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Characterization of the Wind Field at the Aerial Cable Test Capability Site

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13. ABSTRACT *(Maximum 200 words)*

The U.S. Army is building a test facility in which targets will be suspended or dropped from a 5-km-long aerial cable strung between two mountain ranges across a valley. The facility, known as the Aerial Cable Test Capability, will be located near Jim Site in the north central part of White Sands Missile Range. During the winter and spring of 1992, four meteorological towers, a Doppler sodar, and a rawinsonde system were deployed in the area to collect atmospheric data. Statistics of these data are presented to show the characteristics of the wind field at the facility and help decide which meteorological equipment would be appropriate to support missions there.

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Executive Summary

A new facility, known as the Aerial Cable Test Capability, is being installed on White Sands Missile Range. It will consist of a cable, approximately 5-km long, anchored at two locations several hundred meters above the valley floor. Targets will be suspended or dropped from the cable delivery system. The facility will be used for approximately 400 tests per year. About 20 percent of the tests will involve missile firings from a ground-based launcher system, and the remainder of the tests will consist of items dropped from the cable to simulate an airborne delivery system.

Before the installation of the cable system, atmospheric data were collected for several months to characterize the winds at the site. Four Surface Atmospheric Measurement Stations (SAMS) were situated in the general area that provided measurements. One was located at Jim Site, two were situated in the valley beneath the cable, and another was located at Mockingbird Gap, a few kilometers to the southeast. In order to collect data at the cable height, a phased array sodar was deployed to provide wind measurements every 50 m at 50 to approximately 500 m above the surface. The sodar was initially installed in the valley beneath the cable and was powered by large solar panels. It was found that the solar panels did not provide sufficient power. The sodar was, therefore, moved to Mockingbird Gap and operated on hard power. Additional upper-air wind data were provided by seven rawinsondes flown during March and May.

Analyses of the data provides the following information: (1) there is good agreement in winds among the three valley stations, (2) there is a lack of agreement between the valley winds and the winds at Jim Site near the upper anchor, and (3) the winds measured at Jim Site generally compared with the winds measured by the sodar at 400 and 500 m above Mockingbird Gap, although there was less agreement in direction.

Based on these analyses, the following recommendations are made: (1) utilize the Jim Site SAMS to provide wind loading information at the cable height, and (2) install a SAMS and a sodar on the valley floor to provide continuous vertical profiles of winds from the surface to cable height for operational support. The sodar is completely automatic, and data can be transmitted to other locations. In addition, there are no manpower requirements other than for maintenance.

1. Introduction

The U.S. Army is building a new facility on White Sands Missile Range (WSMR) called the Aerial Cable Test Capability (ACTC). An aerial cable, approximately 5-km long, will be hung several hundred meters above the ground to test missiles and other materials. Targets will be suspended or dropped from a trolley that moves along the cable. The trolley will be capable of accelerations to approximately 150 kn by gravity or up to 500 kn by rockets. Trolley and target combined may weigh up to 7000 lb.

The ACTC will be used for approximately 400 tests per year. About 20 percent of the tests will involve a missile firing from a ground-based launcher toward a suspended target, and the rest will involve items dropped from the trolley to simulate airborne delivery. Figures 1 and 2 show an artists conception of the two types of simulations. Using the cable will be much faster and less expensive than flying remotely controlled targets or dropping material from aircraft.

The ACTC will be approximately 8 km northeast of Mockingbird Gap in the north central part of WSMR. The upper anchor of the cable will be at Jim Site on the crest of the Oscura Mountains at 2530 m above mean sea level (msl), and the lower anchor will be in the Little Burro Mountains at 1830 m msl. The missile impact area occupies the valley floor in between, which slopes from 1700 to 1330 m msl. Figure 3 shows a map. Vegetation is typical of the southwestern U.S. desert. The environmental impact statement gives a more detailed description. [1]

Between February and June 1992, four meteorological towers, a Doppler sodar, and a rawinsonde system were deployed by the U.S. Army Research Laboratory to collect surface and upper-air wind data in the vicinity of the ACTC. Results of analyses of these data is presented in this report to show the characteristics of the wind field in the area of the facility and to help decide which meteorological instrumentation should be installed for mission support.

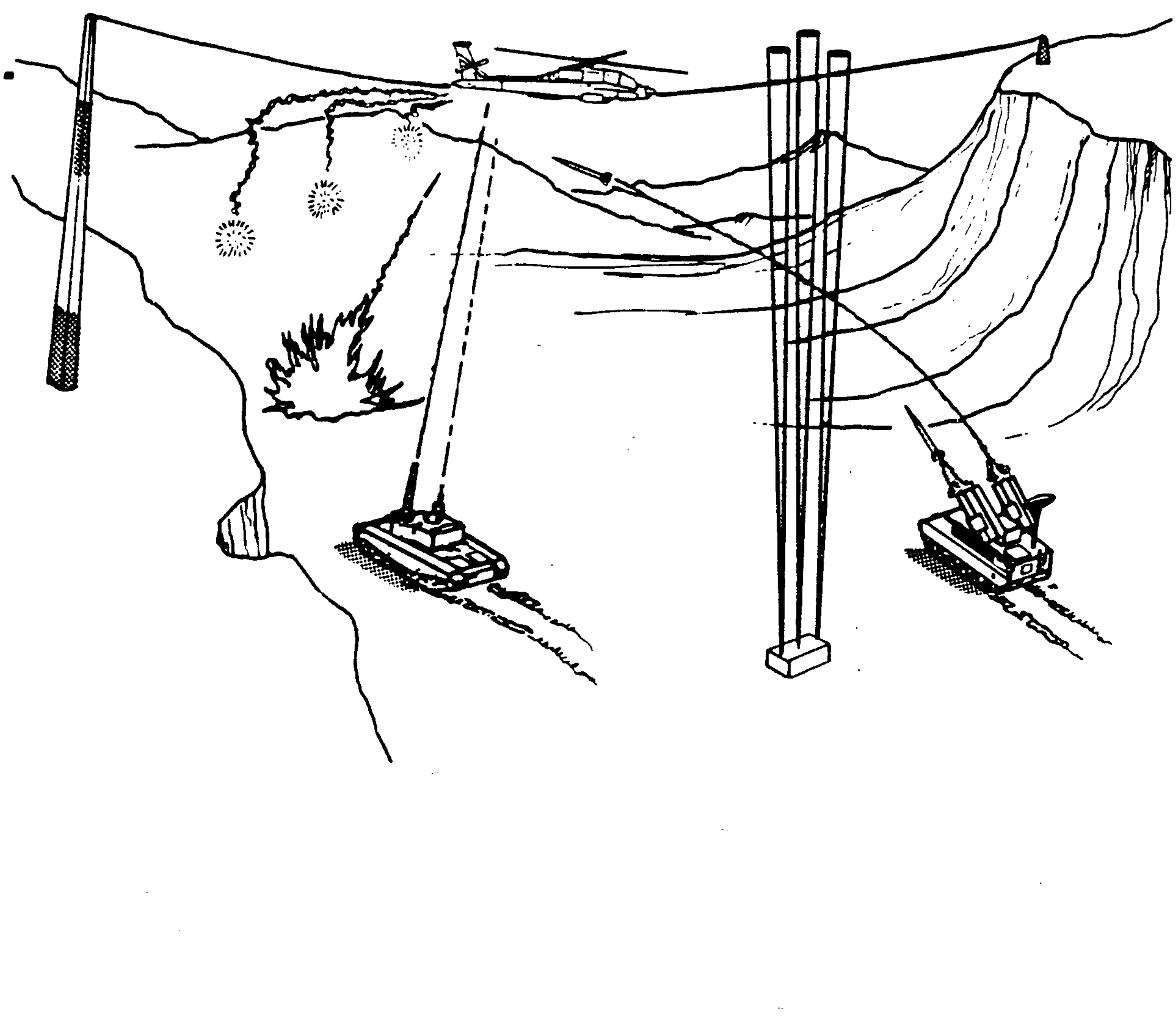


Figure 1. Conceptual operations using suspended target at proposed aerial cable range. Remote wind sensor is shown at center right. [2]

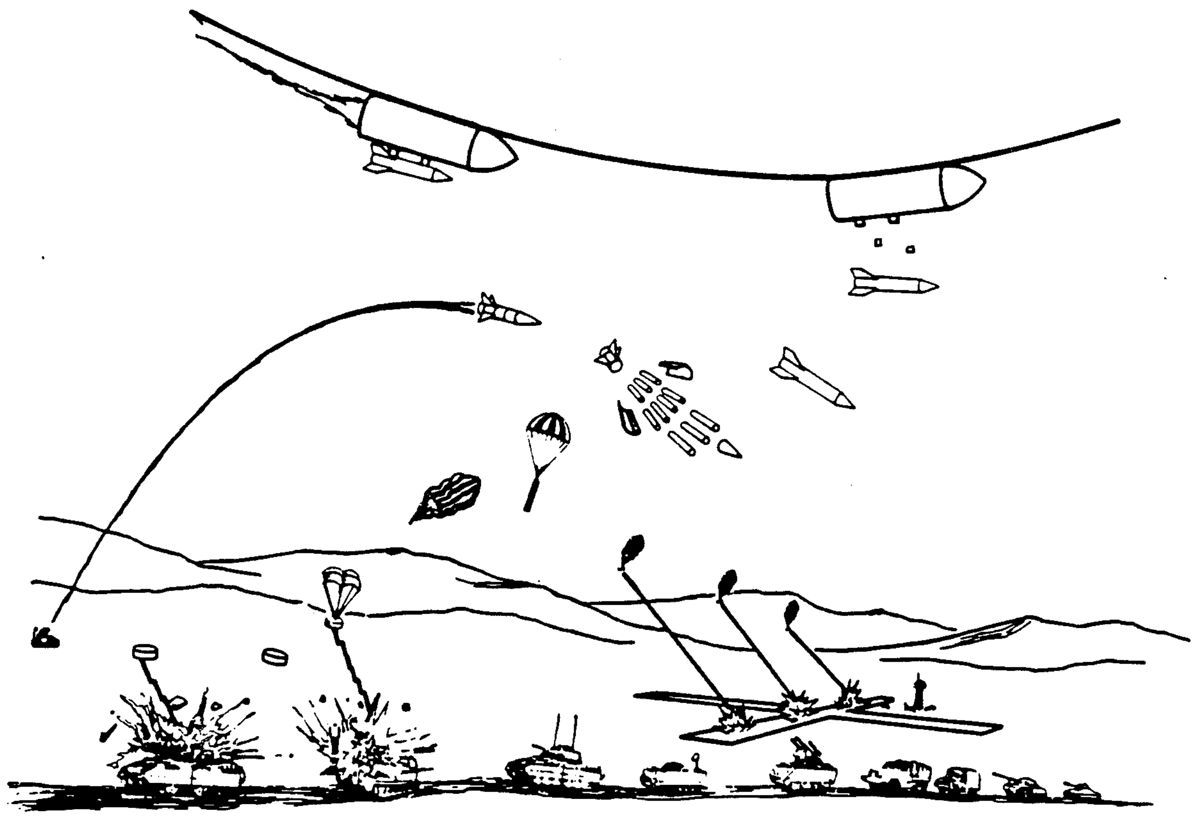


Figure 2. Conceptual operations using dropped material at proposed aerial cable range. [2]

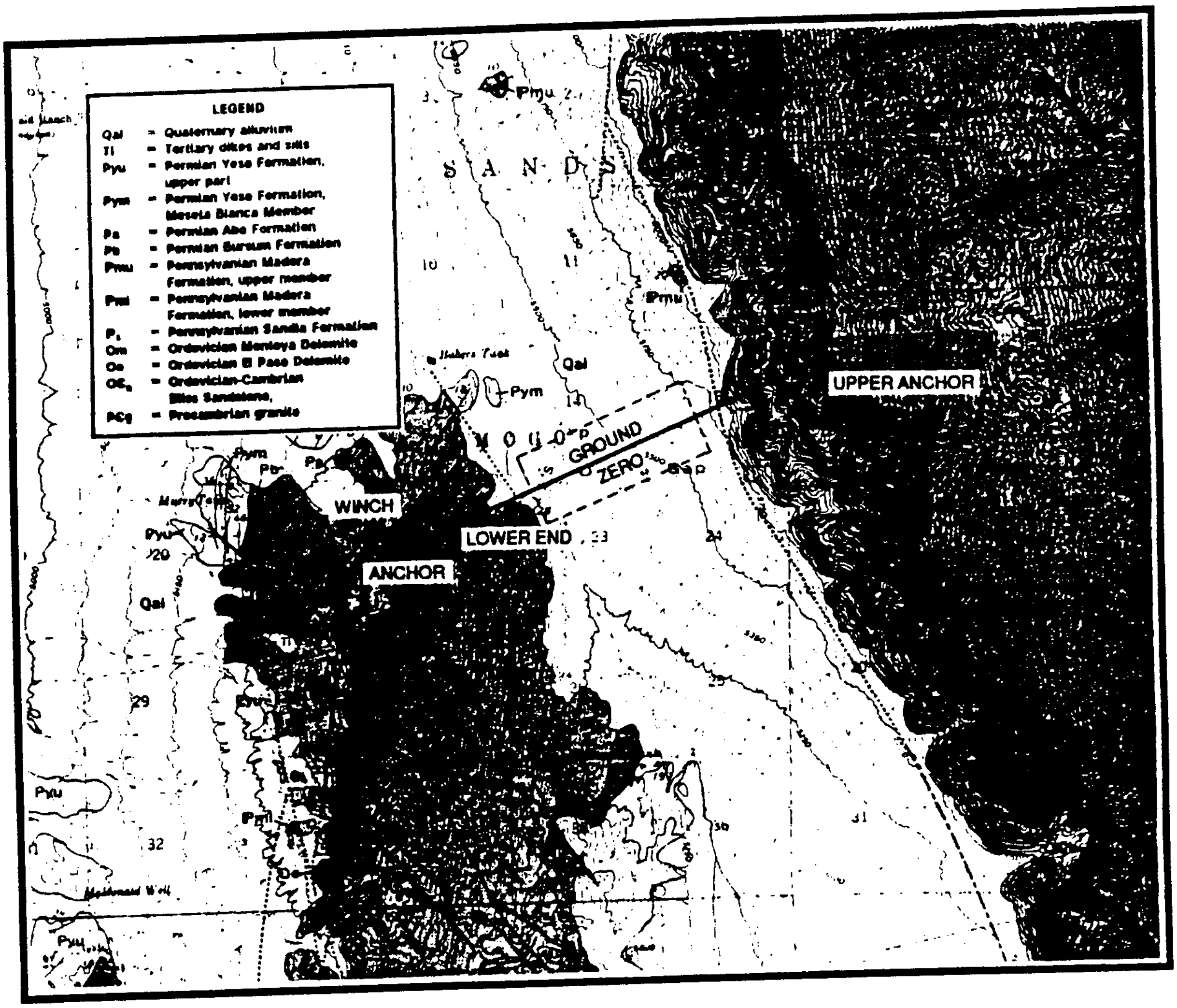


Figure 3. Map of proposed aerial cable range area. [3]

2. Instrumentation and Data Collection

2.1 SAMS

Surface data were collected by four Surface Atmospheric Measurement Stations (SAMS). The SAMS consist of 10-m masts instrumented with standard meteorological sensors. One was situated near the upper anchor at Jim Site (2576 m msl), and two others, Yaw Line (1646 m msl) and Little Burro (1591 m msl), were deployed in the valley to the east. Yaw Line was located near the center of the valley, and Little Burro was situated at the western end, closer to the lower anchor. The remaining tower, at Mockingbird Gap (1633 m msl), was several kilometers southwest of the area on the opposite side of the Little Burro Mountains.

Two-meter wind speed and direction, measured at each tower by wind vanes and propeller anemometers, were processed by SAMS reduction programs to calculate 1-h averaged wind speeds and directions and 1-h peak wind gusts for each hour of the day. The information was available for the Yaw Line, Jim Site, and Little Burro stations between 1 Feb and 30 Apr 92 and for Mockingbird Gap between 1 Feb and 23 Jun 92.

2.2 Sodar

Figure 4 shows upper-air wind data collected by a phased array Doppler sodar. The Doppler sodar remotely measures wind parameters using acoustic soundings. One vertical and two tilted beams are transmitted upward. Changes in the acoustic refractive index caused by temperature fluctuations scatter some of this energy back to the antennas. Doppler shifts in the backscattered signals are used to derive wind velocities along the three beam paths. Horizontal wind speeds and directions are calculated from the radial velocities. Wind data can be measured at heights between 50 m and several hundred meters above the surface continuously for several days without human attention.

The sodar was situated near Yaw Line from 19 Feb to 31 Mar 92 and powered by the solar panel pictured in figure 5. Solar powering was unsuccessful, however, and it was moved to Mockingbird Gap, where power was available. The sodar operated at Mockingbird Gap from 15 Apr to 26 May 92 and again from 17 Jun to 23 Jun 92. The 15-min averaged wind data were collected at 15 heights, 50 m apart, from 50 to 750 m above the surface.

2.3 Rawinsonde

A total of seven radiosondes were released near the site in March and May 1992 and were tracked by a radio theodolite from the surface to 2500 to 3500 m above the surface. Height, derived from sonde pressure and temperature measurements, and balloon-to-ground azimuth and elevation angles, measured by the theodolite, were recorded for every few seconds of flight and later used to calculate wind speeds and directions. Five of the flights were released at Yaw Line, three on 27 Mar 92 and two more on 30 Mar 92. The other two soundings were released at Mockingbird Gap on 29 May 92.

Figure 4. Sodar used in study.

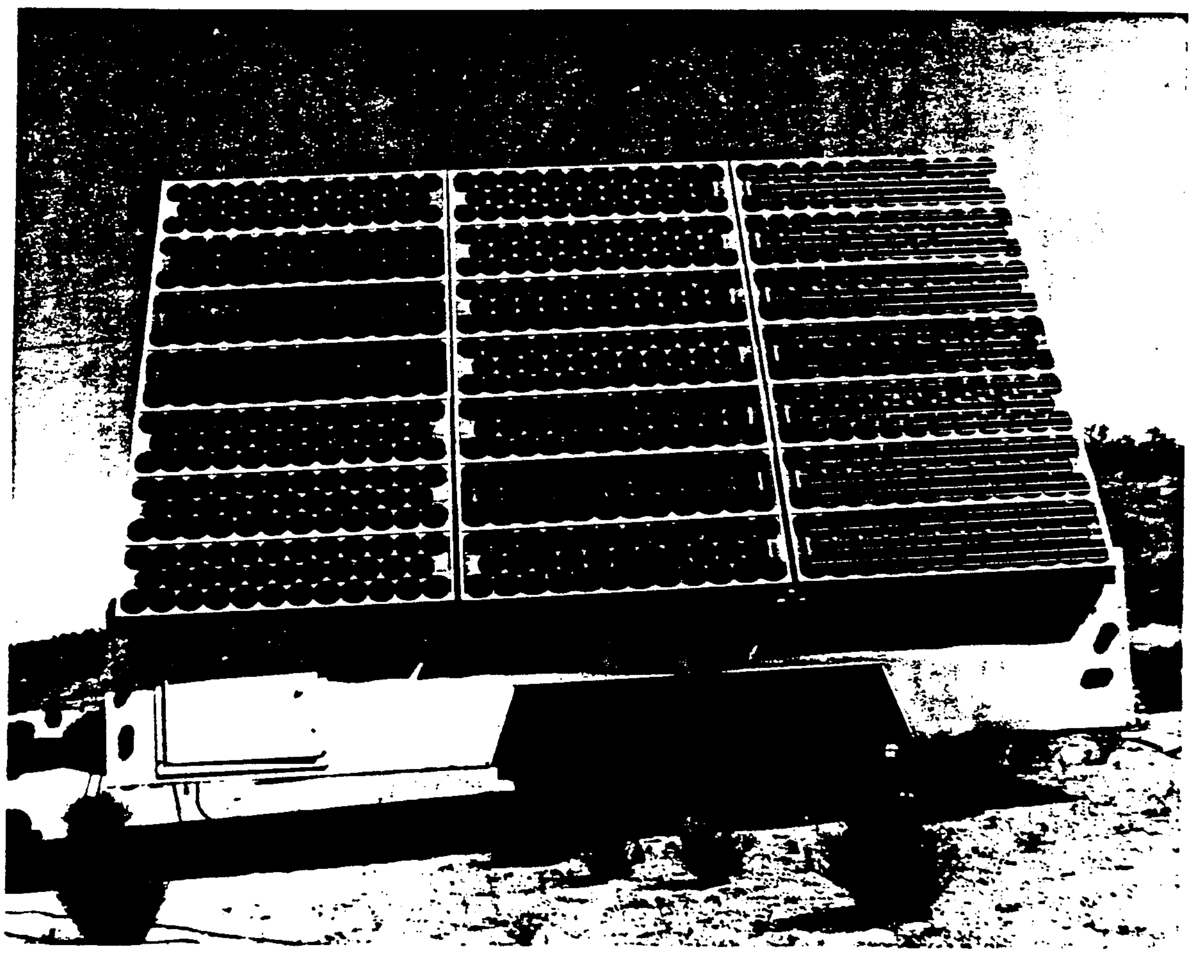


Figure 5. Solar panel used to power sodar during February and March.

