26	1.29	.70	.91	.92	1.12	1.23	1.29

Table 3-7. Correlation Coefficient

SITE	2	3	4	5	6	7	8	9	10
1974									
OCT	.97	.85	.75	.85	.78	.82	.68	.68	.73
NOV	.93	.70	.62	.80	.76	.70	.65	*****	.64
DEC	.95	.80	.75	*****	.86	.82	.80	.69	*****
1975									
JAN	.94	.78	.79	*****	.77	.75	.76	.77	.72
FEB	.95	.82	.83	*****	.85	.81	*****	.82	.76
MAR	.90	.79	.77	*****	.80	.77	.46	.48	.71
APR	.96	.86	.86	*****	.85	.81	.82	.81	.73
MAY	.93	.85	.85	*****	.55	.83	.81	.78	.72
JUN	.91	.80	.80	*****	.71	*****	.78	.76	.22
JUL	.45	.44	.38	*****	.35	*****	.35	.32	.32
AUG	.97	.83	.83	*****	.66	*****	.82	.75	.60
SEP	.69	*****	*****	*****	.58	*****	*****	*****	.30
OCT	.92	*****	*****	*****	.82	*****	*****	*****	.80
NOV	.93	*****	*****	*****	.85	*****	*****	*****	.77
DEC	.96	*****	*****	*****	.83	*****	*****	*****	.64
1976									
JAN	.97	*****	*****	*****	.85	*****	*****	*****	.71
FEB	.98	*****	*****	*****	.92	*****	*****	*****	.79
MAR	.97	*****	*****	*****	.87	*****	*****	*****	.78
APR	.84	*****	*****	*****	.83	*****	*****	*****	.75
MAY	*****	*****	*****	*****	.58	*****	*****	*****	.60
CUMULATIVE									
	.91	.78	.74	.85	.81	.79	.71	.69	.71

SECTION IV

INDIVIDUAL SITE STATISTICS

Tables 4-1 through 4-5 provide the individual site statistics using all available data. These tables summarize the following information: number of observations at each site (Table 4-1), mean monthly speed (Table 4-2), cube root of the expected cubed speed (Table 4-3), standard deviation (Table 4-4), and pattern factor (Table 4-5). As in Tables 3-1 through 3-7, if less than 100 observations occurred in a given month, asterisks indicate that corresponding statistics were omitted. Again, all available observations were included in the cumulative statistics given in the bottom row of each table.

As shown in Table 4-2, mean wind speeds for the period of record were about 10 mph for Sites 1, 2, 6, and 7, and about 15 mph at the remaining sites. With the exception of Site 7, the means were highest in March 1975 at Sites 2 through 10. After deleting the suspect June and July data of Site 1, the maximum monthly mean shifted from July to April, the same month as the maximum for Site 7. Site 9 had the highest monthly mean (22.64 mph in March 1975) as well as the highest cumulative mean (16.53 mph).

The cube roots of the expected cubed speeds (CREC), as shown in Table 4-3, vary from 15 mph for the lower elevation anemometers (Sites 1, 2, 6, and 7) to 20.5 at Sites 3, 4, 8, 9, and 10. In addition to the highest mean speeds, Site 9 has the highest values of CREC: 27.5 mph in March 1975 and 21.62 mph overall.

In order to identify possible seasonal patterns of wind speeds, mean monthly speeds at Sites 1 and 2 were plotted and are shown in Figure 4-1. The great variability of speeds throughout this brief period of record makes it difficult to define any seasonal pattern for these sites. There are neither pronounced maxima nor readily distinguishable seasons of low speeds. Frequently, moving averages can be used to "smooth" an otherwise erratic curve to a point where a pattern is distinguishable. In Figure 4-2, a 3-month moving average (plotted at the middle month) is presented, along with mean speeds of Site 1. The smoothed curve suggests higher speeds between March and July, with a secondary maximum in November.

This very general pattern is also suggested when comparing the monthly means and CRECs of all sites to their respective record values (Table 4-6). Of those sites with 100 or more observations in a given month, more than half have monthly means greater than the respective record mean between February and August (except May) and in October. The monthly CRECs are greater than the record CRECs during a slightly longer period from January through July, and in October.

The standard deviations in Table 4-4 are about the same magnitude as the corresponding mean. Random processes with standard deviations as large as these relative to their means are statistically considered as being erratic and having large variability.

Table 4-5 shows the pattern factor, K_e, which is calculated as

$$K_e = \frac{1}{N}\sum_{i=1}^{N} X_i^3 \Bigg/ \left(\frac{1}{N}\sum_{i=1}^{N} X_i\right)^3 \qquad (6)$$

where X_i is the mean hourly wind speed at any given site. For Sites 1, 2, 6, and 10, the four sites with at least 20 months of data, the summer months (July through August) have smaller values of K_e than during the remainder of the year; maximum values of K_e occur between October and January. The larger pattern factors are associated with lower elevations, indicating that the cube of the mean at lower elevations does not increase as rapidly relative to the mean of cubed speeds as does the cubed mean at higher elevations.

Comparisons of data from anemometers at different heights in the same location were made and cumulative statistics for these comparisons are summarized in Table 4-7. As expected, the lower anemometer of each tower (the first site listed in each column) has the lower speed and lower cubed speed in all cases. Sites 5 and 6 are omitted from the above table because of the small amount of matching data available.

The ratios of means from this series of computations can be used to evaluate α, the power law exponent of the theoretical ratio of speeds at two different heights:

$$\frac{X_a}{X_0} = \left(\frac{Z_a}{Z_0}\right)^{\alpha} \qquad (7)$$

where X_a is the speed at height Z_a and X_0 is the speed at height Z_0. Usually this exponent is expected to range from 1/7 for flat, open country to 1/2.5 for urban areas. The computed values of α, shown in Table 4-8, are considerably smaller than the expected 1/7. Cumulative values range between 1/12 to 1/18 with monthly values ranging from 1/2.2 to 1/35 (September 1975 and April 1975 for Sites 1 and 2).

The cumulative value of α for the Mars site (Sites 1 and 2), 0.0841, can be compared to the value found in JPL TM 33-802, 0.1405. Although the latter value is closer to the theoretical value for this type of terrain, 1/7, the ratio of means as evaluated from the right half of Eq.(7), 1.10, is not much different than that for the 1975 data, 1.06.

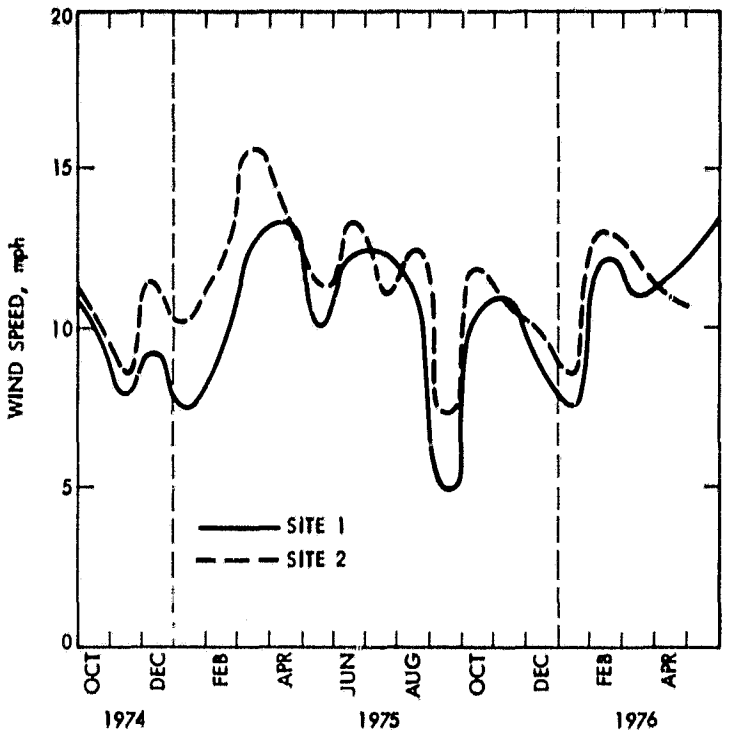


Figure 4-1. 1975 Mean Monthly Wind Speed for Sites 1 and 2

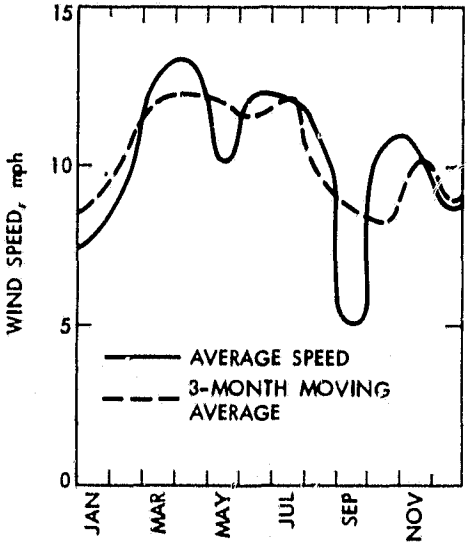


Figure 4-2. 1975 Mean Monthly Wind Speed and 3-Month Moving Average for Site 1

Table 4-1. Total Number of Observations at Each Site

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	671	443	597	596	670	723	649	377	674	675
NOV	655	640	524	295	491	574	656	*****	570	619
DEC	742	724	739	*****	639	639	676	411	*****	737
1975										
JAN	728	533	375	*****	554	350	166	202	200	689
FEB	667	638	507	*****	642	666	*****	318	556	623
MAR	740	649	726	*****	712	102	165	157	430	659
APR	720	720	717	*****	719	350	718	713	716	703
MAY	735	394	663	*****	739	740	656	698	652	696
JUN	716	581	423	*****	430	*****	583	707	286	716
JUL	744	654	711	*****	739	*****	744	629	743	744
AUG	346	332	195	*****	480	*****	105	511	432	583
SEP	718	*****	*****	*****	686	*****	*****	*****	682	697
OCT	742	*****	*****	*****	743	*****	*****	*****	736	557
NOV	715	*****	*****	*****	718	*****	*****	*****	674	461
DEC	738	*****	*****	*****	742	*****	*****	*****	726	652
1976										
JAN	742	*****	*****	*****	741	*****	*****	*****	736	742
FEB	695	*****	*****	*****	694	*****	*****	*****	693	695
MAR	648	*****	*****	*****	715	*****	*****	*****	738	743
APR	716	*****	*****	*****	717	*****	*****	*****	717	719
MAY	*****	*****	*****	*****	744	*****	*****	*****	743	137
CUMULATIVE	13230	6308	6171	891	13315	4230	5121	4773	11763	12847