3. SAMS Data

3.1 Wind Speed

To characterize the surface wind field at the future ACTC, the available 1-h SAMS data were divided into two groups. The first group was composed of data collected during February, March, and April, when all four stations were operating, and the second consisted of the Mockingbird Gap data collected in May and June, after the other stations were shutdown.

Scalar average wind speeds were calculated for each hour of the day and plotted in figures 6 and 7 for the two data groups. Wind speeds at the three valley locations were comparable, ranging from approximately 3 m s^{-1} in the morning to 4 – 4.5 m s^{-1} in the late afternoon. The Jim Site winds, near the upper anchor, were between 5.5 and 8 m s^{-1}. Unlike the other three stations, the winds were highest in the late evening and early morning and lowest in late morning.

Similarly, in figures 8 and 9, the average peak wind is plotted for each hour. Values at the three valley stations ranged from 5 m s^{-1} in the early morning to 9 m s^{-1} in late afternoon. The Jim Site winds were higher and ranged from 10 to 12 m s^{-1}. The highest wind gusts recorded during the two periods, shown in figures 10 and 11, ranged between 15 and 39 m s^{-1}.

The 25th, 50th, and 75th percentiles of the wind speeds versus time of day are shown in figures 12 through 16. The plot legends represent the percent of data greater than the y-axis value. In figure 12, for example, 25 and 75 percent of the Jim Site winds were greater than 9.5 and 5 m s^{-1}, respectively, at 0100.

The wind-speed frequency distributions for each station are plotted in figures 17 and 18. Again, the three valley locations were comparable, but the Jim Site wind speeds were higher.

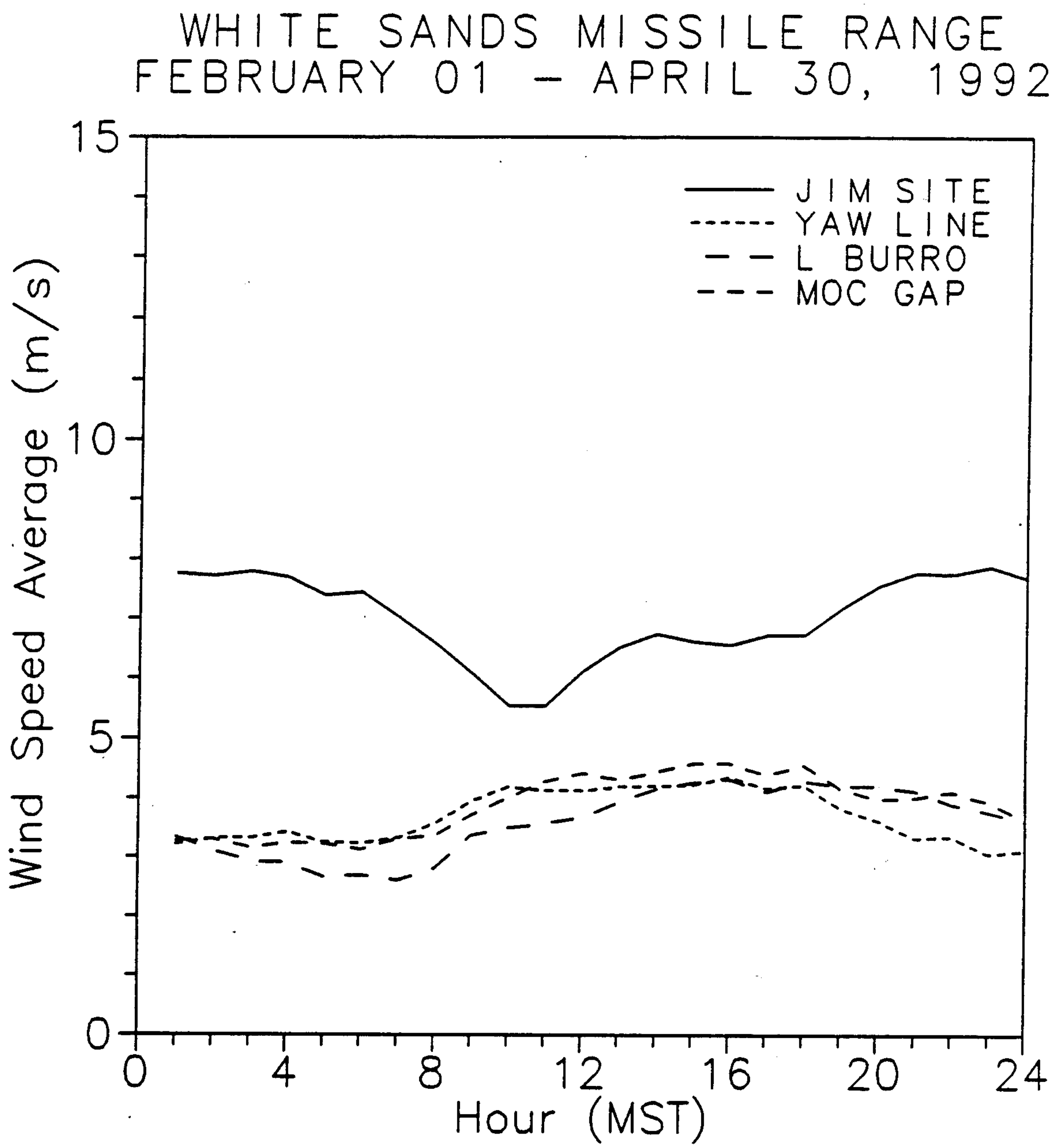


Figure 6. Scalar average wind speed versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap between 1 Feb and 30 Apr 92.

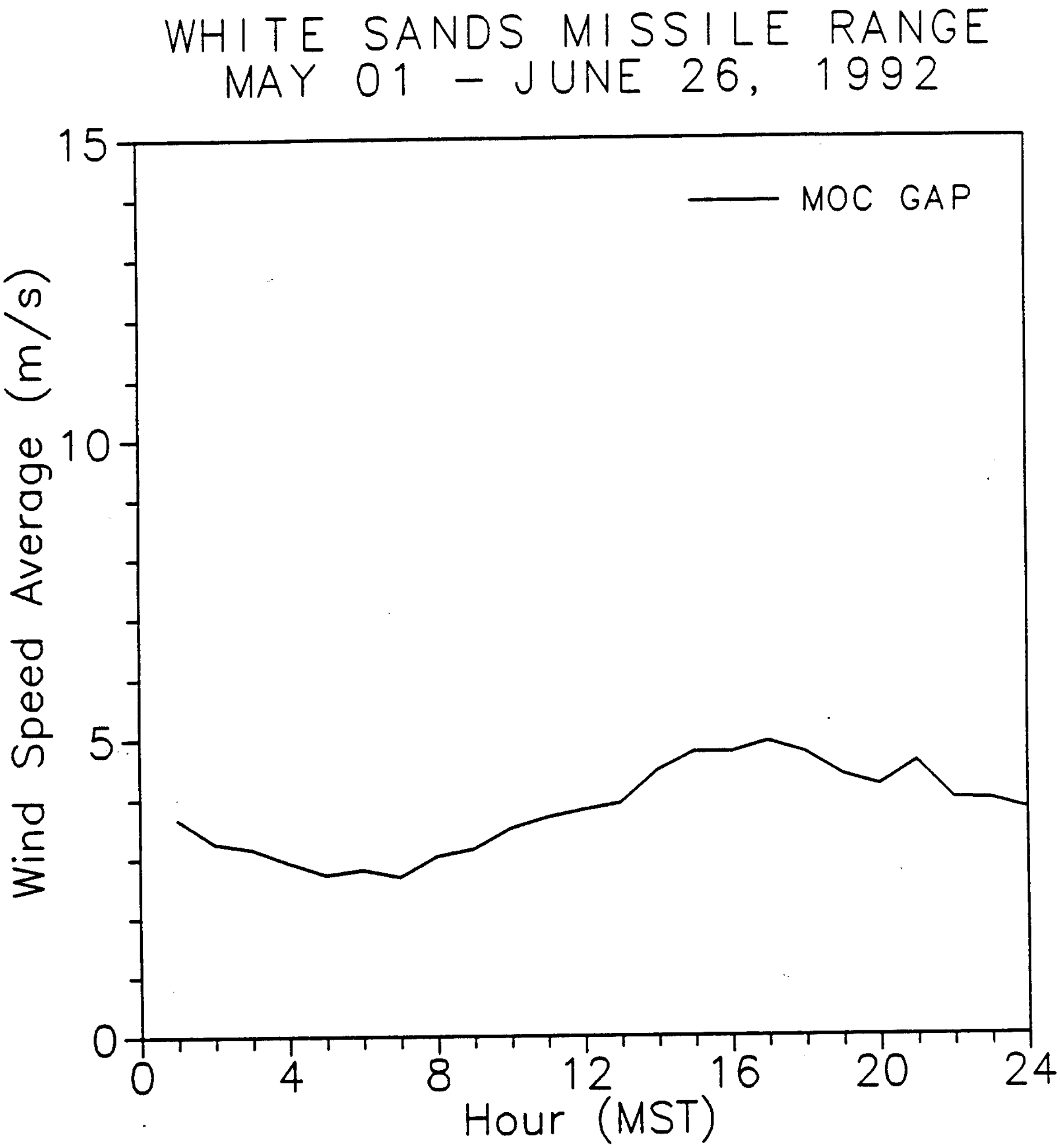


Figure 7. Scalar average wind speed versus time of day at Mockingbird Gap between 1 May and 26 Jun 92.

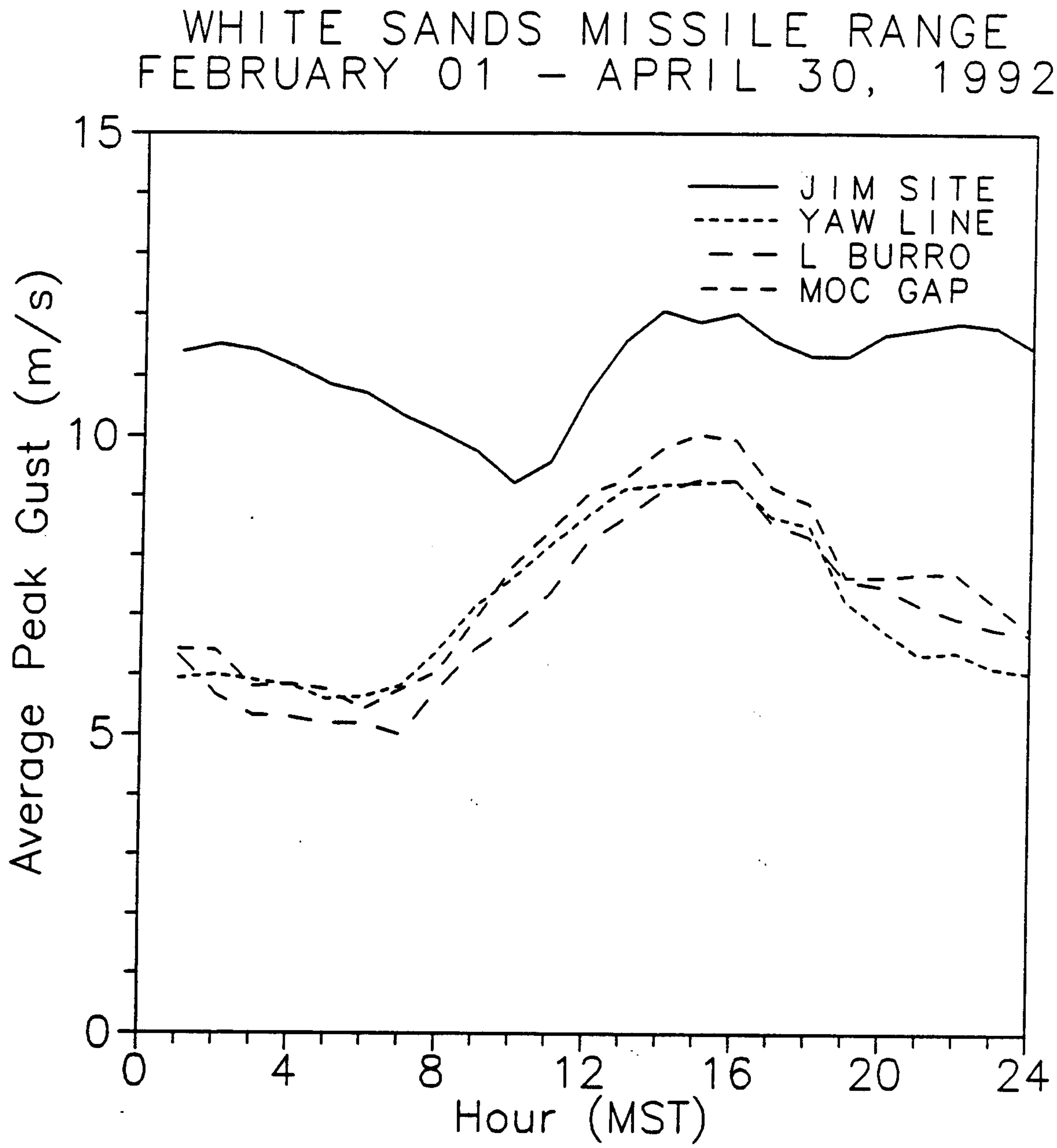


Figure 8. Average peak wind gust versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap between 1 Feb and 30 Apr 92.

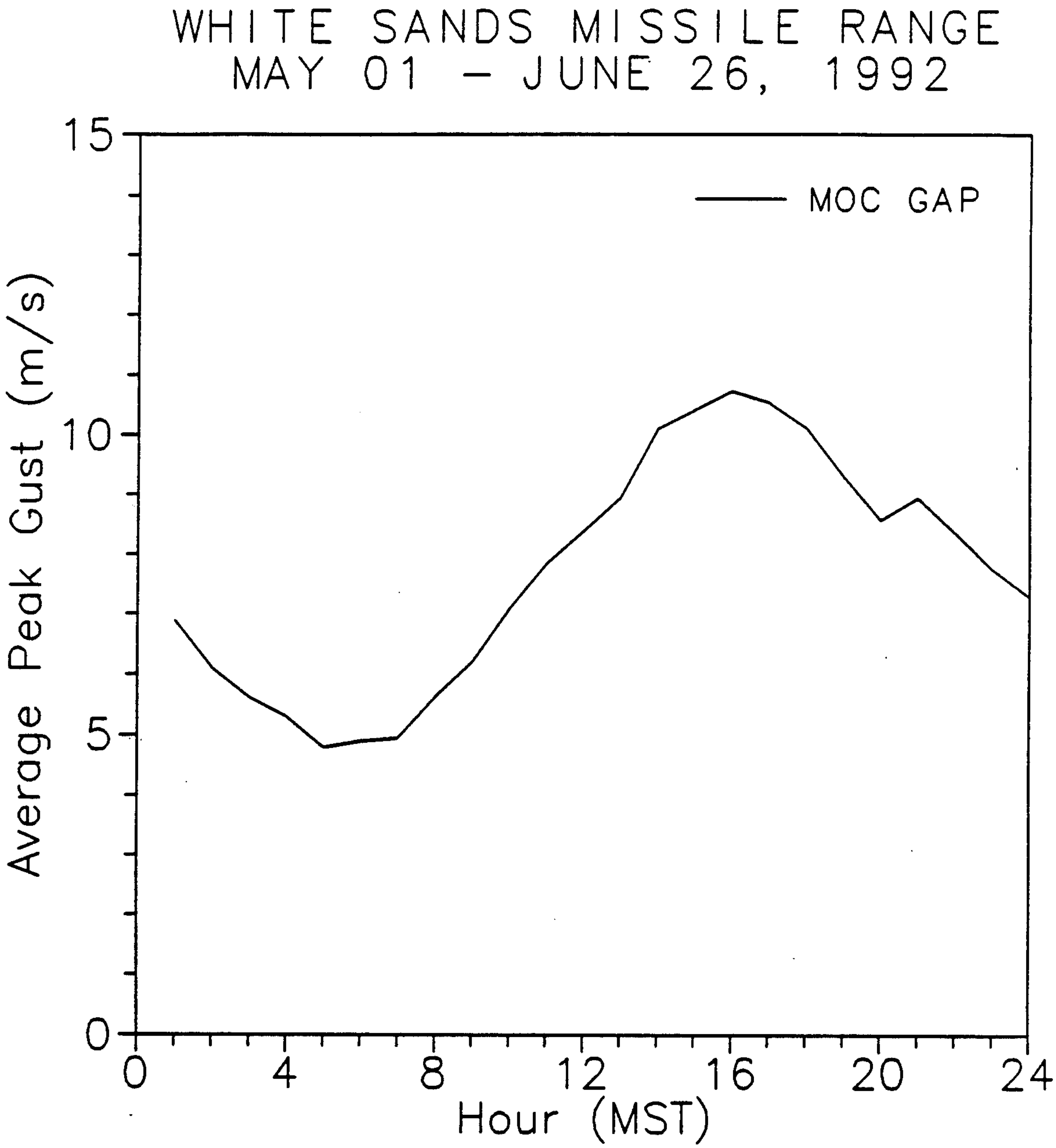


Figure 9. Average peak wind gust versus time of day at Mockingbird Gap between 1 May and 26 Jun 92.

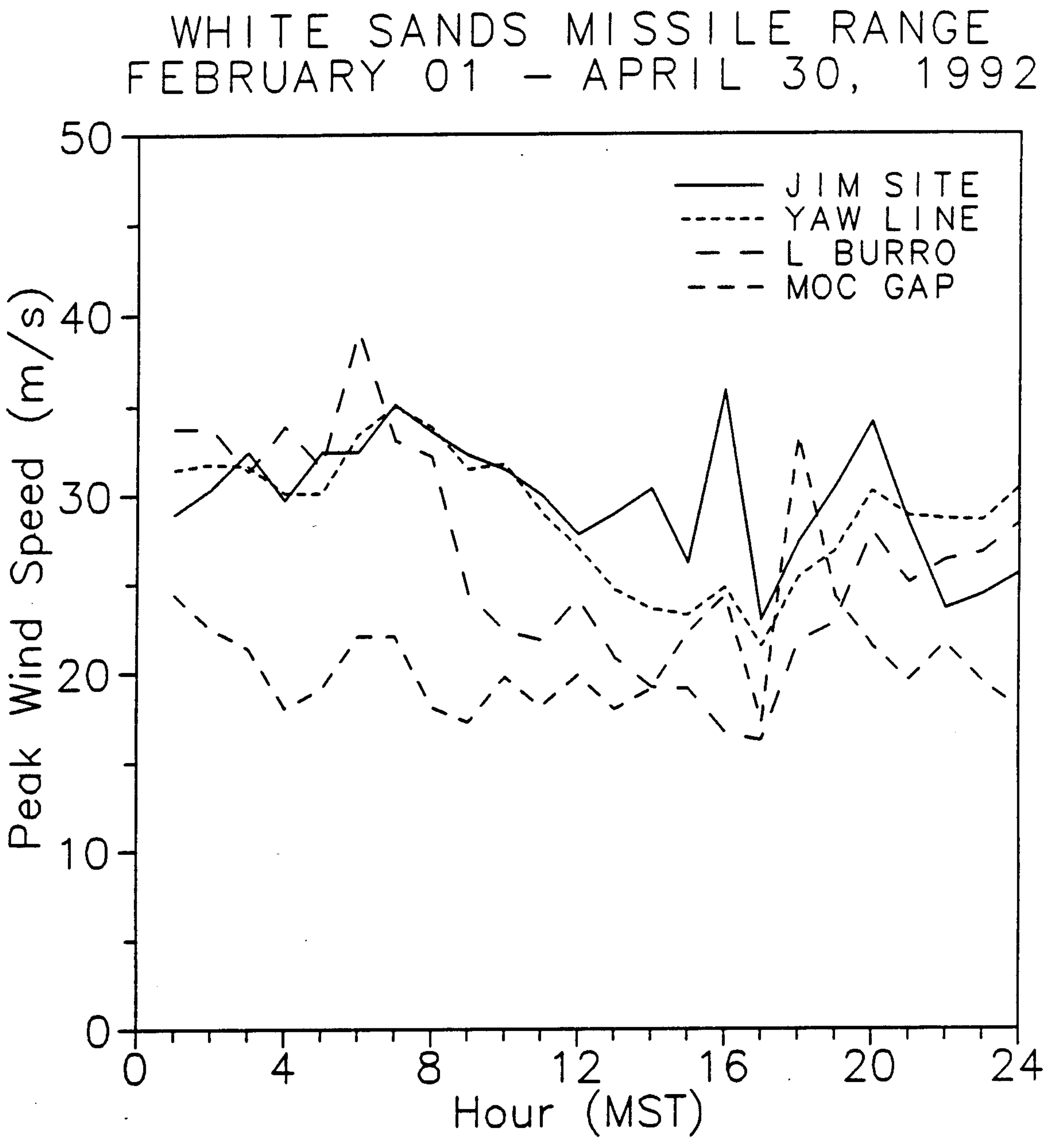


Figure 10. Highest wind gust versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap between 1 Feb and 30 Apr 92.