Table 4-2. Mean Wind Speed--All Observations

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	10.65	12.74	13.61	7.83	8.45	9.23	10.39	14.23	14.44	11.26
NOV	8.78	10.98	13.10	4.68	6.19	6.66	9.75	*****	10.91	8.21
DEC	11.30	13.50	14.86	*****	8.26	8.66	11.42	17.20	*****	9.08
1975										
JAN	9.12	13.01	15.40	*****	8.72	10.03	16.25	17.73	13.34	7.88
FEB	12.22	15.28	15.07	*****	11.40	11.46	*****	18.82	13.36	9.55
MAR	15.54	20.45	20.66	*****	14.75	8.90	20.62	22.64	21.44	12.95
APR	13.30	18.21	18.87	*****	13.22	12.54	17.01	17.40	19.40	13.11
MAY	11.60	14.07	15.45	*****	11.39	10.75	13.55	13.99	16.64	10.50
JUN	13.20	14.95	17.97	*****	12.99	*****	16.57	17.48	19.53	13.41
JUL	11.55	15.79	15.93	*****	11.75	*****	14.95	15.22	16.89	14.31
AUG	12.51	14.62	14.83	*****	10.51	*****	9.51	16.33	16.68	11.49
SEP	7.52	*****	*****	*****	6.06	*****	*****	*****	8.06	5.31
OCT	11.74	*****	*****	*****	9.18	*****	*****	*****	15.57	10.58
NOV	10.33	*****	*****	*****	8.57	*****	*****	*****	13.36	10.76
DEC	9.63	*****	*****	*****	7.86	*****	*****	*****	11.39	8.78
1976										
JAN	8.62	*****	*****	*****	5.96	*****	*****	*****	10.67	7.70
FEB	12.62	*****	*****	*****	10.69	*****	*****	*****	16.62	12.04
MAR	12.10	*****	*****	*****	10.96	*****	*****	*****	16.38	11.15
APR	10.93	*****	*****	*****	10.96	*****	*****	*****	17.62	11.83
MAY	*****	*****	*****	*****	12.07	*****	*****	*****	17.96	12.73
CUMULATIVE										
	11.14	15.03	16.17	6.79	10.01	9.80	13.64	16.53	15.10	10.56

Table 4-3. Cube Root of Expected Cubed Speed--All Observations

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	14.00	16.81	17.24	11.60	12.95	13.39	15.27	19.27	18.42	14.07
NOV	11.49	13.86	15.72	7.34	9.83	9.84	13.18	*****	15.18	10.90
DEC	15.98	16.68	18.85	*****	13.97	15.95	16.45	21.47	*****	13.94
1975										
JAN	14.72	19.35	21.44	*****	15.37	16.56	21.97	22.99	21.81	12.56
FEB	18.02	21.19	21.09	*****	17.74	17.99	*****	24.60	20.81	14.31
MAR	20.41	25.56	25.55	*****	20.16	11.85	25.01	27.51	27.12	18.19
APR	17.30	22.87	23.34	*****	17.69	17.50	22.42	22.69	24.28	16.92
MAY	16.04	18.75	20.33	*****	16.30	15.66	19.50	19.60	21.58	15.23
JUN	16.59	19.88	22.06	*****	16.05	*****	21.79	21.99	23.36	16.58
JUL	13.81	18.97	19.20	*****	14.08	*****	18.31	18.75	20.12	16.57
AUG	15.30	18.44	19.17	*****	13.25	*****	12.50	19.83	19.66	14.40
SEP	10.06	*****	*****	*****	8.67	*****	*****	*****	12.03	8.19
OCT	16.44	*****	*****	*****	14.96	*****	*****	*****	22.05	15.80
NOV	15.66	*****	*****	*****	15.18	*****	*****	*****	19.88	16.60
DEC	13.91	*****	*****	*****	13.93	*****	*****	*****	16.19	13.71
1976										
JAN	13.00	*****	*****	*****	10.73	*****	*****	*****	16.85	12.04
FEB	18.64	*****	*****	*****	17.72	*****	*****	*****	23.29	18.13
MAR	17.10	*****	*****	*****	17.34	*****	*****	*****	23.57	16.59
APR	15.02	*****	*****	*****	15.18	*****	*****	*****	23.36	15.75
MAY	*****	*****	*****	*****	14.80	*****	*****	*****	22.26	14.40
CUMULATIVE										
	15.81	20.15	20.88	10.55	15.54	15.14	18.96	21.62	20.97	15.13

Table 4-4. Standard Deviation--All Observations

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	6.27	7.43	7.32	5.85	6.81	6.67	7.47	8.91	7.93	5.79
NOV	4.95	5.80	6.06	4.03	5.35	5.14	6.04	*****	7.09	4.87
DEC	7.67	9.20	8.21	*****	8.05	7.80	8.18	9.09	*****	7.27
1975										
JAN	7.85	9.79	10.39	*****	8.63	9.18	10.43	10.72	12.10	6.56
FEB	9.33	10.42	10.44	*****	9.69	9.81	*****	13.56	11.11	7.44
MAR	9.41	11.19	10.90	*****	9.83	5.80	10.16	11.52	12.22	9.07
APR	7.76	9.82	9.75	*****	8.39	8.53	10.38	10.37	10.51	7.56
MAY	7.59	8.55	9.16	*****	8.01	7.73	9.60	9.48	9.54	7.58
JUN	7.13	9.66	9.27	*****	6.79	*****	10.13	9.67	9.35	7.04
JUL	5.67	7.52	7.71	*****	5.62	*****	7.54	7.76	7.86	6.12
AUG	6.57	7.94	8.58	*****	5.76	*****	5.61	8.19	7.45	6.25
SEP	4.56	*****	*****	*****	4.33	*****	*****	*****	6.08	4.54
OCT	8.03	*****	*****	*****	8.08	*****	*****	*****	11.06	8.33
NOV	8.11	*****	*****	*****	8.57	*****	*****	*****	10.34	8.88
DEC	6.76	*****	*****	*****	7.63	*****	*****	*****	7.82	7.15
1976										
JAN	6.55	*****	*****	*****	6.22	*****	*****	*****	8.72	6.30
FEB	9.16	*****	*****	*****	9.67	*****	*****	*****	11.16	9.24
MAR	9.29	*****	*****	*****	9.33	*****	*****	*****	11.97	8.43
APR	6.83	*****	*****	*****	7.17	*****	*****	*****	10.61	7.07
MAY	*****	*****	*****	*****	6.20	*****	*****	*****	9.46	4.78
CUMULATIVE										
	7.66	9.45	9.29	5.52	8.08	7.97	9.16	9.90	10.20	7.54

Table 4-5. Pattern Factor--All Observations

SITE	2	3	4	5	6	7	8	9	10	SITE 1
1974										
OCT	2.28	2.30	2.05	3.25	3.61	3.06	3.17	2.48	2.08	1.95
NOV	2.24	2.01	1.75	3.85	4.00	3.22	2.47	*****	2.69	2.34
DEC	2.83	2.77	2.04	*****	4.84	4.19	2.99	1.95	*****	3.62
1975										
JAN	4.20	3.29	2.70	*****	5.48	4.50	2.47	2.18	4.37	4.04
FEB	3.21	2.67	2.74	*****	3.77	3.87	*****	2.82	3.78	3.37
MAR	2.27	1.95	1.89	*****	2.55	2.36	1.76	1.79	2.02	2.77
APR	2.20	1.98	1.89	*****	2.40	2.72	2.29	2.22	1.96	2.15
MAY	2.64	2.37	2.29	*****	2.93	3.09	2.98	2.75	2.18	3.06
JUN	1.98	2.35	1.85	*****	1.89	*****	2.27	1.99	1.71	1.89
JUL	1.80	1.74	1.78	*****	1.72	*****	1.84	1.87	1.69	1.55
AUG	1.92	2.01	2.16	*****	2.00	*****	2.27	1.79	1.64	1.97
SEP	2.39	*****	*****	*****	2.92	*****	*****	*****	3.32	3.65
OCT	2.75	*****	*****	*****	4.33	*****	*****	*****	2.84	3.33
NOV	3.48	*****	*****	*****	5.55	*****	*****	*****	3.29	3.67
DEC	3.01	*****	*****	*****	5.58	*****	*****	*****	2.87	3.81
1976										
JAN	3.43	*****	*****	*****	5.44	*****	*****	*****	3.94	3.82
FEB	3.04	*****	*****	*****	4.55	*****	*****	*****	2.75	3.41
MAR	2.82	*****	*****	*****	3.96	*****	*****	*****	2.98	3.29
APR	2.59	*****	*****	*****	2.65	*****	*****	*****	2.33	2.36
MAY	*****	*****	*****	*****	1.85	*****	*****	*****	1.90	1.45
CUMULATIVE										
	2.82	2.41	2.15	3.76	3.60	3.68	2.68	2.24	2.68	2.94

Table 4-6. Mean and Cube Root of Expected Cube (CREC) Comparisons

Month, 1975	No. of Sites With Means Greater Than Respective Record Means	No. of Sites With More Than 100 Observations	No. of Sites With CREC Greater Than Record CREC
January	3	9	6
February	5	8	6
March	8	9	8
April	9	9	9
May	4	9	6
June	7	8	7
July	6	8	1
August	4	8	0
September	0	3	0
October	3	4	3
November	1	4	1
December	0	4	0

Table 4-7. Wind Speed Variation With Height

Comparative Statistics	Sites		
	1 and 2	3 and 4	8 and 9
Ratio of means	0.93	0.94	0.93
Ratio of cubes	0.86	0.91	0.83
Slope	0.96	0.95	0.92
Correlation of coefficient, r	0.936	0.965	0.952
Range of r	0.910 to 0.982	0.913 to 0.991	0.706 to 0.889

Table 4-8. Computed Values of the Power Law Exponent, α

Year	Month	Sites		
		1 and 2	3 and 4	8 and 9
1974	October	-0.09	0.0752	0.0091
	November	0.12	--	0.12
	December	0.32	0.19	0.09
1975	January	0.16	-0.02	0.09
	February	0.21	--	0.04
	March	0.19	0.15	0.04
	April	0.03	0.03	0.04
	May	0.18	0.07	0.06
	June	-0.03	0.06	0.07
	July	-0.34	0.04	0.04
	August	0.04	0.07	0.03
	September	0.46	--	--
	October	0.19	--	--
	November	0.18	--	--
	December	0.23	--	--
1976	January	0.16	--	--
	February	0.08	--	--
	March	0.07	--	--
	April	-0.10	--	--
	May	--	--	--
Cumulative		0.0841	0.0655	0.0558