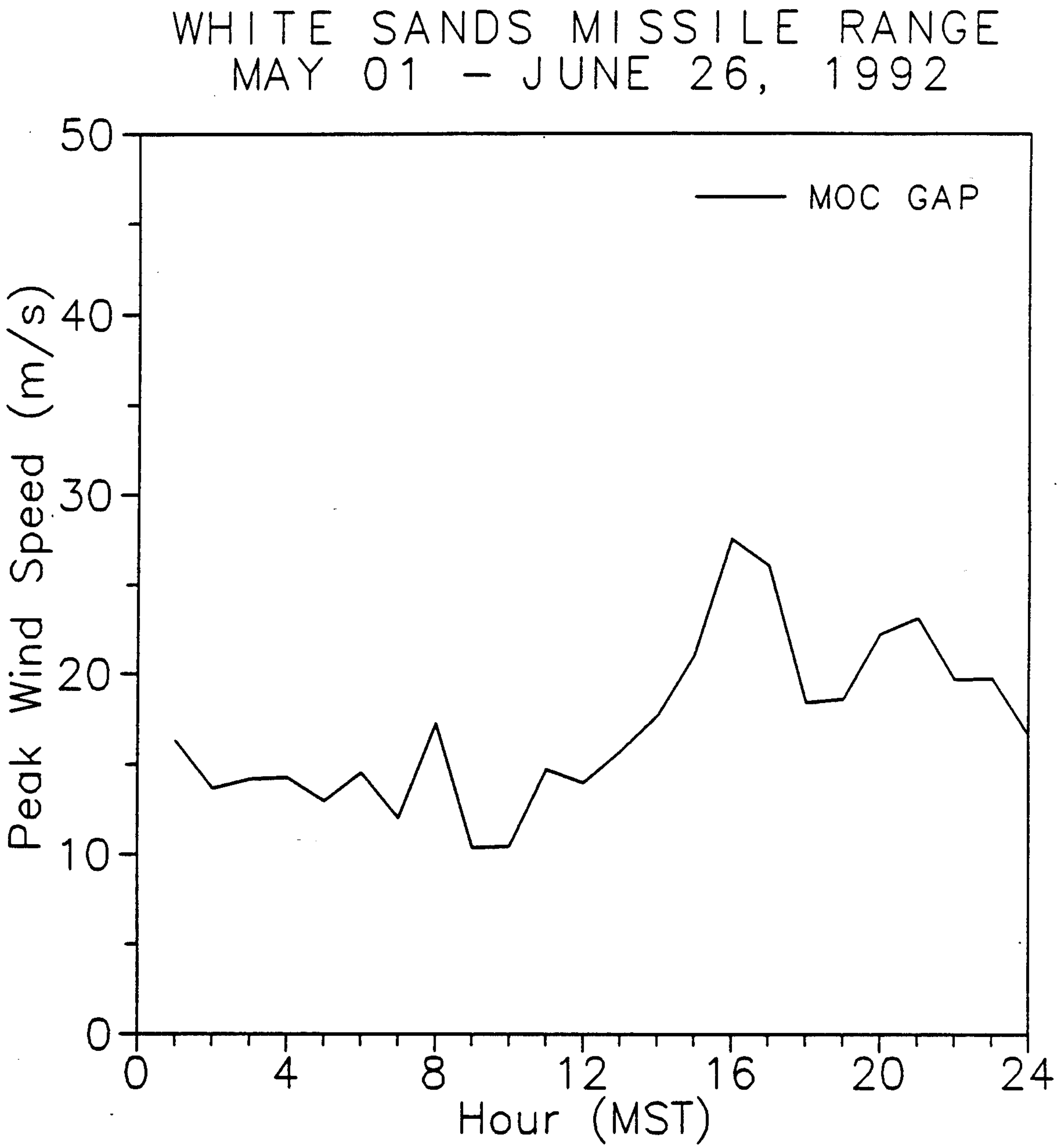


Figure 11. Highest wind gust versus time of day at Mockingbird Gap between 1 May and 26 Jun 92.

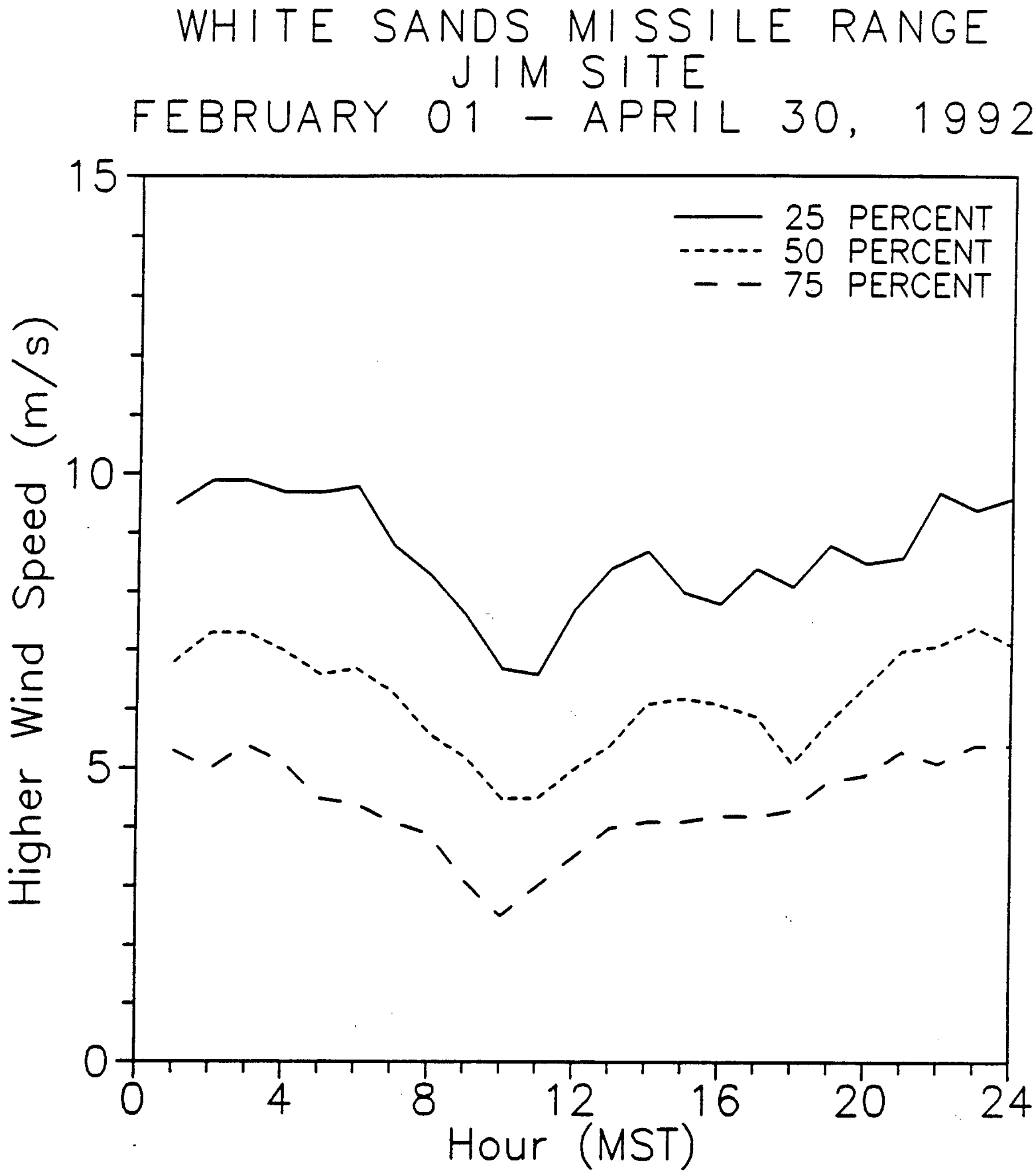


Figure 12. The 25th, 50th, and 75th percentile wind speeds at Jim Site between 1 Feb and 30 Apr 92.

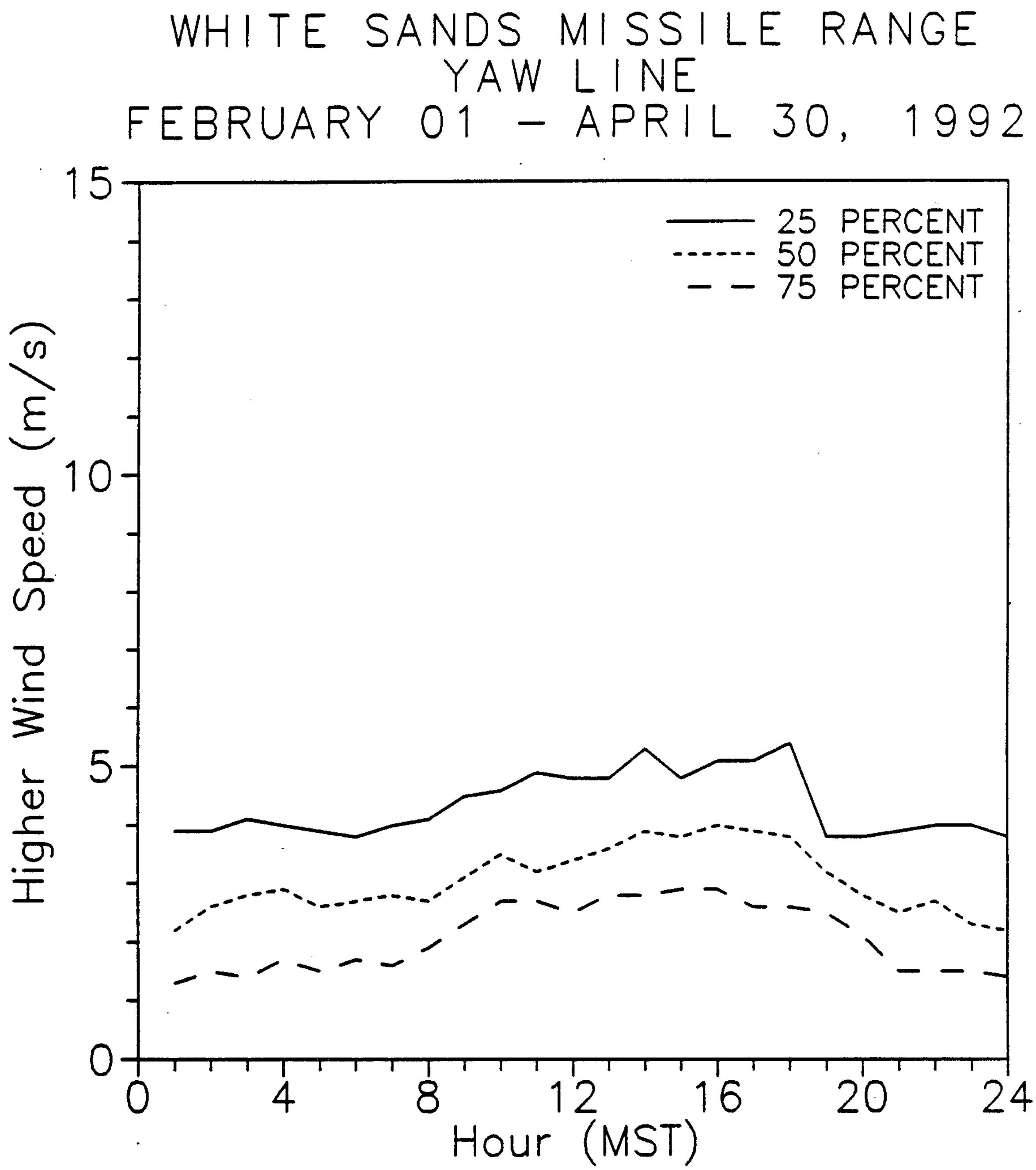


Figure 13. The 25th, 50th, and 75th percentile wind speeds at Yaw Line between 1 Feb and 30 Apr 92.

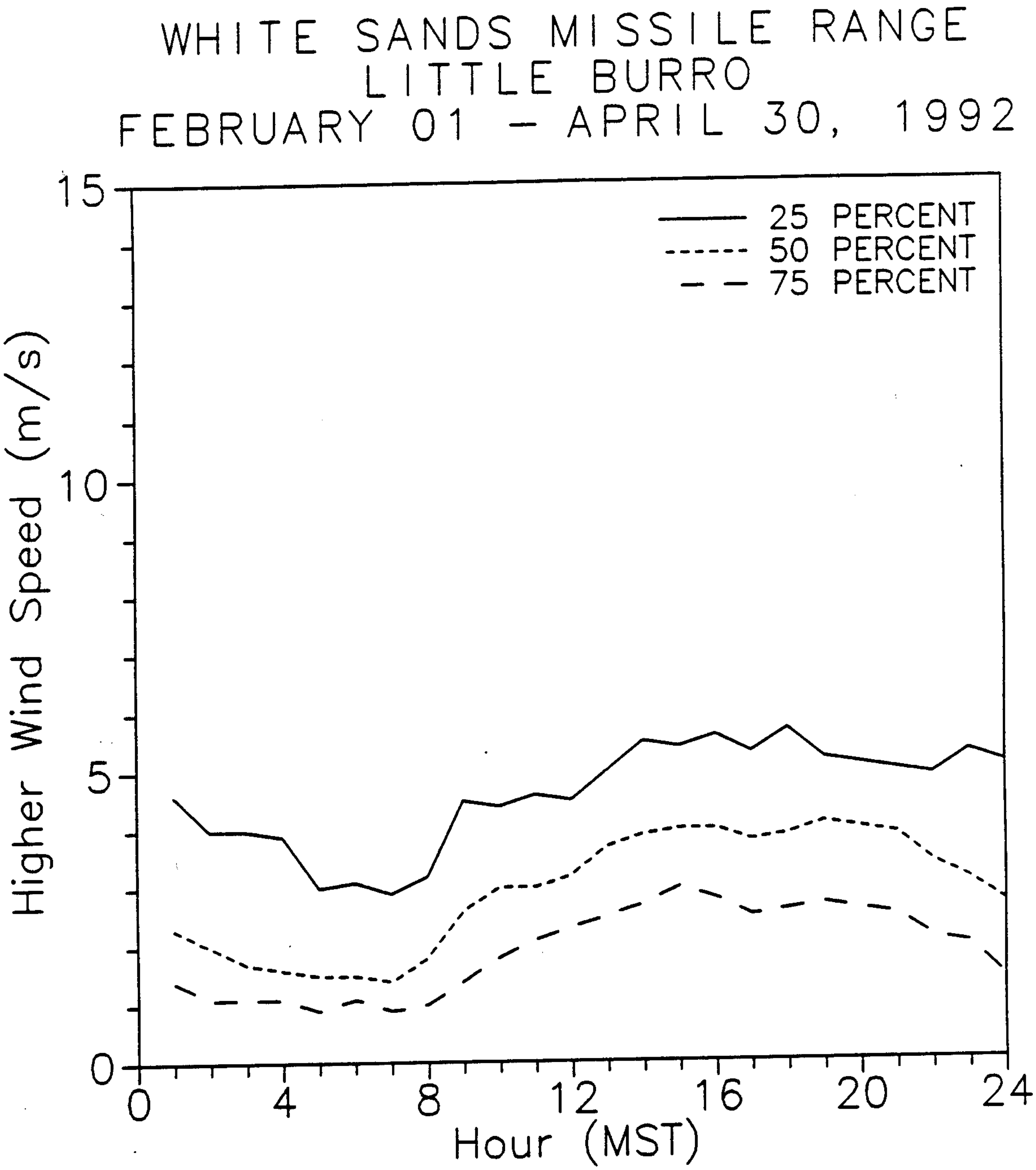


Figure 14. The 25th, 50th, and 75th percentile wind speeds at Little Burro between 1 Feb and 30 Apr 92.

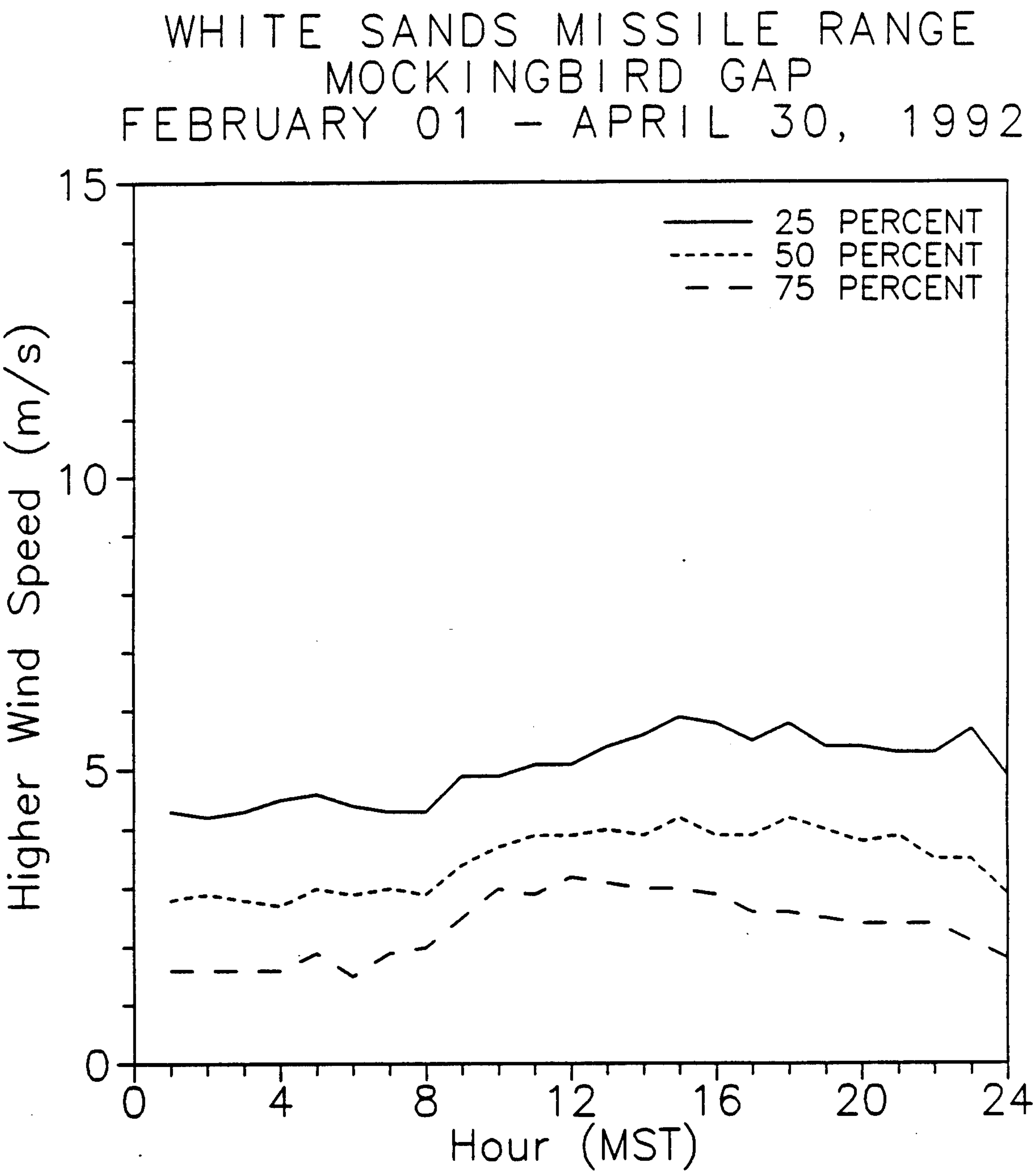


Figure 15. The 25th, 50th, and 75h percentile wind speeds at Mockingbird Gap between 1 Feb and 30 Apr 92.