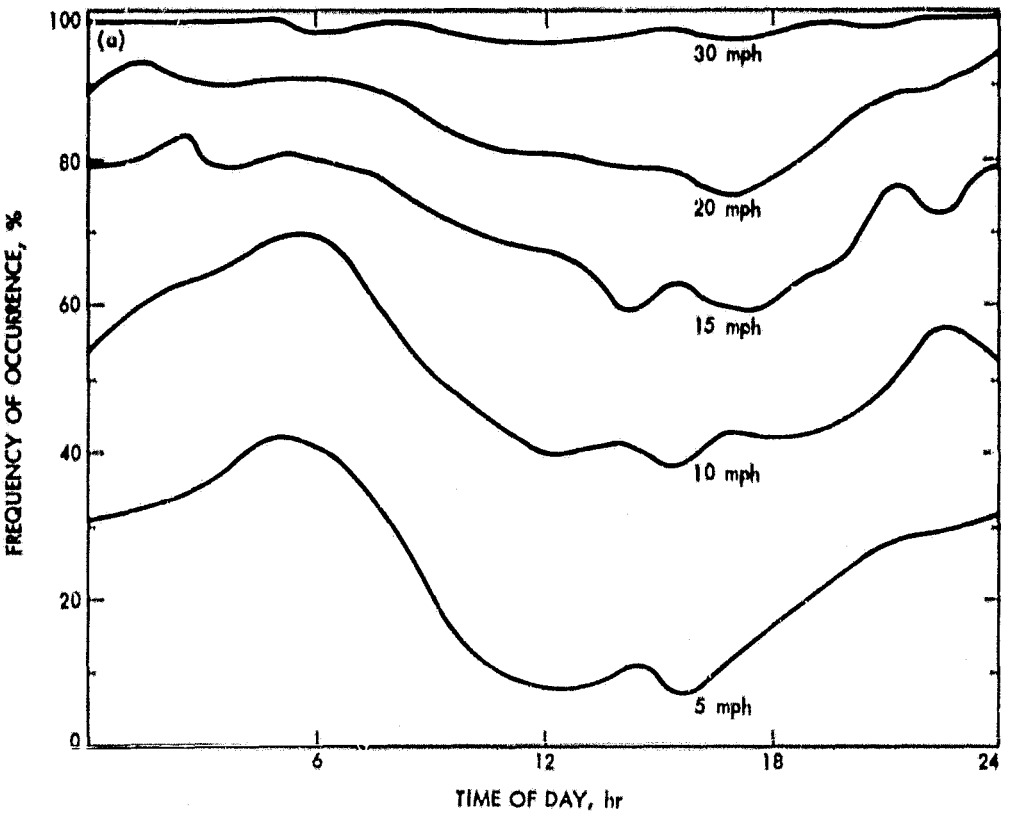
SECTION V

DIURNAL VARIATIONS

Figures 5-1 through 5-4 show curves for the data of Sites 1, 2, 6, and 10 (those with the longest records) categorized and plotted according to hour and frequency of occurrence. With the exception of wind speeds greater than 30 mph, which are likely to occur anytime during the day, the overall pattern for Site 1 is one with higher wind speeds during the afternoon.

While Sites 2 and 6 have diurnal patterns similar to those of Site 1 (Figures 5-2 and 5-3), the patterns for Site 10 differ considerably (Figure 5-4). Wind speeds less than 10 mph and those greater than 29 mph occurred with relatively uniform frequencies at any hour of the day. Wind speeds between 10 and 19 mph are less frequent between 6 PM and midnight, which is the period of maximum frequency for the 20- to 29-mph class. This pattern of higher wind speeds at night more closely resembles that of free air.

Also shown in Figures 5-1 through 5-4 is wind speed frequency for 1975. At Sites 1, 2, and 6, the distributions are quite similar: speeds less than 10 mph occurred about one-half of the time, and speeds between 10 and 20 mph occurred about one-third of the time. At Site 10, however, speeds ranging from 10 to 20 mph are almost as frequent as those less than 10 mph, and wind speeds greater than 20 mph occurred almost 30 percent of the time.



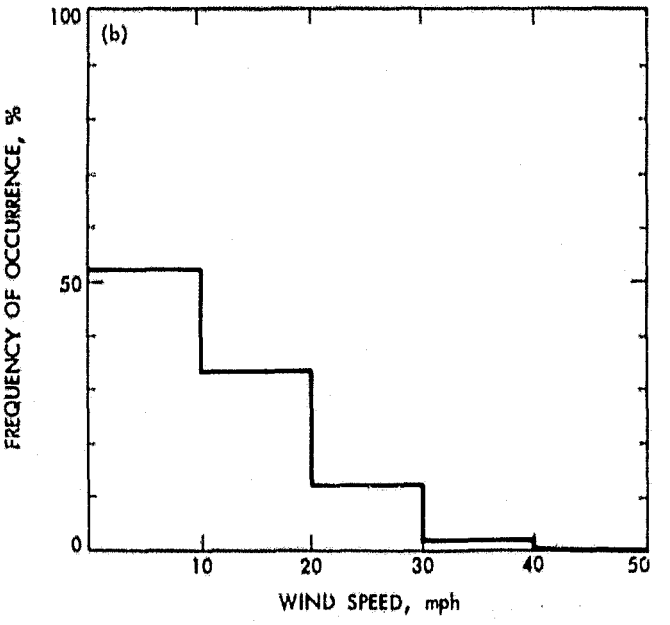


Figure 5-1. 1975 Diurnal Wind Speed Variation for Site 1: (a) Percent of Time Wind Speed Less Than Given Speed, and (b) Annual Frequency of Occurrence

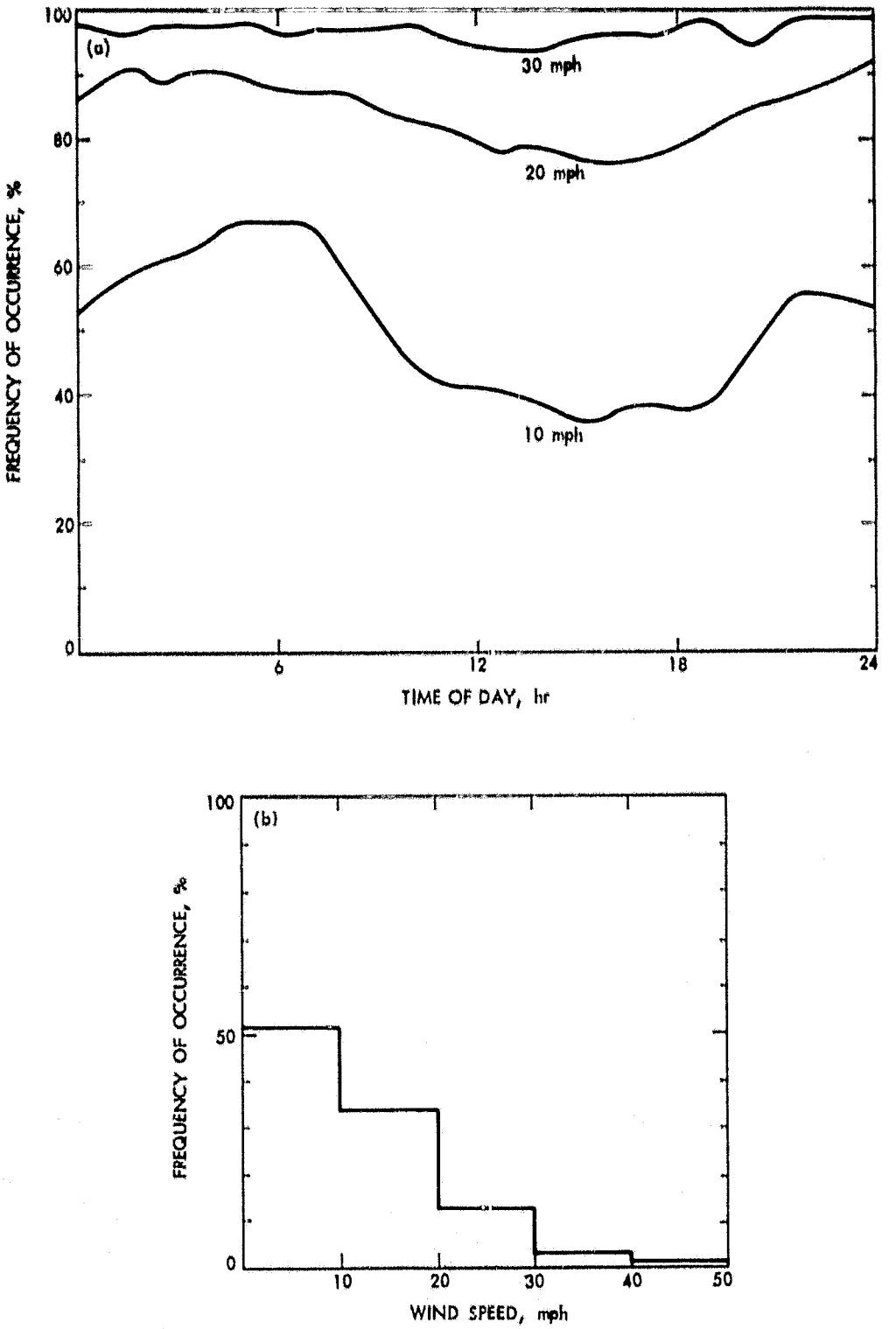
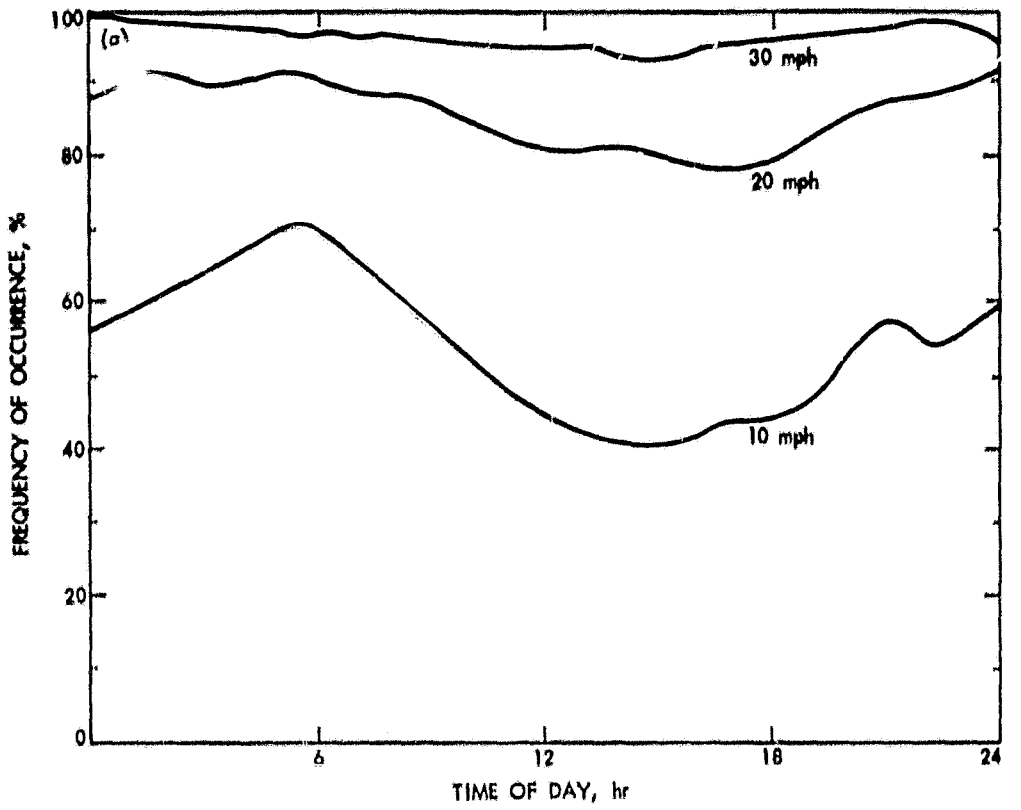