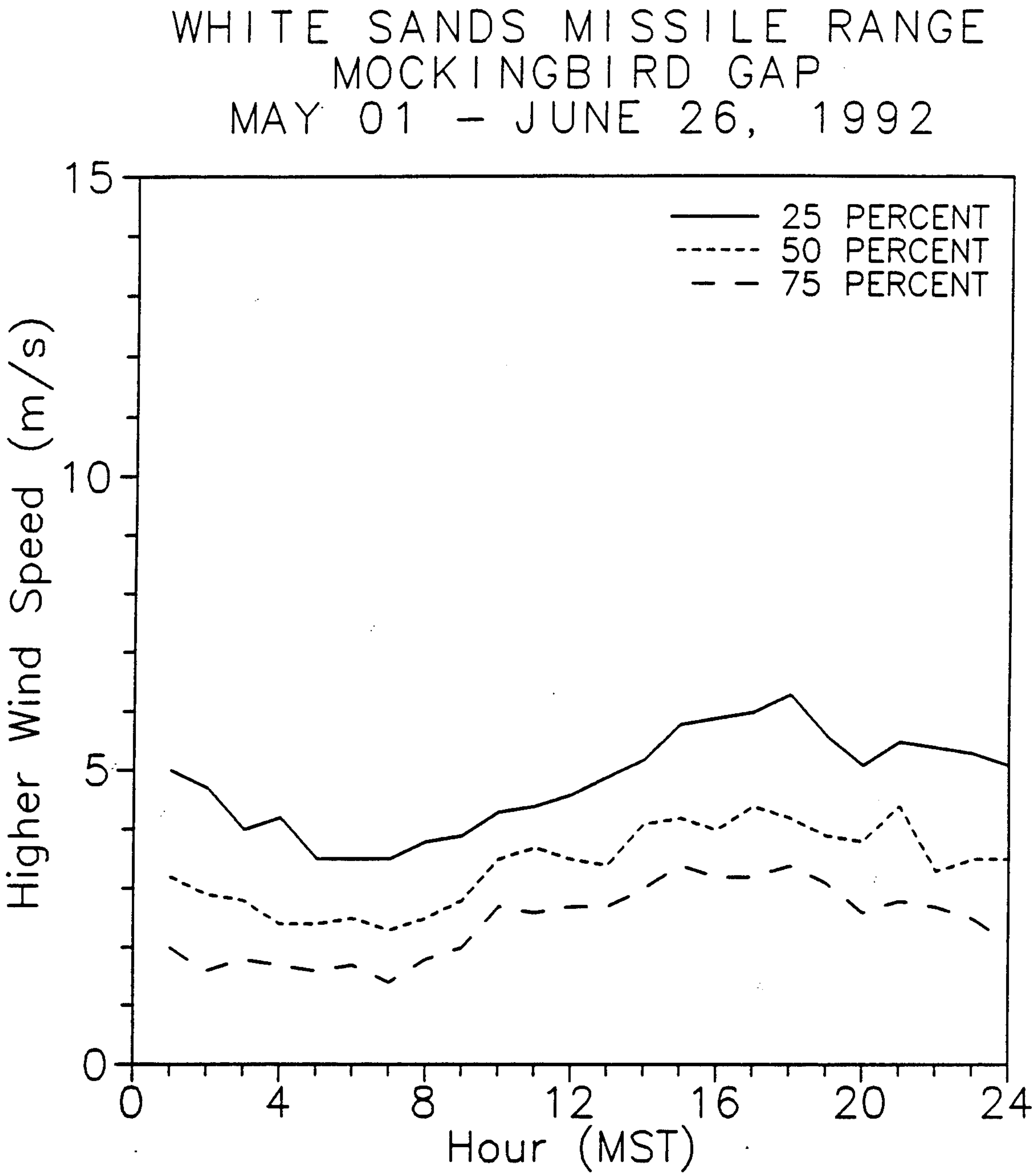


Figure 16. The 25th, 50th, and 75th percentile wind speeds at Mockingbird Gap between 1 May and 26 Jun 92.

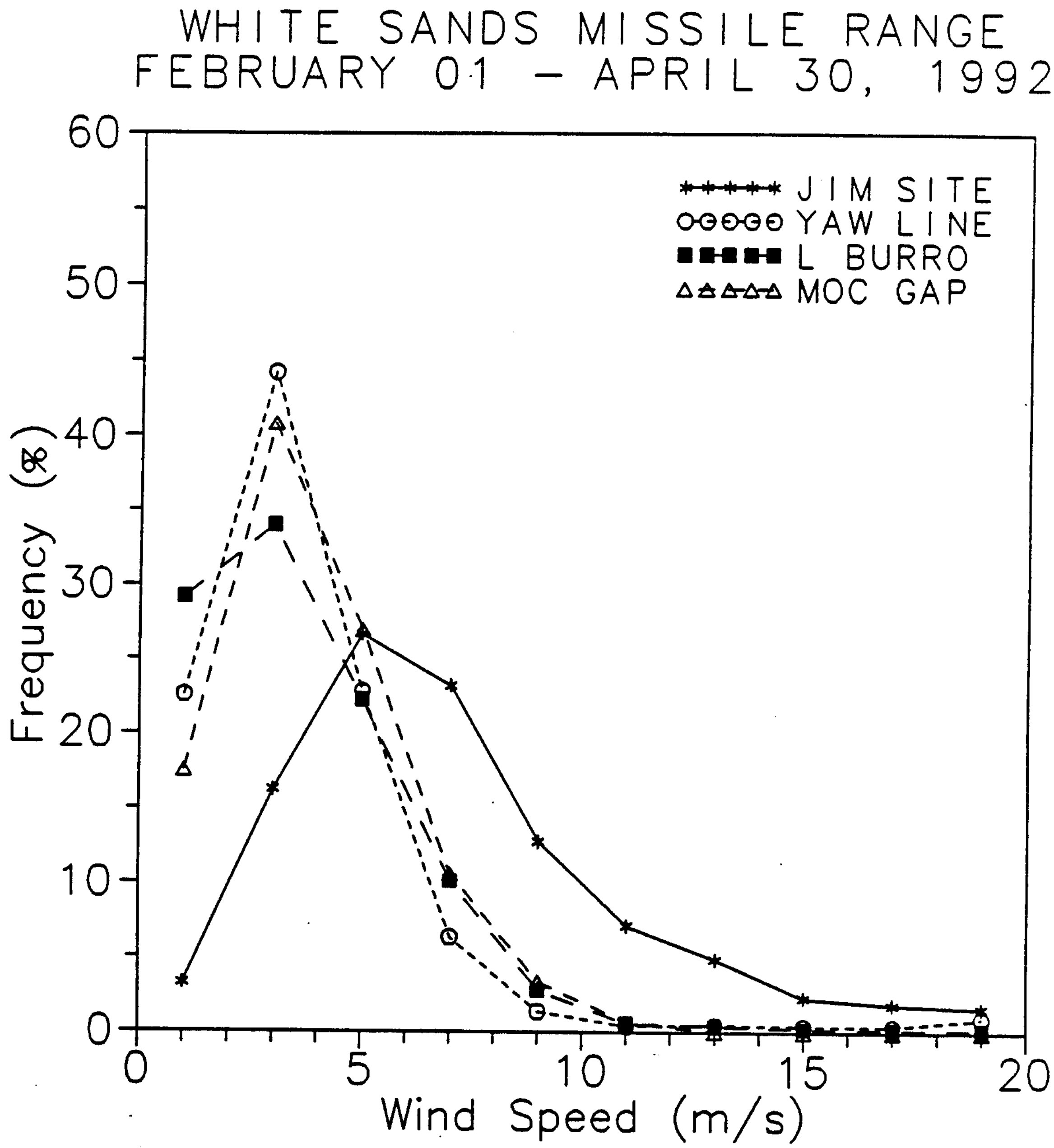


Figure 17. Frequency distribution of wind speed measured at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

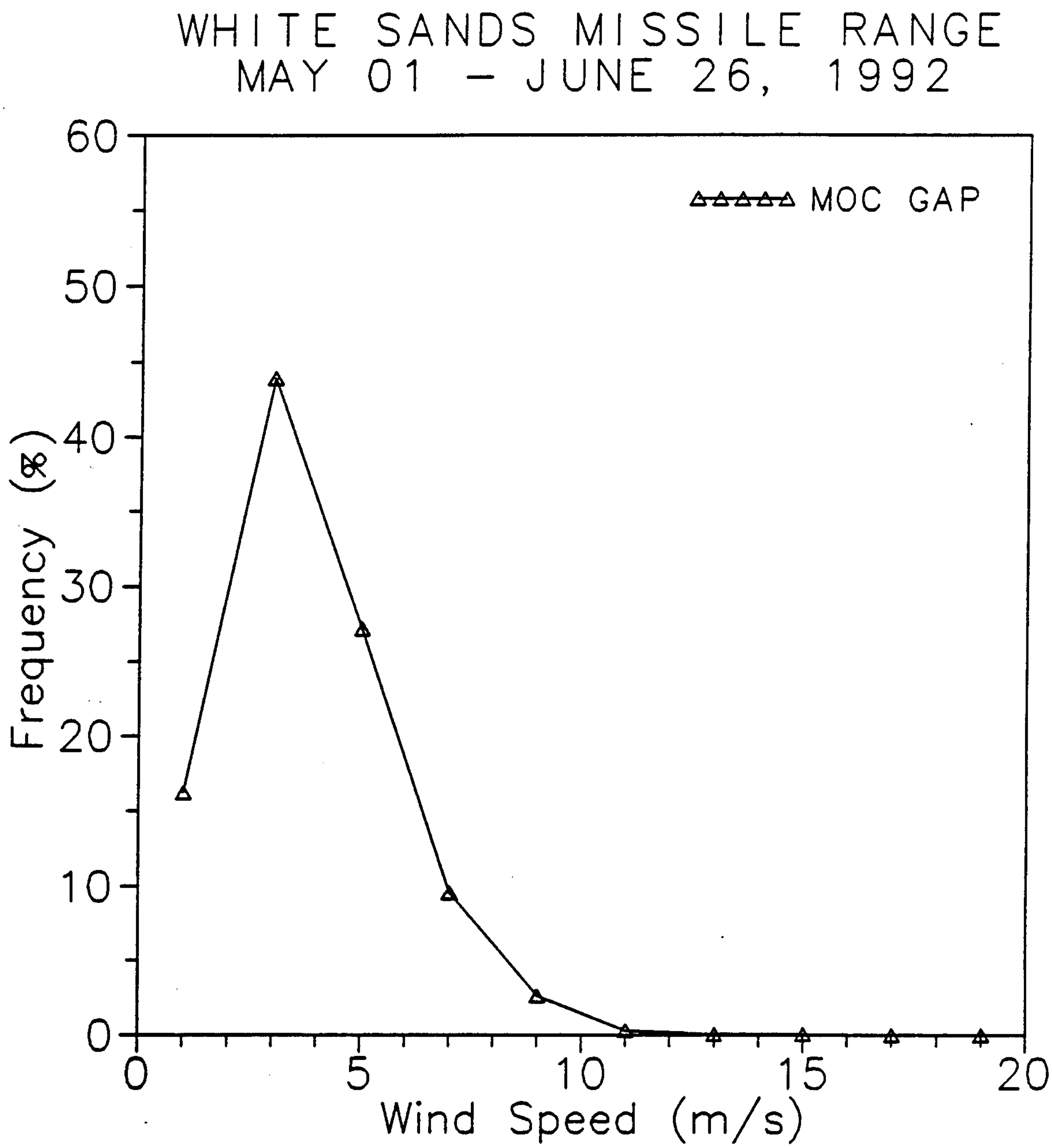


Figure 18. Frequency distribution of wind speed measured at Mockingbird Gap from 1 May to 26 Jun 92.

3.2 Wind Direction

For the two SAMS data groups defined in the previous section, frequency distributions of the wind direction measurements were computed and are plotted and listed in figures 19 and 20 and tables 1 and 2. The tables include the scalar mean wind speeds and minimum and maximum 1-h averaged wind speeds for each direction. Frequency distributions of eight wind directions as a function of time of day were calculated and are plotted in figures 21 to 36.

Most of the Jim Site winds were from the southwest to northwest. The Little Burro winds were more evenly distributed, but most frequently blew from the southwest. Mockingbird Gap winds were primarily from the north, south, and southwest, and Yaw Line winds were most frequently from the north and southeast. At Mockingbird Gap and Yaw Line, the northerly winds were more likely to occur in the early morning hours, and the southerly winds occurred more often in the afternoon. The strongest average winds were from the east-northeast at Jim Site and Yaw Line, from the northeast at Little Burro, and from the east at Mockingbird Gap. The highest 1-h averaged wind was 26.8 m s^{-1} from the northeast at Jim Site.

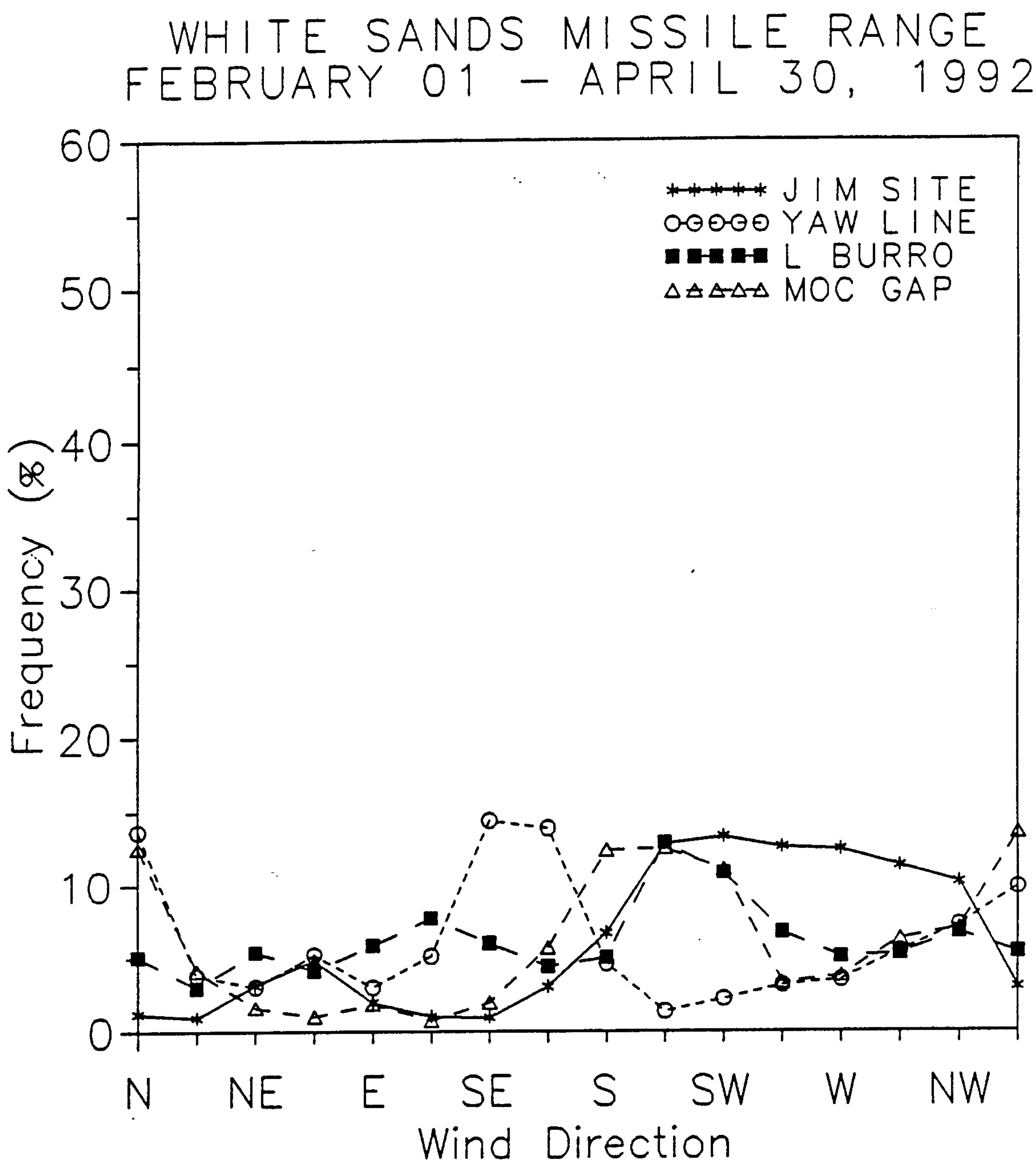


Figure 19. Frequency distribution of wind direction measured at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

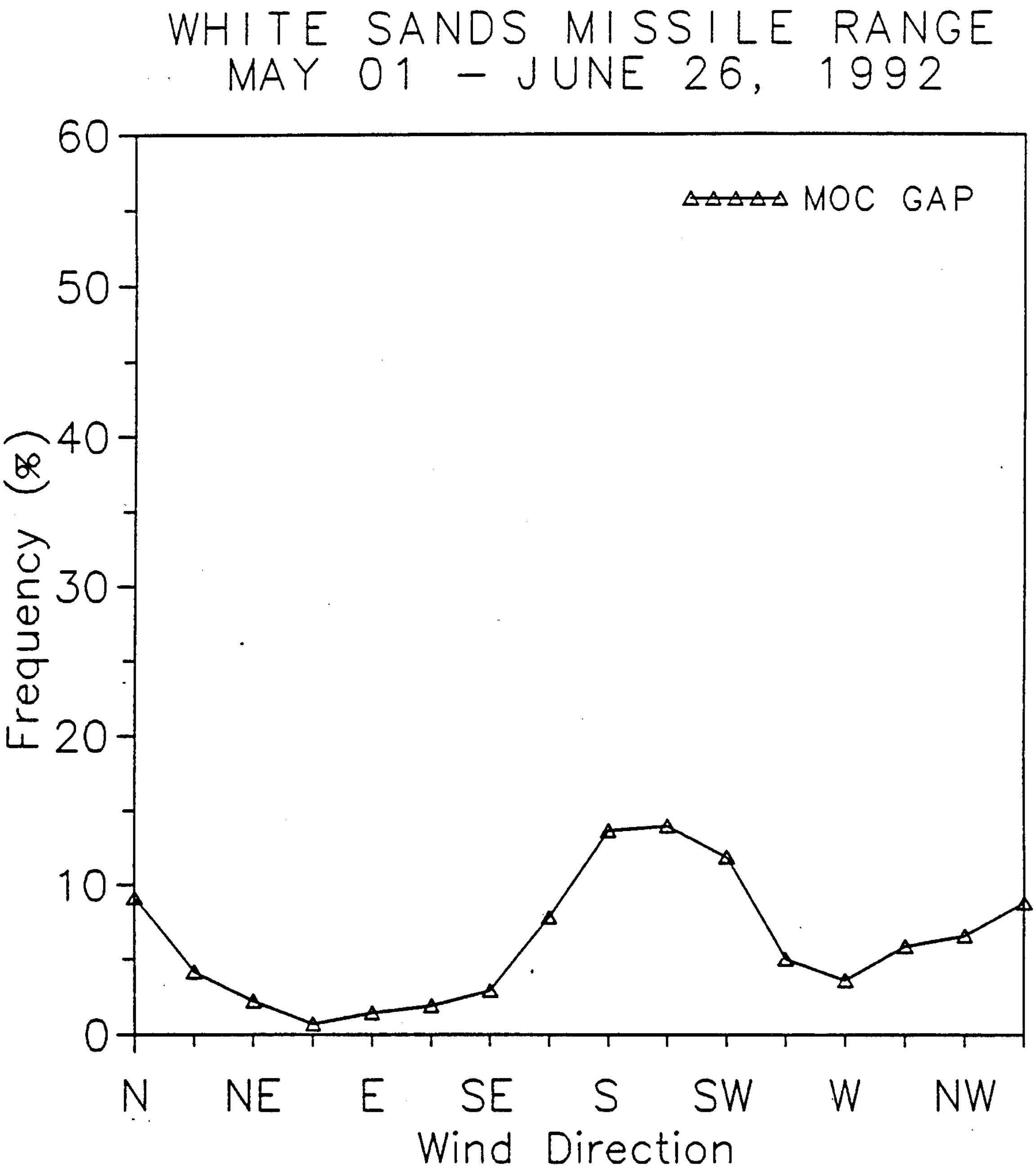


Figure 20. Frequency distribution of wind direction measured at Mockingbird Gap from 1 May to 26 Jun 92.