Figure 5-2. 1975 Diurnal Wind Speed Variation for Site 2: (a) Percent of Time Wind Speed Less Than Given Speed, and (b) Annual Frequency of Occurrence



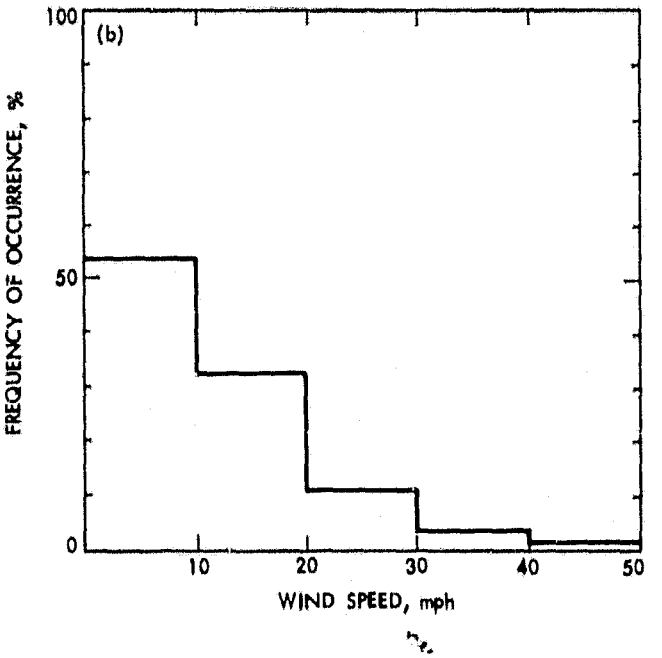
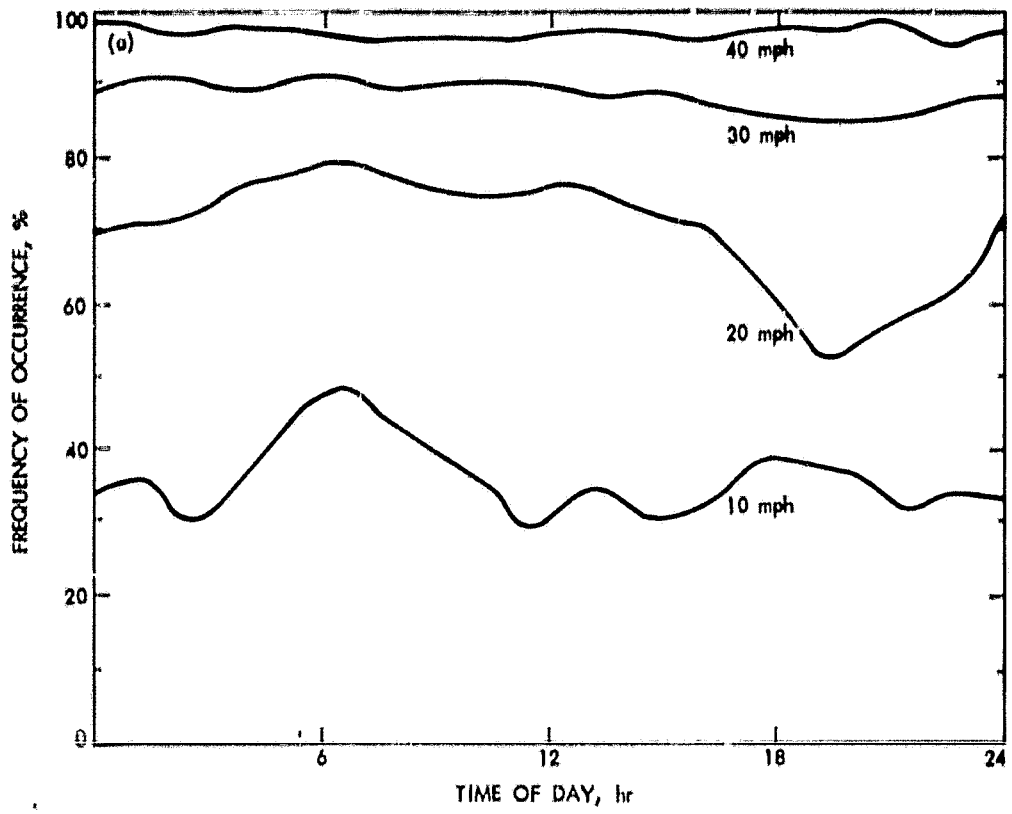