Table 1. Frequency distribution of wind directions collected 1 Feb – 30 Apr 92 at SAMS stations

Direction	Frequency (%)	Wind Speed (m/s) Mean	Max	Min
	Jim Site			
N	1.	5.3	8.2	1.0
NNE	1.	4.9	9.4	1.0
NE	3.	7.7	26.8	1.7
ENE	5.	11.7	25.5	1.3
E	2.	4.3	17.2	1.6
ESE	1.	4.3	12.3	1.1
SE	1.	5.2	9.0	1.3
SSE	3.	5.5	9.7	1.4
S	7.	4.9	9.9	1.2
SSW	13.	5.7	11.3	.9
SW	13.	6.8	17.8	.9
WSW	13.	7.2	19.8	1.1
W	12.	8.0	20.3	1.6
WNW	11.	7.6	18.6	1.1
NW	10.	8.3	19.6	1.0
NNW	3.	6.0	13.5	.6
	Yaw Line			
N	14.	4.0	13.3	.4
NNE	4.	2.4	6.5	.8
NE	3.	4.0	20.5	.5
ENE	5.	9.1	20.1	.3
E	3.	2.7	7.7	.4
ESE	5.	2.5	6.2	.3
SE	14.	2.8	7.5	.6
SSE	14.	3.3	8.6	.4
S	5.	3.6	7.2	.7
SSW	1.	3.4	5.9	1.1
SW	2.	3.1	6.1	.6
WSW	3.	3.6	7.5	1.6
W	4.	3.3	6.3	1.0
WNW	5.	3.8	9.2	.7
NW	7.	3.8	8.3	.6
NNW	10.	4.0	9.1	.7

Table 1. Frequency distribution of wind directions collected 1 Feb – 30 Apr 92 at SAMS stations (continued)

Direction	Frequency (%)	Wind Speed (m/s) Mean	Max	Min
		Little Burro		
N	5.	3.5	8.3	.6
NNE	3.	2.9	7.8	.3
NE	5.	5.8	17.0	.5
ENE	4.	4.2	17.6	.4
E	6.	3.5	18.4	.4
ESE	8.	4.1	18.5	.4
SE	6.	3.5	19.2	.5
SSE	4.	2.3	9.7	.4
S	5.	2.4	8.1	.4
SSW	13.	4.4	10.3	.3
SW	11.	3.7	9.9	.8
WSW	7.	3.0	10.1	.5
W	5.	2.8	10.0	.6
WNW	5.	3.1	7.5	.6
NW	7.	3.4	10.1	.8
NNW	5.	3.3	8.6	.8
		Mockingbird Gap		
N	13.	4.3	10.9	.7
NNE	4.	3.2	11.1	.9
NE	2.	2.4	3.7	.8
ENE	1.	4.1	8.1	.9
E	2.	6.4	12.4	.8
ESE	1.	4.1	8.6	.9
SE	2.	2.9	6.7	1.0
SSE	6.	3.2	6.6	.9
S	12.	4.2	10.5	.7
SSW	13.	3.6	10.2	.6
SW	11.	3.3	9.6	.7
WSW	3.	2.6	8.7	.6
W	4.	3.8	9.9	.5
WNW	6.	4.1	10.0	.7
NW	7.	4.2	10.0	.7
NNW	14.	4.4	10.3	.5

Table 2. Frequency distribution of wind directions collected 1 May – 26 Jun 92 at Mockingbird Gap

Direction	Frequency (%)	Wind Speed (m/s) Mean	Max	Min
		Mockingbird Gap		
N	9.	3.8	7.8	.6
NNE	4.	3.3	10.6	1.0
NE	2.	2.5	8.0	.9
ENE	1.	1.9	2.7	.8
E	1.	3.8	9.3	1.0
ESE	2.	4.3	11.6	.9
SE	3.	2.9	7.6	.8
SSE	8.	3.3	8.9	1.0
S	14.	4.4	10.2	.8
SSW	14.	3.9	9.3	.7
SW	12.	3.6	9.2	.5
WSW	5.	3.3	6.8	.9
W	4.	4.3	12.9	.8
WNW	6.	4.4	14.8	.6
NW	7.	3.9	8.9	.9
NNW	9.	4.2	7.9	1.0

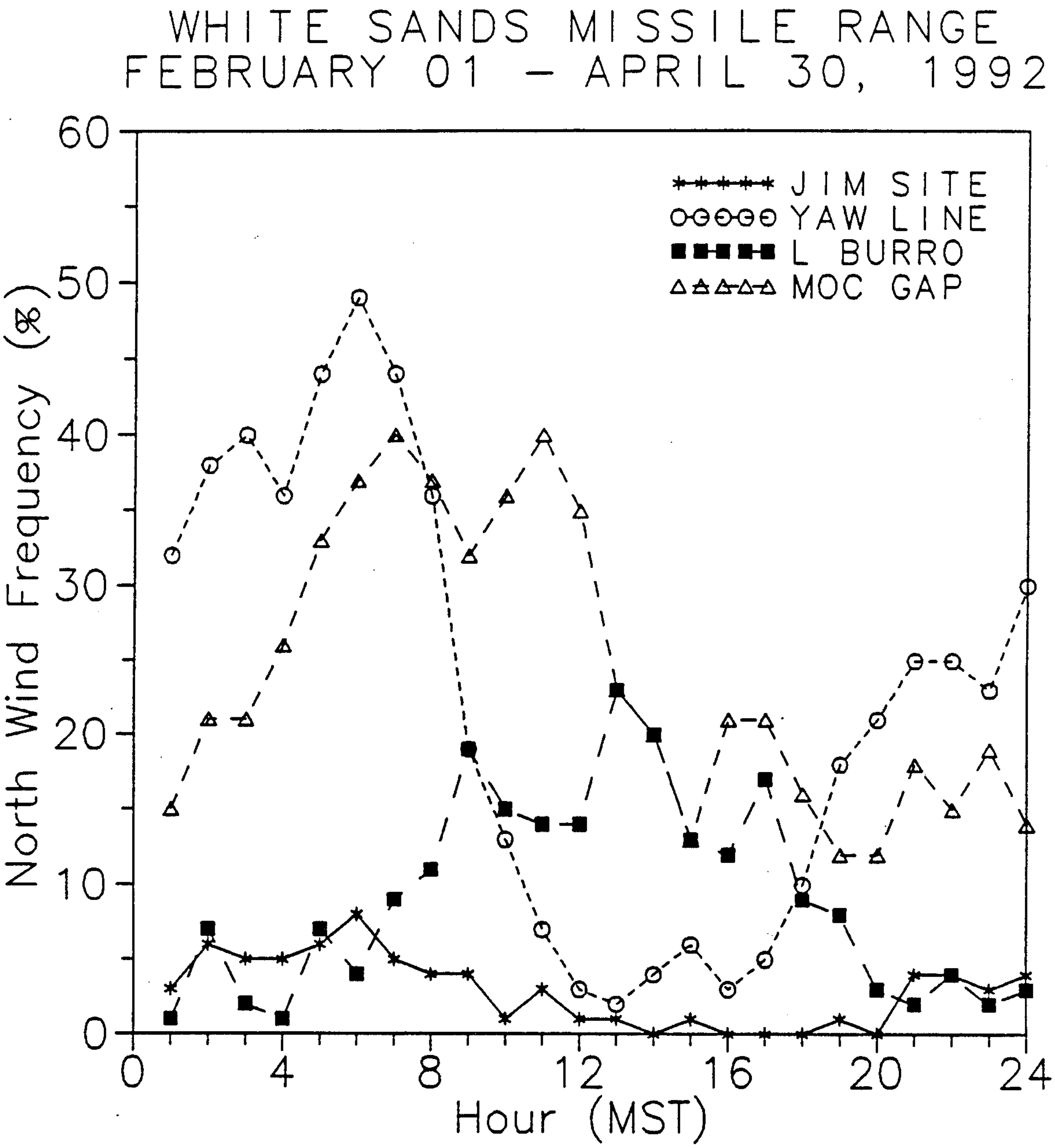


Figure 21. Frequency of north winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

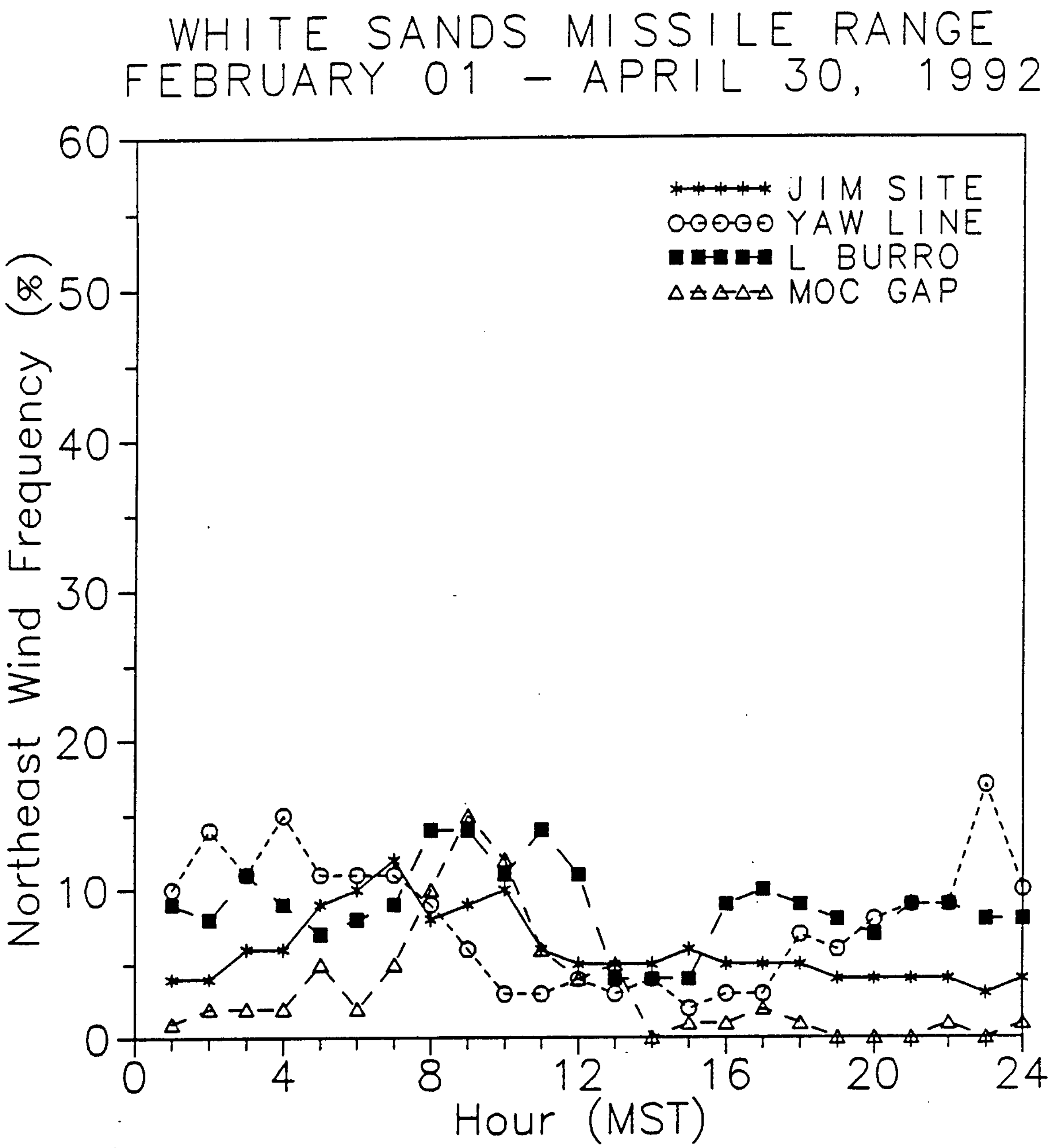


Figure 22. Frequency of northeast winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

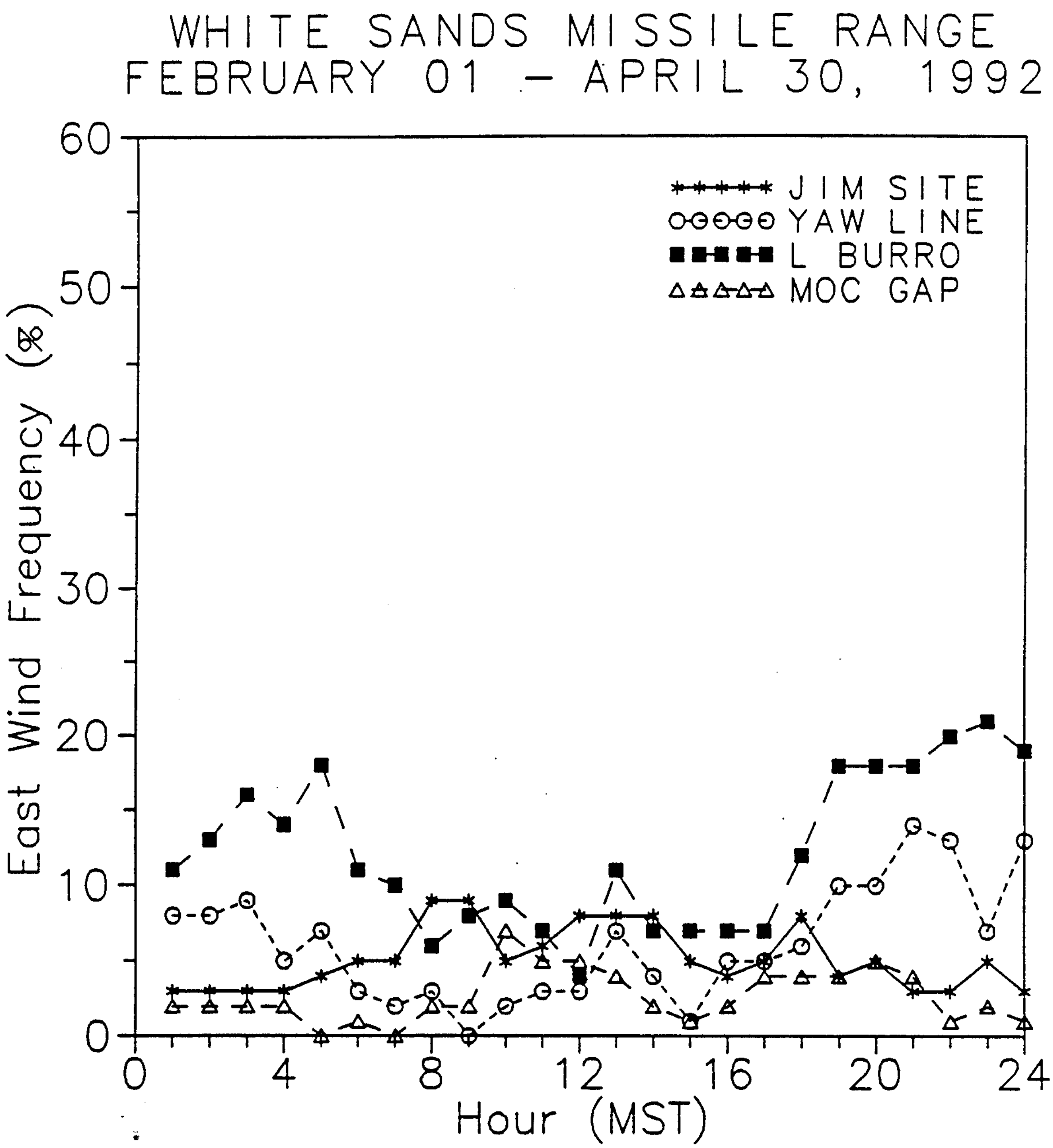


Figure 23. Frequency of east winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

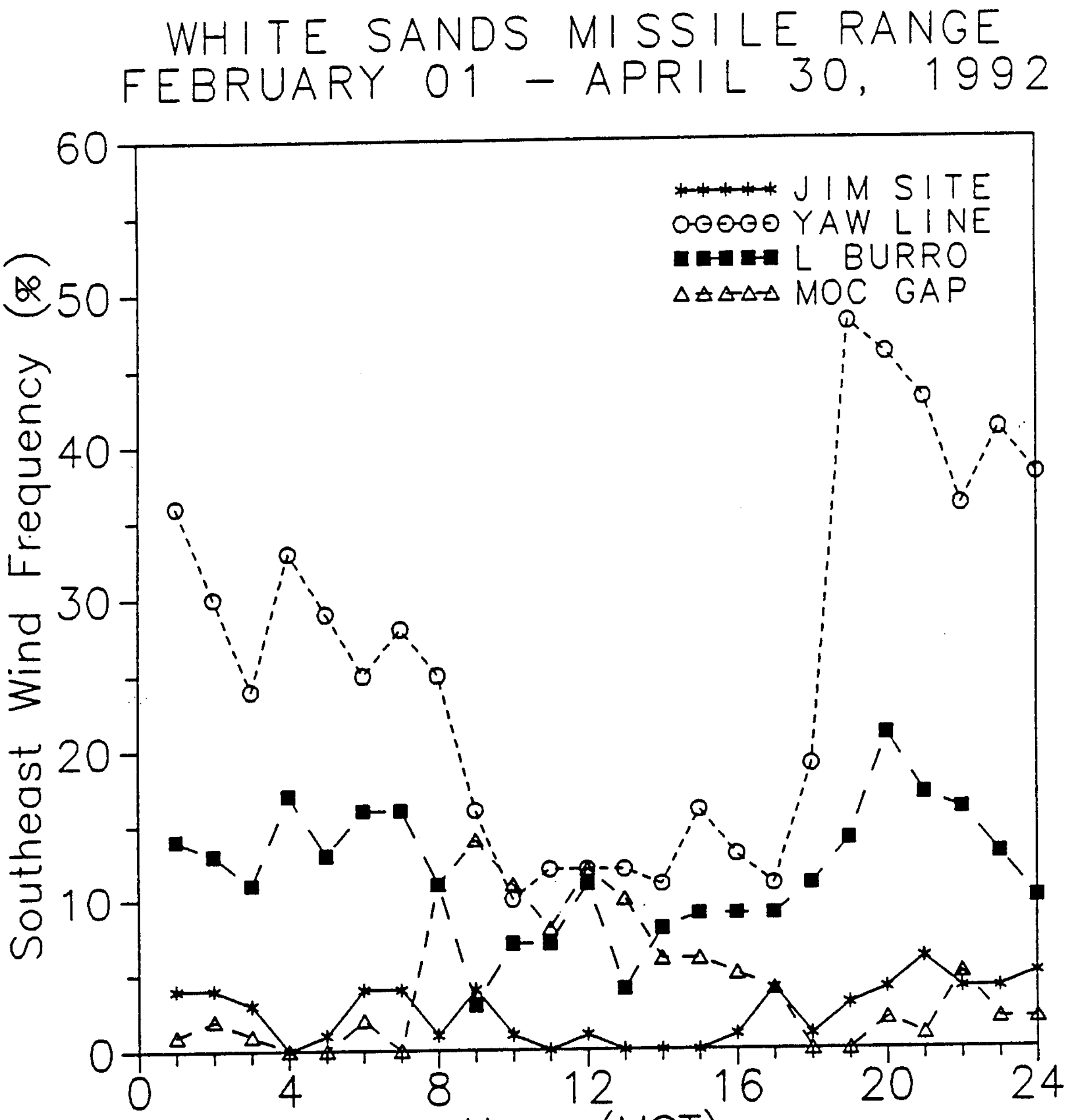


Figure 24. Frequency of southeast winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

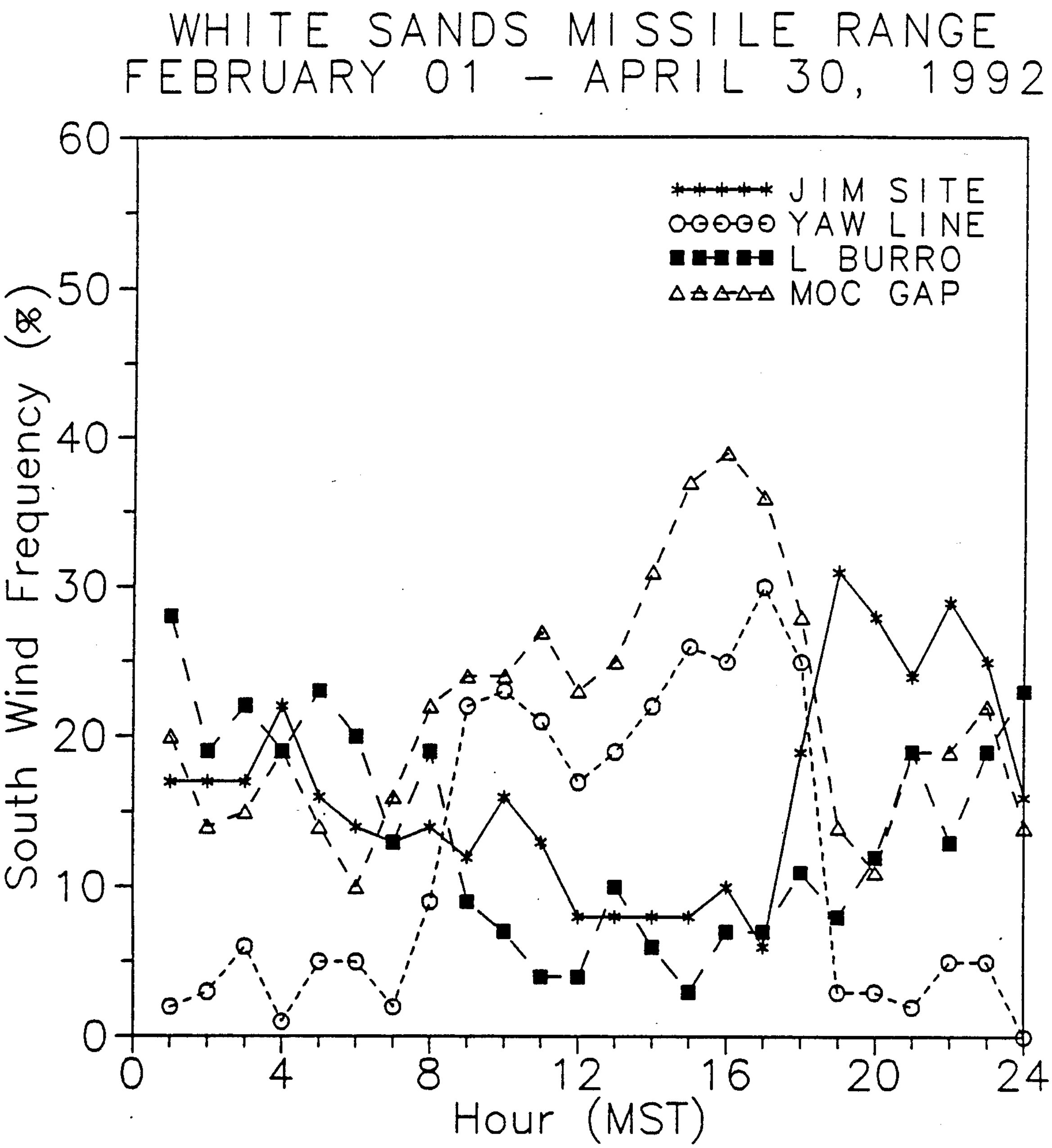


Figure 25. Frequency of south winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

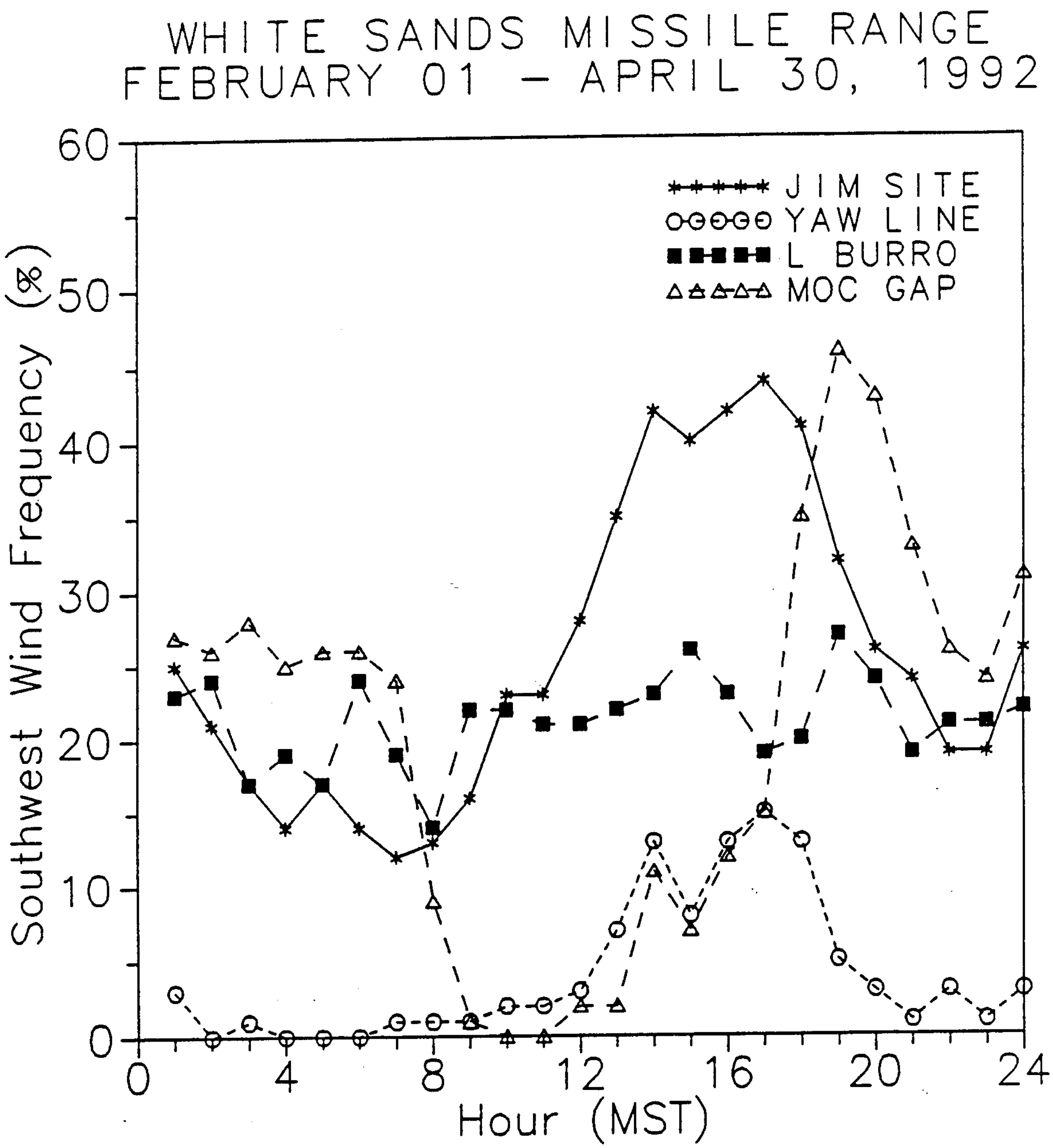


Figure 26. Frequency of southwest winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

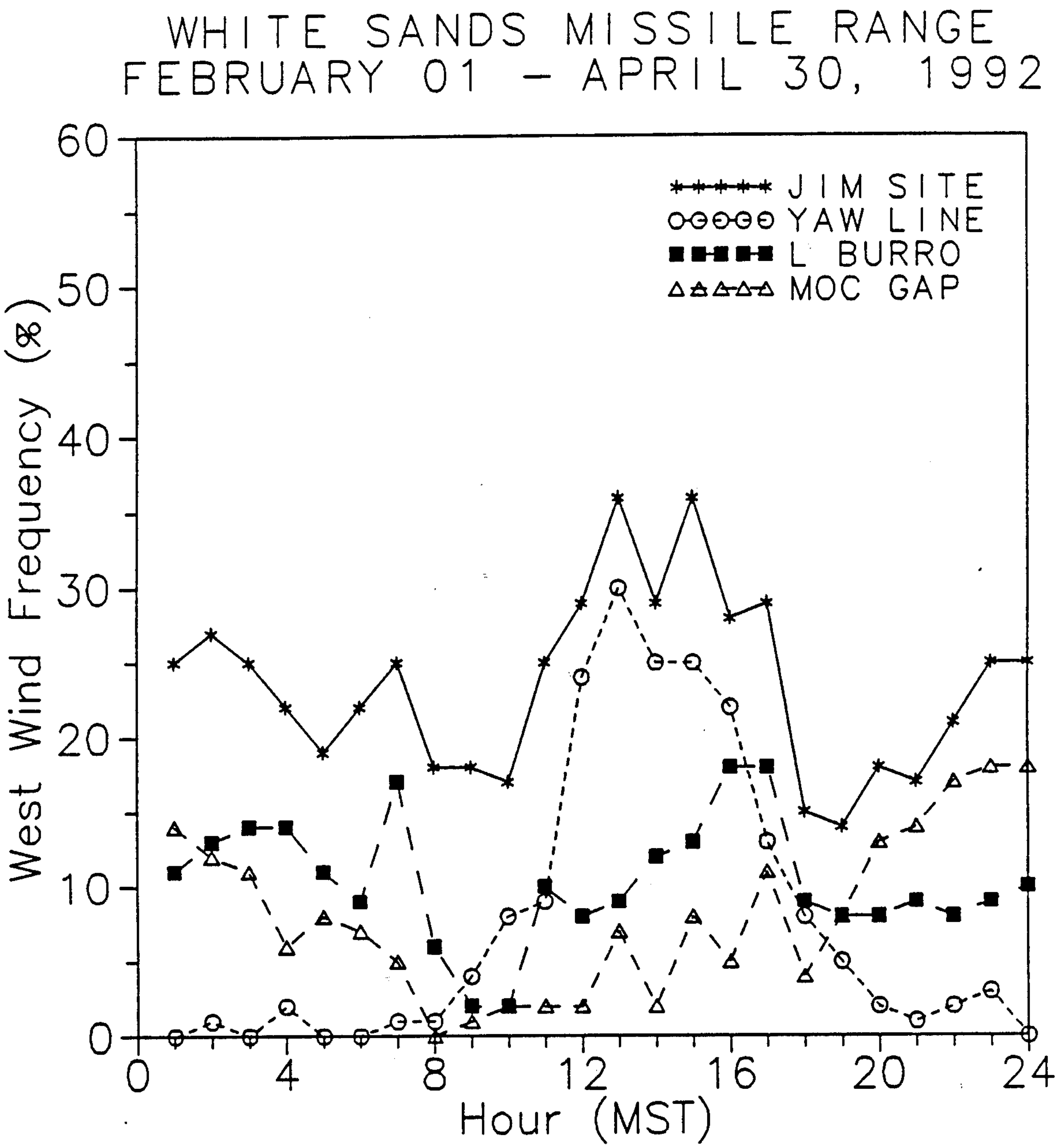


Figure 27. Frequency of west winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

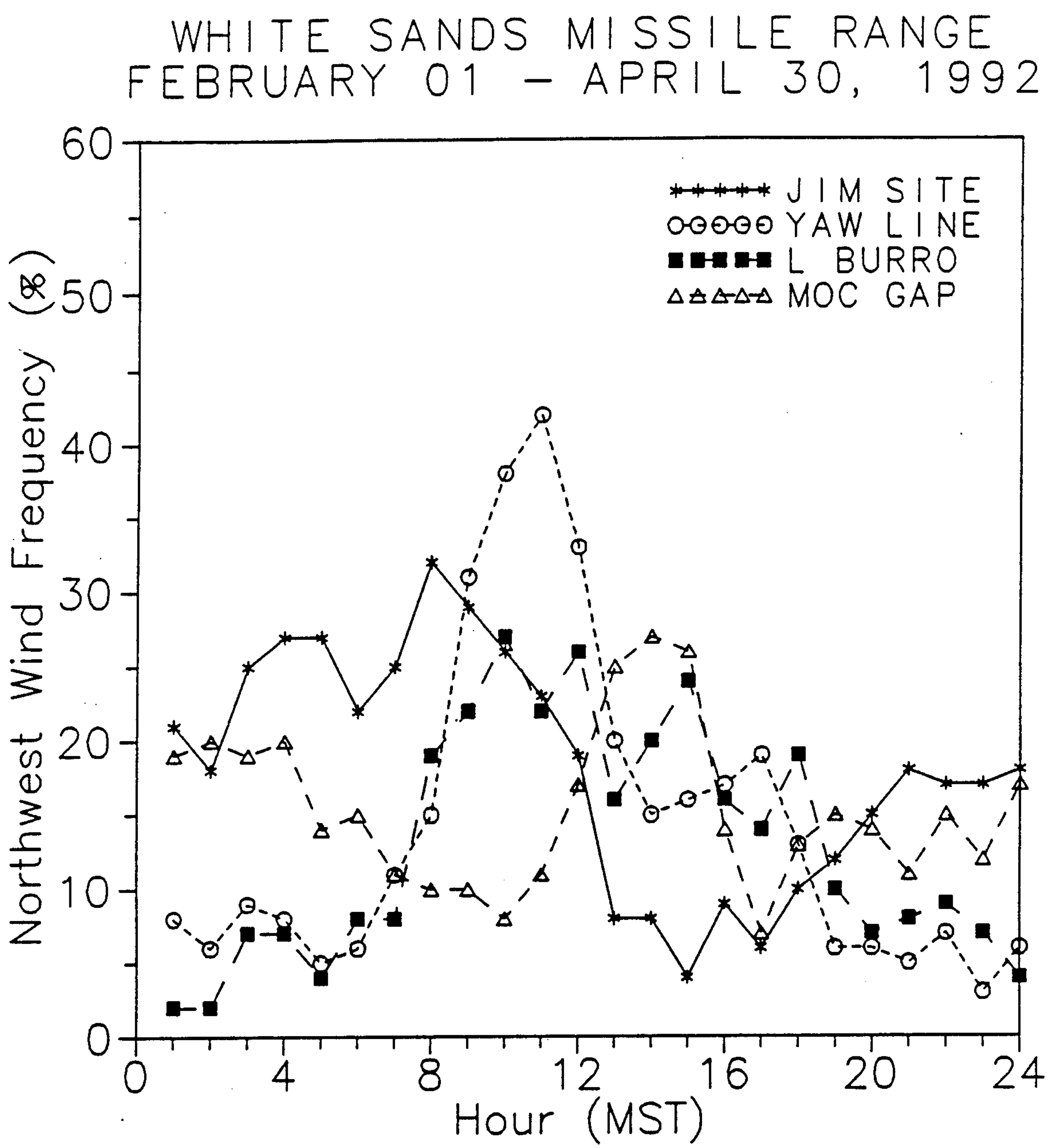


Figure 28. Frequency of northwest winds versus time of day at Jim Site, Yaw Line, Little Burro, and Mockingbird Gap from 1 Feb to 30 Apr 92.

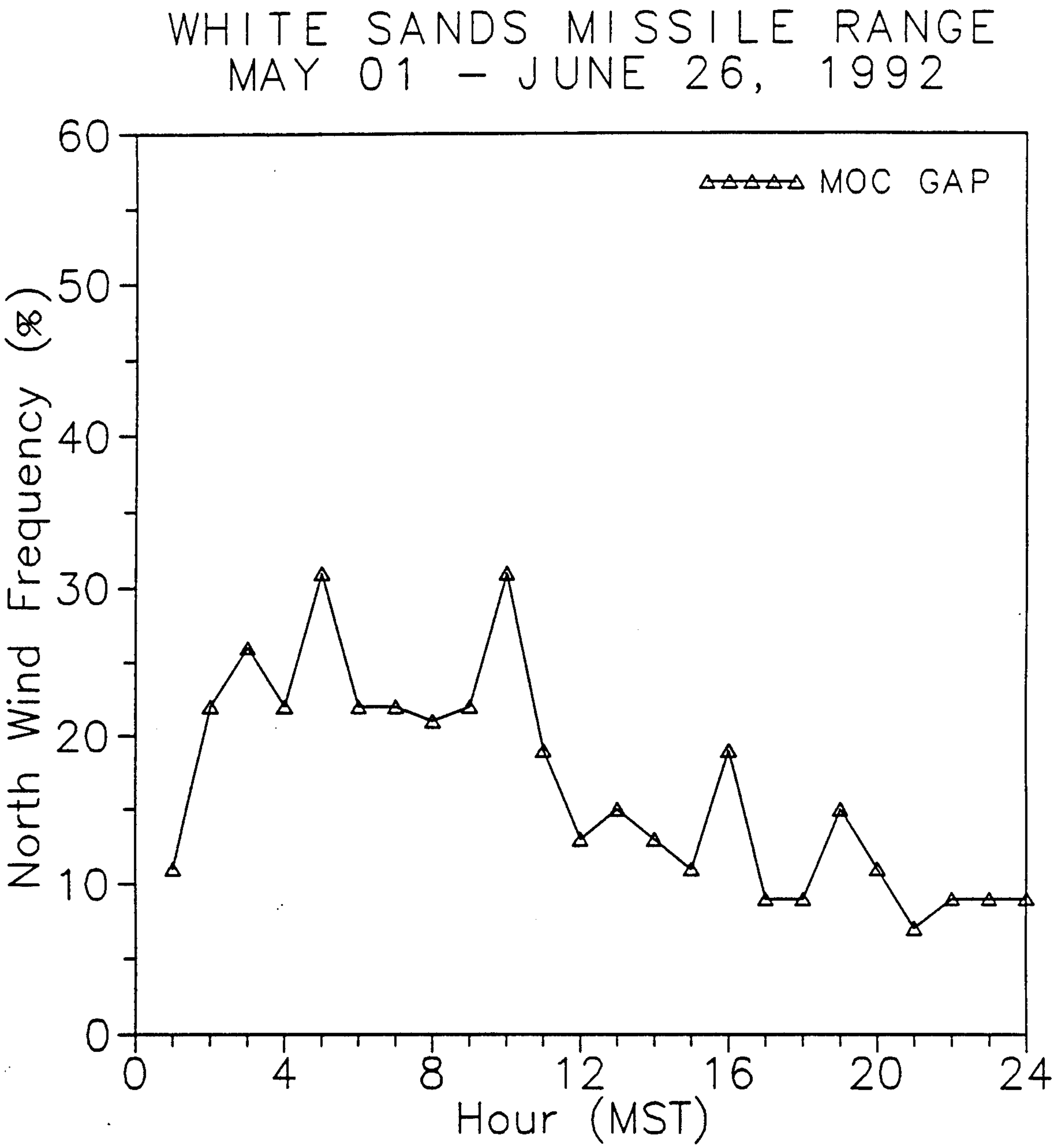


Figure 29. Frequency of north winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

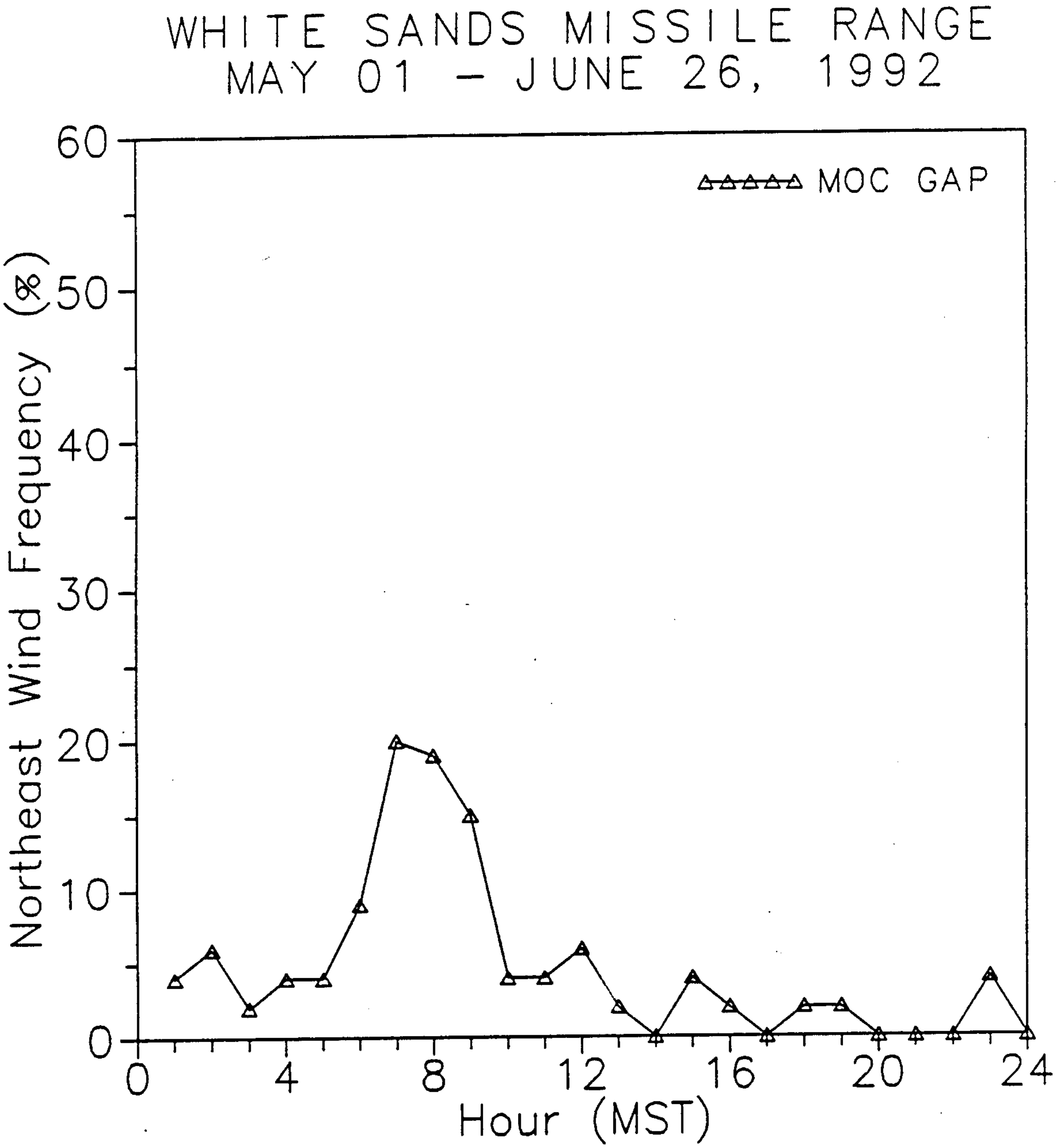


Figure 30. Frequency of northeast winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