Figure 5-3. 1975 Diurnal Wind Speed Variation for Site 6: (a) Percent of Time Wind Speed Less Than Given Speed, and (b) Annual Frequency of Occurrence



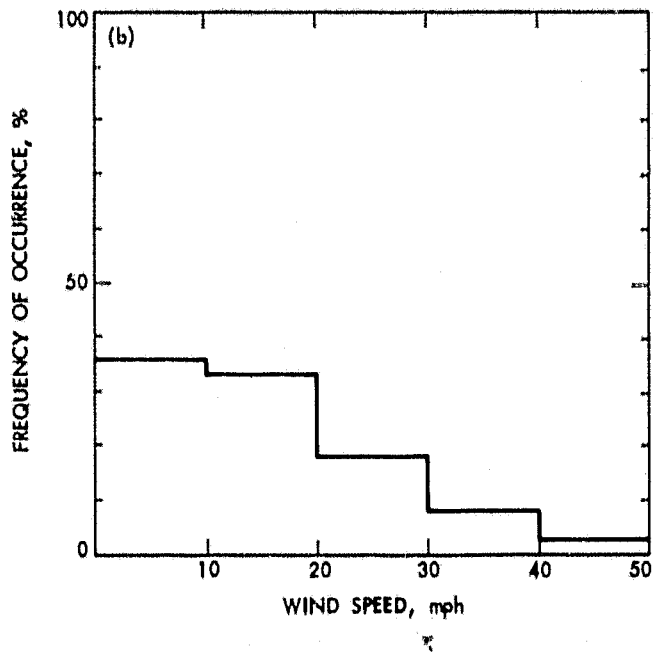


Figure 5-4. 1975 Diurnal Wind Speed Variation for Site 10: (a) Percent of Time Wind Speed Less Than Given Speed, and (b) Annual Frequency of Occurrence

SECTION VI

COMPARISON WITH EARLIER RESULTS

In Table 6-1, some of the statistics of this report are compared with those of the earlier study of winds at Goldstone (Wind Power Prediction Models, Technical Memorandum 33-802, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 15, 1976). Extended data collection during 1966 to 1967 was restricted to the anemometers near the Mars site. Means of Sites 1 and 2 data recorded in 1966 to 1967 are approximately the same as those for 1975. The means of the earlier data fell well within one standard deviation of the later means (standard deviation at Site 1 is 7.54 mph).

Limited sampling was performed at five other locations during 2 days in October (1974), 8 days in November, 5 days in February, and 1 day in March. Despite this relatively small sample, the ratios of means for Sites 4, 9, and 10 are reasonable approximations of the ratios calculated in this report. For Sites 6 and 7, the ratios in the earlier report indicate lower speeds than those at Site 1, whereas the ratios computed in this report indicate speeds of about the same order.

Table 6-1. Comparison of Wind Speed Statistics

Site Number	Mean Wind Speed, mph (Number of Observations)	
	Jan. Through Dec. 1975	Sept. 1966 Through Aug. 1967[a]
1	10.75 (7780)	9.97 (3387)
2	11.45 (8307)	10.94 (3480)
	Ratio of Mean Wind Speed to Site 1 (Number of Observations)	
	All Data, 1975	16 Days, October 1974 Through March 1975
4	1.43 (5913)	1.52 (384)
6	0.94 (11867)	0.739 (360)
7	0.94 (4040)	0.846 (384)
9	1.34 (10416)	1.24 (312)
10	1.43 (12847)	1.47 (360)

[a]Reported earlier in TM 33-802

SECTION VII

SUMMARY

The following points summarize the results of this report:

(1) Sites at lower elevations (1, 2, 6, and 7) have mean and cubed speeds of roughly the same magnitude, while Sites 3, 4, 8, 9, and 10 have higher speeds. Site 9 has the highest cumulative means and cubed speeds.

(2) The monthly variation of wind is similar at all sites. Correlation with Site 1 decreases with increasing distance. At a given location, the correlation of the lower anemometer with Site 1 is stronger than that of the upper anemometer.

(3) Because of the short period of record, only a general description of any seasonal pattern can be made. Higher mean speeds occurred between February and May, and cubed speeds were higher between January and July. Mean and cubed speeds were also relatively high in October.

(4) Diurnal patterns apparently vary with elevation. Sites 1, 2, and 6 have higher speeds in the afternoon, whereas Site 10 and presumably the other higher elevation sites have higher speeds at night.

(5) For Sites 1, 2, and 6, wind speeds of 10 mph and less occurred more than 50 percent of the time. At a windier location such as Site 10, the frequency of these lower speeds is reduced to about 36 percent.

(6) General agreement of the ratio of means with Site 1 and the ratios given in JPL TM 33-802, despite the small sample size of the earlier data, tends to eliminate the need for further sampling to determine available wind energy at Goldstone.

(7) Because of larger mean and cubed speeds and because of accessibility, the three locations of Sites 3, 4, 8, 9, and 10 are considered to be the best possibilities for a demonstration windmill project.