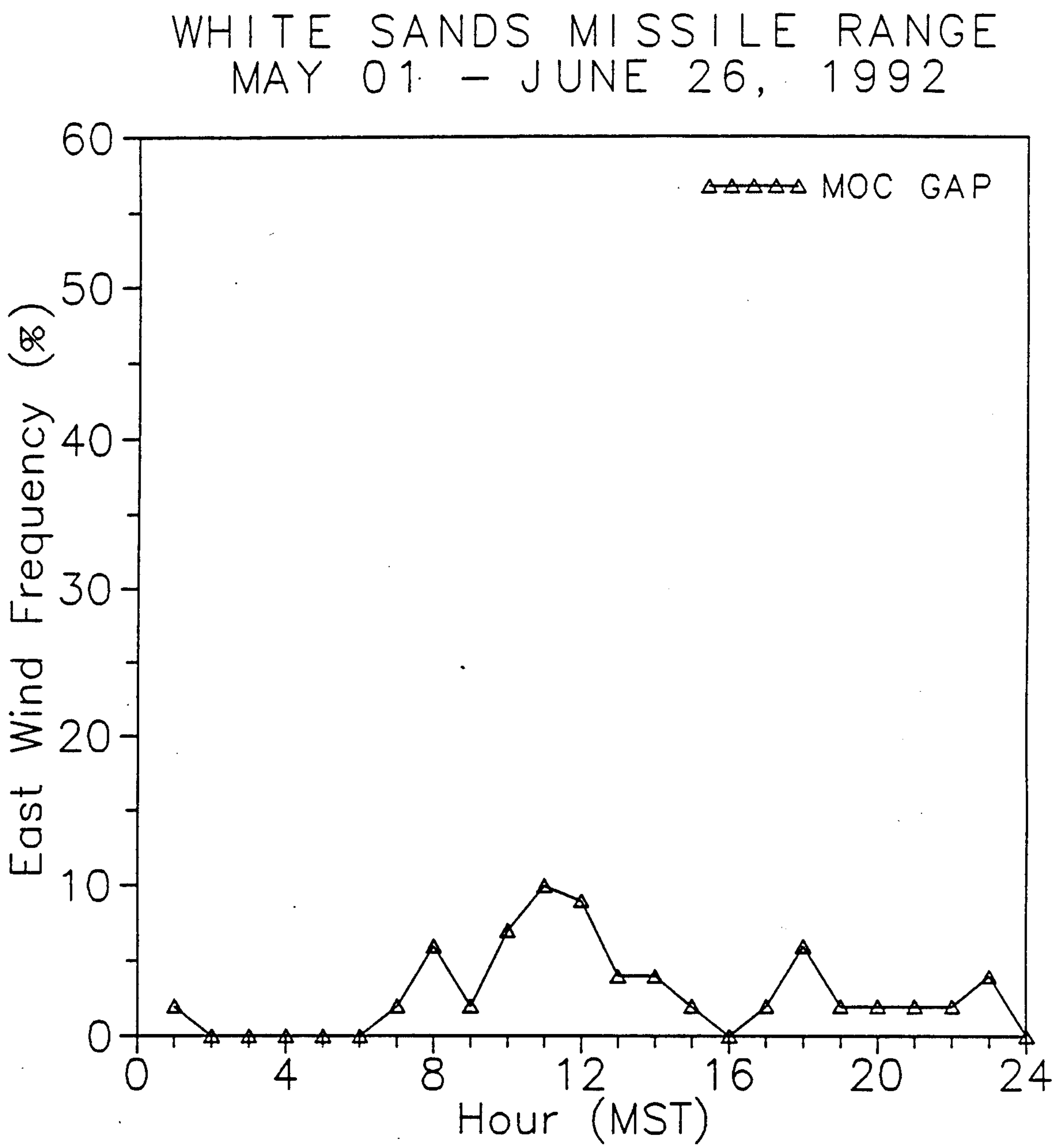


Figure 31. Frequency of east winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

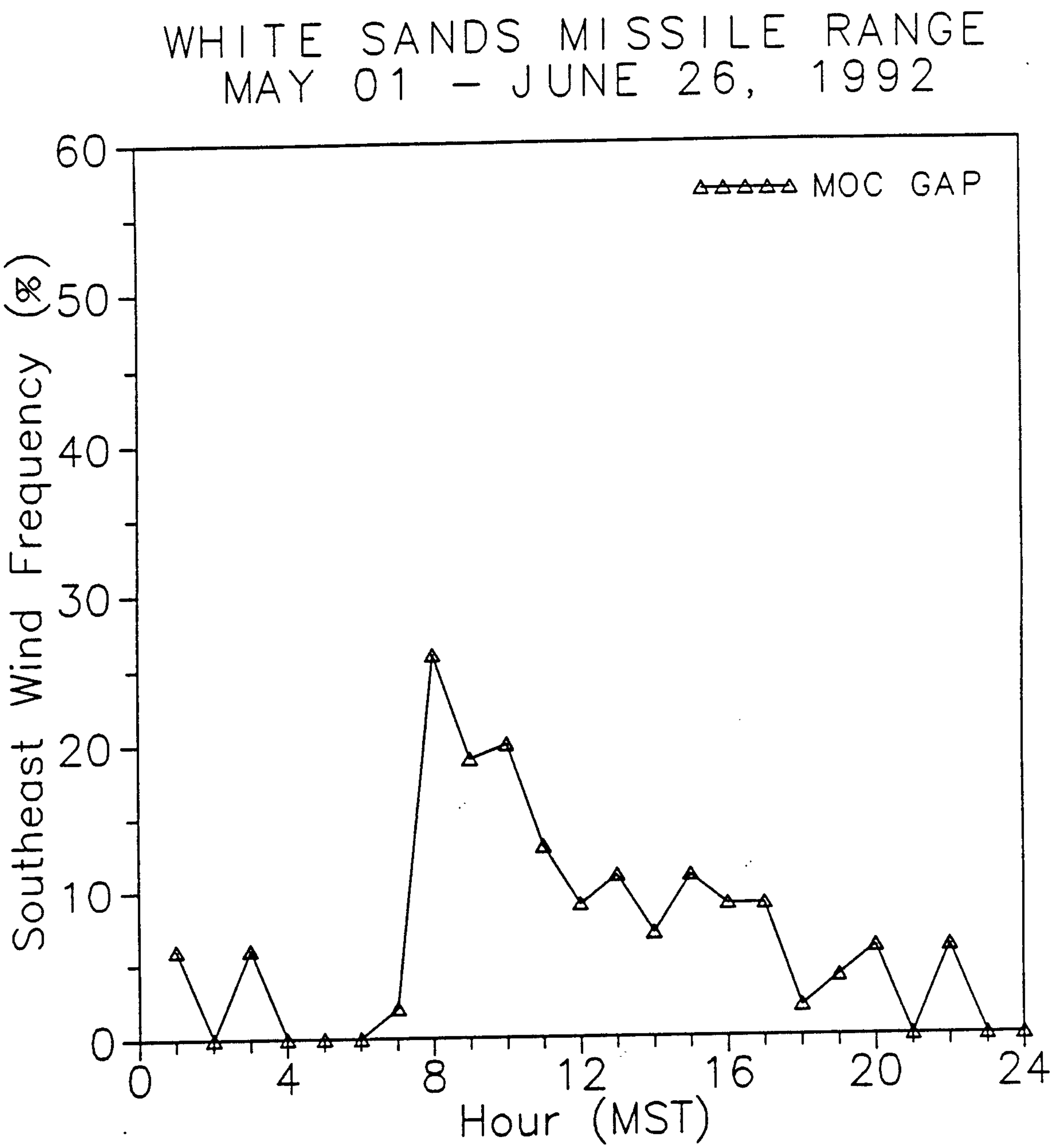


Figure 32. Frequency of southeast winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

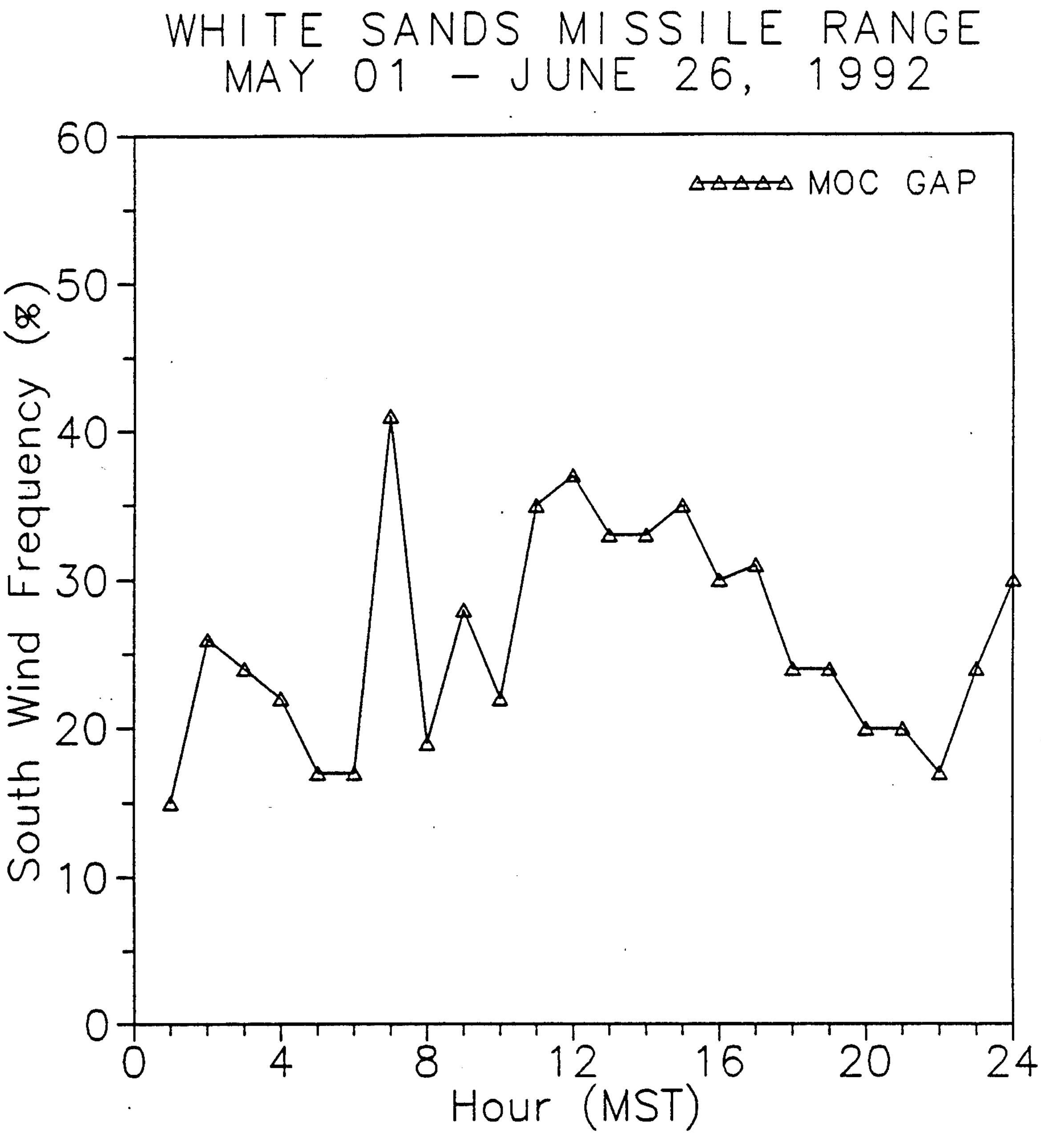


Figure 33. Frequency of south winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

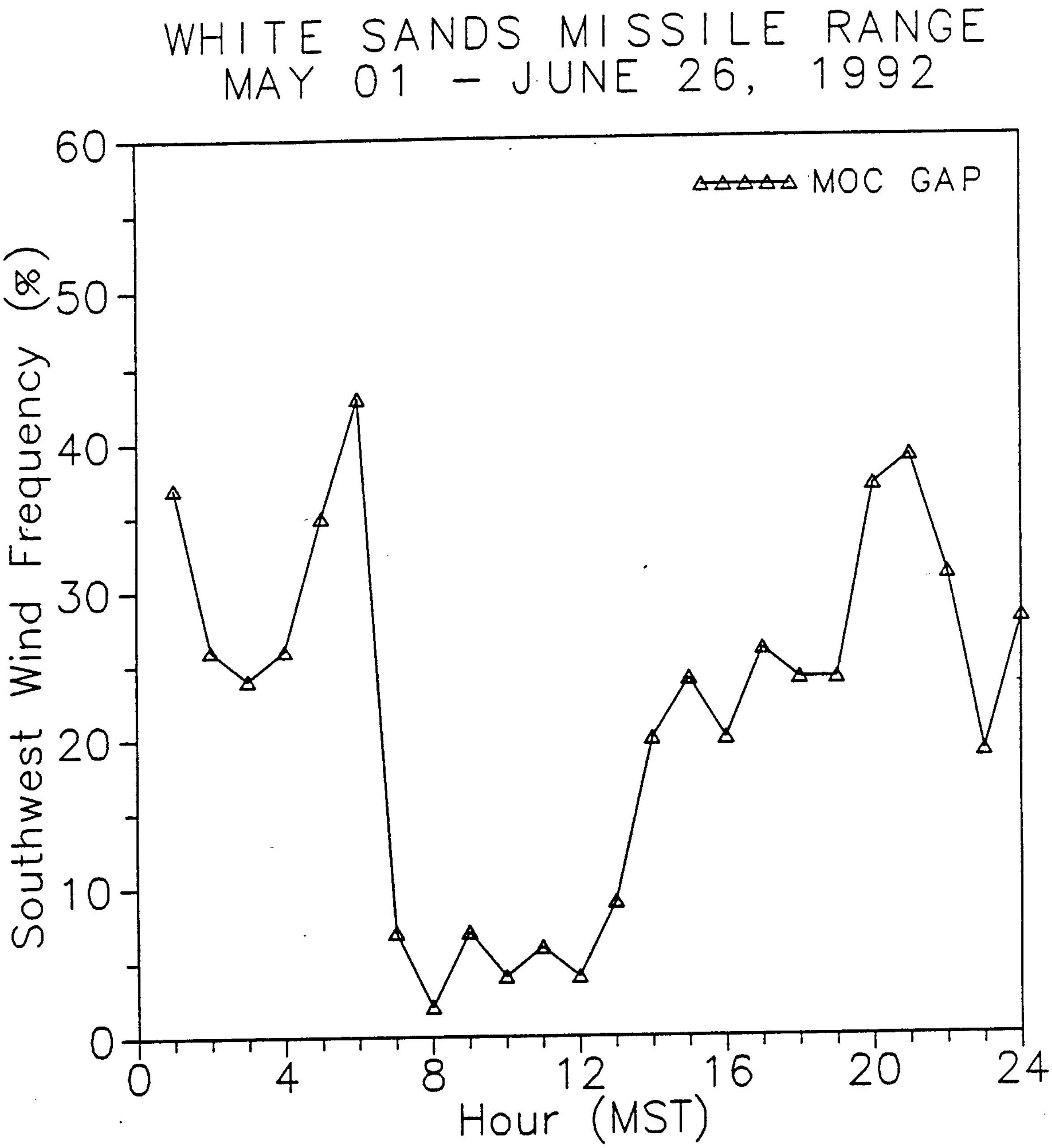


Figure 34. Frequency of southwest winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

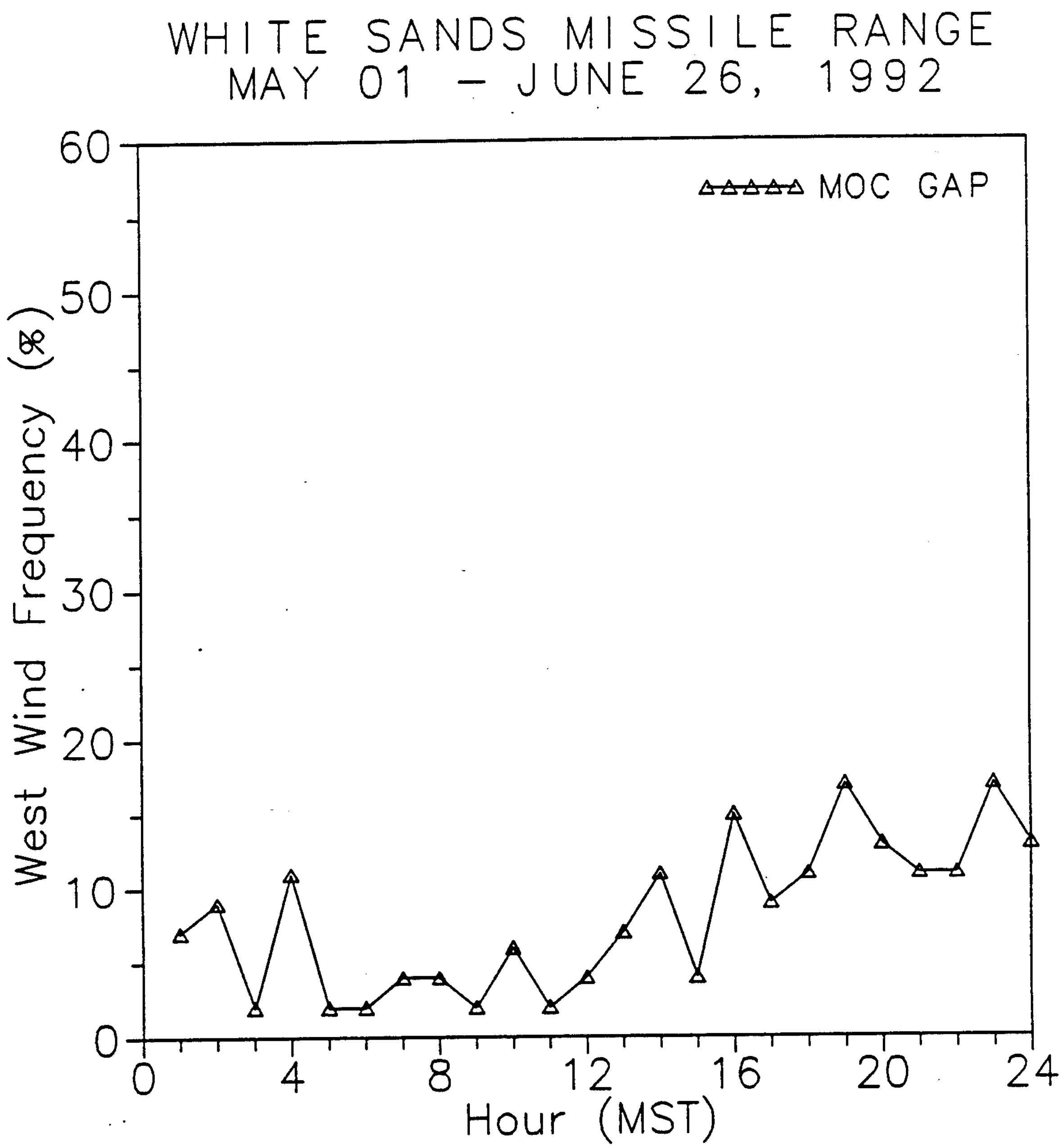


Figure 35. Frequency of west winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

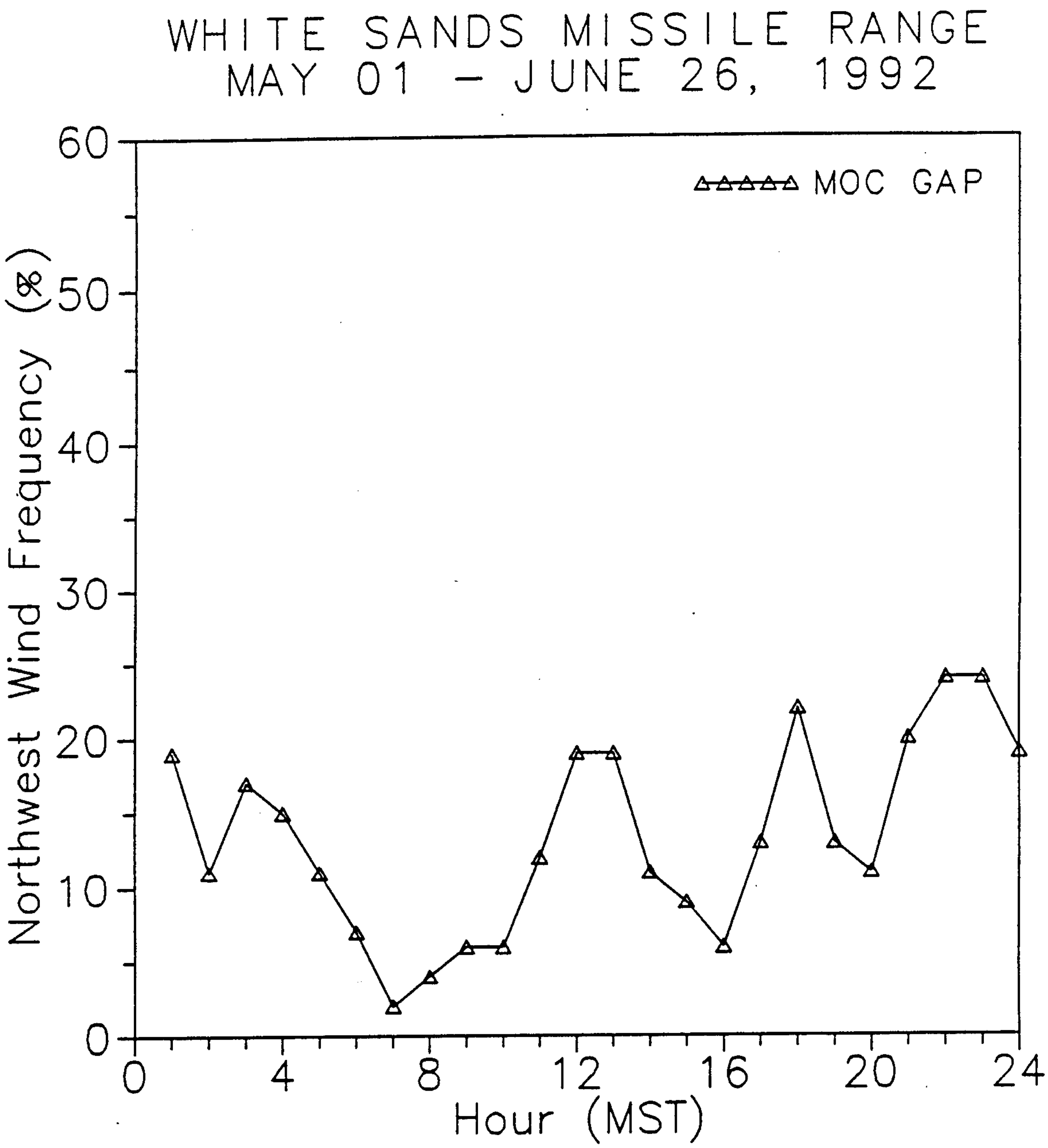


Figure 36. Frequency of northwest winds versus time of day at Mockingbird Gap from 1 May to 26 Jun 92.

4. Sodar Data

4.1 Percent Data Collected

Figure 37 shows the percent wind data successfully collected by the sodar as a function of height when it was operated at Yaw Line using solar power, between 19 Feb and 31 Mar 92, and after it was moved to Mockingbird Gap on 15 Apr 92 and run on hard power. The diagram illustrates the great improvement in sodar functioning after the sodar was relocated. Wind data were successfully measured at least 75 percent of the time at Mockingbird Gap at all heights up to 500 m.

4.2 Wind Speed and Direction Characteristics

A statistical summary of the 15-min averaged sodar wind data collected at Mockingbird Gap is listed in tables 3, 4, and 5. Tables 3 and 4 show frequency distributions of the wind speed and direction, respectively, as a function of sodar measurement height and time of day. Also included in table 4 are the scalar mean wind speeds and maximum and minimum wind speeds for each height and time. In table 5, frequencies, scalar mean wind speeds, and maximum and minimum wind speeds are listed for eight wind directions. The first set of statistics was computed using sodar data collected between 50 and 300 m, and the second set was calculated using data measured between 350 and 600 m.

Most of the sodar wind speeds were between 2 and 6 m s^{-1}. The highest average winds were from the north, and the strongest wind was 28.6 m s^{-1} from the northwest. At the lowest measurement heights, the most common direction was southeast, but southerly winds were more frequent above 300 m.

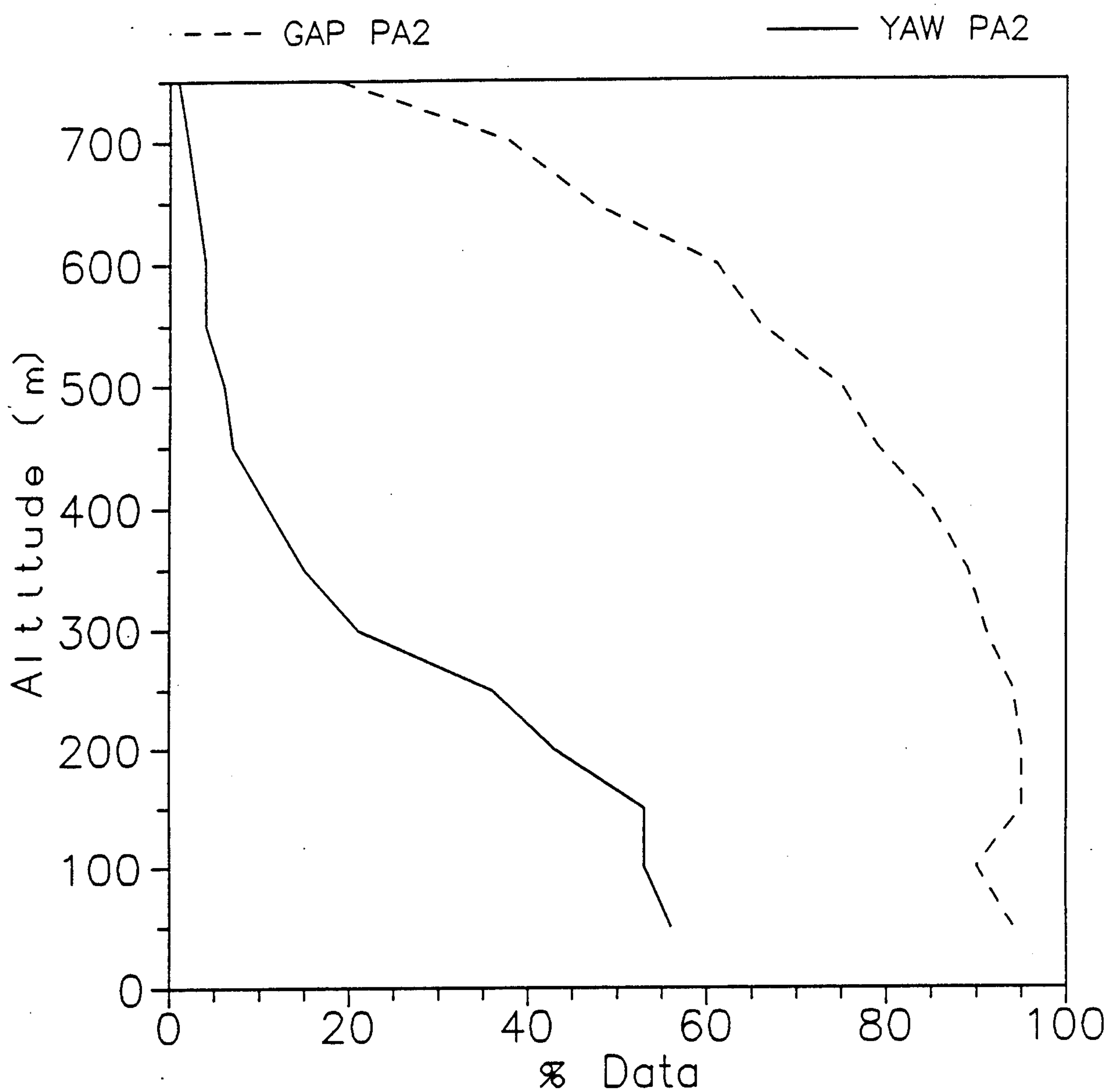


Figure 37. Percent sodar wind data collected as a function of height at Yaw Line and Mockingbird Gap sites.

Table 3. Frequency distribution of sodar wind speed for each altitude and time of day

	Wind Speed (m/s)								
Hours (MST)	00-02	02-04	04-06	06-08	08-10	10-12	12-14	14-16	>16
	Wind Speed Frequency (%)								
	Mockingbird Gap 50 m								
0000-0400	11.	36.	24.	16.	7.	4.	1.	1.	0.
0400-0800	20.	39.	28.	10.	3.	0.	0.	0.	0.
0800-1200	11.	43.	27.	14.	4.	0.	0.	0.	0.
1200-1600	3.	37.	30.	18.	6.	5.	1.	0.	0.
1600-2000	3.	28.	28.	18.	13.	8.	3.	0.	1.
2000-2400	8.	31.	24.	19.	7.	5.	2.	2.	0.
	Mockingbird Gap 100 m								
0000-0400	11.	33.	27.	15.	8.	4.	1.	0.	0.
0400-0800	18.	40.	27.	11.	3.	0.	0.	0.	0.
0800-1200	13.	41.	28.	14.	3.	0.	0.	0.	0.
1200-1600	3.	35.	32.	17.	8.	4.	1.	0.	0.
1600-2000	3.	29.	27.	18.	11.	8.	3.	0.	1.
2000-2400	8.	29.	25.	19.	8.	5.	2.	2.	1.
	Mockingbird Gap 150 m								
0000-0400	12.	28.	26.	19.	7.	5.	2.	1.	1.
0400-0800	16.	37.	30.	12.	4.	1.	0.	0.	0.
0800-1200	14.	37.	30.	14.	4.	0.	0.	0.	0.
1200-1600	2.	33.	31.	19.	8.	4.	2.	0.	1.
1600-2000	2.	26.	27.	19.	12.	9.	3.	0.	2.
2000-2400	7.	24.	24.	20.	11.	5.	3.	2.	2.
	Mockingbird Gap 200 m								
0000-0400	12.	24.	23.	22.	10.	6.	2.	1.	1.
0400-0800	13.	36.	28.	16.	6.	1.	0.	0.	0.
0800-1200	14.	34.	31.	15.	4.	1.	0.	0.	0.
1200-1600	2.	30.	32.	20.	8.	3.	2.	0.	1.
1600-2000	2.	23.	27.	22.	12.	8.	3.	1.	2.
2000-2400	7.	20.	27.	21.	11.	7.	3.	2.	3.

Table 3. Frequency distribution of sodar wind speed for each altitude and time of day (continued)

	Wind Speed (m/s)								
	00-02	02-04	04-06	06-08	08-10	10-12	12-14	14-16	>16
Hours (MST)	Wind Speed Frequency (%)								
			Mockingbird Gap 250 m						
0000-0400	10.	26.	23.	20.	11.	7.	2.	1.	1.
0400-0800	14.	30.	26.	19.	7.	2.	1.	0.	0.
0800-1200	14.	33.	29.	16.	6.	1.	0.	0.	0.
1200-1600	3.	28.	32.	22.	7.	4.	1.	1.	2.
1600-2000	2.	23.	26.	22.	15.	6.	3.	1.	2.
2000-2400	7.	20.	24.	23.	12.	8.	2.	2.	3.
			Mockingbird Gap 300 m						
0000-0400	11.	24.	23.	20.	12.	7.	2.	0.	1.
0400-0800	17.	27.	21.	21.	10.	3.	1.	0.	1.
0800-1200	15.	30.	28.	17.	6.	2.	1.	0.	0.
1200-1600	3.	26.	33.	22.	8.	4.	1.	1.	2.
1600-2000	2.	22.	25.	24.	15.	6.	4.	1.	3.
2000-2400	7.	20.	22.	21.	12.	10.	3.	1.	4.
			Mockingbird Gap 350 m						
0000-0400	10.	24.	23.	18.	12.	8.	2.	0.	1.
0400-0800	16.	26.	20.	21.	11.	5.	1.	0.	1.
0800-1200	17.	27.	28.	16.	8.	2.	1.	0.	1.
1200-1600	4.	27.	33.	21.	8.	4.	1.	1.	2.
1600-2000	2.	21.	26.	23.	13.	7.	3.	1.	3.
2000-2400	8.	20.	20.	22.	13.	9.	3.	1.	4.
			Mockingbird Gap 400 m						
0000-0400	9.	23.	23.	18.	14.	9.	2.	1.	2.
0400-0800	16.	25.	18.	20.	14.	5.	0.	0.	1.
0800-1200	16.	30.	25.	16.	10.	2.	1.	1.	1.
1200-1600	5.	27.	32.	20.	9.	3.	1.	0.	2.
1600-2000	4.	22.	25.	22.	14.	7.	3.	1.	3.
2000-2400	9.	20.	18.	23.	12.	9.	4.	1.	3.

Table 3. Frequency distribution of sodar wind speed for each altitude and time of day (continued)

Hours (MST)	00-02	02-04	04-06	06-08	08-10	10-12	12-14	14-16	>16
	Wind Speed (m/s) – Wind Speed Frequency (%)								
				Mockingbird Gap 450 m					
0000-0400	9.	22.	22.	19.	14.	9.	2.	1.	2.
0400-0800	18.	23.	19.	18.	15.	5.	1.	0.	1.
0800-1200	15.	31.	24.	16.	8.	3.	1.	1.	1.
1200-1600	6.	32.	28.	18.	10.	3.	1.	0.	2.
1600-2000	5.	24.	25.	22.	12.	5.	3.	1.	3.
2000-2400	9.	22.	18.	23.	11.	7.	5.	1.	3.
				Mockingbird Gap 500 m					
0000-0400	11.	20.	19.	20.	15.	10.	3.	1.	1.
0400-0800	18.	21.	21.	18.	13.	8.	1.	0.	1.
0800-1200	16.	30.	23.	16.	10.	4.	0.	1.	0.
1200-1600	7.	32.	28.	18.	9.	3.	1.	1.	1.
1600-2000	7.	25.	26.	20.	10.	5.	3.	1.	4.
2000-2400	9.	21.	20.	21.	13.	6.	7.	1.	1.
				Mockingbird Gap 550 m					
0000-0400	13.	21.	17.	20.	14.	10.	4.	1.	1.
0400-0800	19.	21.	21.	16.	13.	7.	2.	0.	0.
0800-1200	16.	28.	26.	14.	13.	2.	1.	1.	0.
1200-1600	9.	34.	29.	15.	7.	3.	1.	1.	1.
1600-2000	10.	27.	26.	18.	8.	4.	2.	1.	4.
2000-2400	12.	18.	21.	20.	13.	7.	6.	1.	2.
				Mockingbird Gap 600 m					
0000-0400	13.	17.	19.	20.	15.	10.	4.	1.	1.
0400-0800	16.	23.	21.	17.	12.	9.	2.	0.	0.
0800-1200	14.	29.	25.	14.	13.	3.	1.	1.	0.
1200-1600	11.	37.	27.	14.	5.	3.	0.	1.	1.
1600-2000	10.	31.	24.	17.	8.	3.	2.	1.	4.
2000-2400	15.	18.	20.	19.	13.	9.	4.	1.	1.

Table 3. Frequency distribution of sodar wind speed for each altitude and time of day (continued)

Hours (MST)	00-02	02-04	04-06	06-08	08-10	10-12	12-14	14-16	>16
	Wind Speed (m/s) — Wind Speed Frequency (%)								
				Mockingbird Gap 650 m					
0000-0400	14.	17.	17.	19.	18.	11.	3.	1.	1.
0400-0800	14.	25.	19.	17.	13.	9.	1.	0.	0.
0800-1200	12.	31.	28.	14.	10.	4.	1.	1.	0.
1200-1600	11.	42.	24.	12.	6.	4.	0.	0.	1.
1600-2000	11.	38.	22.	13.	8.	4.	1.	1.	3.
2000-2400	16.	21.	22.	16.	11.	8.	4.	1.	1.
				Mockingbird Gap 700 m					
0000-0400	13.	19.	18.	16.	17.	11.	4.	1.	1.
0400-0800	12.	26.	20.	16.	15.	8.	2.	0.	0.
0800-1200	10.	28.	29.	16.	9.	4.	2.	1.	0.
1200-1600	14.	40.	23.	13.	5.	4.	0.	0.	1.
1600-2000	12.	37.	19.	15.	5.	6.	2.	1.	3.
2000-2400	17.	24.	22.	15.	7.	8.	4.	0.	1.
				Mockingbird Gap 750 m					
0000-0400	9.	20.	21.	19.	15.	9.	5.	1.	1.
0400-0800	10.	19.	22.	18.	22.	7.	2.	0.	0.
0800-1200	13.	26.	30.	17.	9.	2.	3.	0.	0.
1200-1600	15.	45.	22.	11.	5.	2.	0.	0.	0.
1600-2000	19.	39.	19.	15.	3.	0.	0.	1.	3.
2000-2400	22.	20.	23.	14.	9.	10.	2.	1.	0.

Table 4. Frequency distribution of sodar wind direction for each altitude and time of day

	Wind Speed (m/s)			Wind Direction Frequency (%)							
Hours (MST)	Mean	Max	Min	N	NE	E	SE	S	SW	W	NW
				Mockingbird Gap 50 m							
0000-0400	4.9	23.8	.3	4.	2.	10.	39.	9.	4.	14.	18.
0400-0800	3.8	24.5	.0	5.	2.	9.	32.	9.	3.	7.	33.
0800-1200	4.2	23.7	.3	6.	4.	4.	38.	6.	3.	5.	33.
1200-1600	5.2	26.2	.8	3.	7.	6.	33.	12.	11.	8.	20.
1600-2000	6.0	25.0	.6	2.	3.	9.	32.	21.	13.	11.	9.
2000-2400	5.4	18.6	.6	4.	4.	7.	31.	23.	10.	9.	12.
				Mockingbird Gap 100 m							
0000-0400	5.0	26.1	.2	4.	3.	8.	40.	10.	3.	15.	18.
0400-0800	3.9	24.5	.2	4.	2.	6.	36.	10.	2.	8.	33.
0800-1200	4.1	23.9	.1	6.	4.	4.	40.	7.	2.	4.	33.
1200-1600	5.2	26.3	.6	2.	6.	5.	36.	11.	10.	10.	20.
1600-2000	6.0	25.0	.7	2.	3.	7.	32.	21.	14.	12.	9.
2000-2400	5.7	18.7	.3	5.	5.	6.	30.	24.	11.	8.	10.
				Mockingbird Gap 150 m							
0000-0400	5.2	26.2	.2	5.	2.	5.	38.	14.	4.	16.	15.
0400-0800	4.1	25.7	.2	5.	3.	2.	37.	12.	3.	10.	28.
0800-1200	4.2	24.1	.3	5.	3.	5.	37.	8.	4.	7.	30.
1200-1600	5.5	26.6	.8	3.	5.	5.	32.	14.	12.	10.	18.
1600-2000	6.4	26.0	.8	2.	3.	6.	29.	23.	17.	12.	9.
2000-2400	6.1	26.6	.4	5.	3.	6.	26.	28.	13.	9.	10.
				Mockingbird Gap 200 m							
0000-0400	5.6	26.8	.2	5.	2.	5.	30.	22.	5.	15.	16.
0400-0800	4.4	23.9	.1	7.	2.	2.	33.	17.	4.	10.	25.
0800-1200	4.3	24.1	.1	7.	3.	5.	34.	12.	3.	9.	27.
1200-1600	5.7	26.6	.2	2.	5.	5.	29.	18.	12.	11.	18.
1600-2000	6.5	26.2	.6	2.	3.	6.	29.	23.	17.	12.	7.
2000-2400	6.4	26.8	.0	5.	3.	5.	23.	30.	14.	9.	9.

Table 4. Frequency distribution of sodar wind direction for each altitude and time of day (continued)

	Wind Speed (m/s)			Wind Direction Frequency (%)							
Hours (MST)	Mean	Max	Min	N	NE	E	SE	S	SW	W	NW
				Mockingbird Gap 250 m							
0000-0400	5.7	27.8	.2	5.	2.	6.	24.	26.	7.	14.	16.
0400-0800	4.7	26.6	.2	9.	2.	4.	26.	23.	4.	10.	23.
0800-1200	4.5	24.3	.2	7.	4.	5.	29.	15.	4.	8.	27.
1200-1600	5.9	27.5	.7	2.	5.	5.	27.	19.	13.	13.	16.
1600-2000	6.6	28.0	.8	2.	3.	6.	28.	23.	18.	13.	8.
2000-2400	6.6	27.0	.3	5.	2.	6.	21.	31.	15.	11.	9.
				Mockingbird Gap 300 m							
0000-0400	5.8	26.9	.3	6.	3.	5.	21.	26.	10.	12.	17.
0400-0800	5.0	26.6	.3	10.	3.	3.	23.	24.	6.	9.	22.
0800-1200	4.6	25.1	.1	8.	5.	6.	25.	16.	6.	10.	25.
1200-1600	5.9	28.2	.4	2.	6.	6.	26.	21.	13.	11.	15.
1600-2000	6.8	28.5	.9	2.	3.	7.	28.	24.	17.	13.	8.
2000-2400	6.7	27.3	.4	5.	2.	6.	21.	29.	16.	11.	9.
				Mockingbird Gap 350 m							
0000-0400	5.9	27.1	.2	5.	3.	5.	18.	25.	14.	12.	19.
0400-0800	5.2	26.5	.3	10.	3.	2.	19.	27.	8.	10.	21.
0800-1200	4.7	25.0	.1	8.	5.	6.	19.	21.	6.	12.	23.
1200-1600	5.8	27.7	.6	2.	6.	6.	24.	21.	13.	12.	15.
1600-2000	6.8	28.0	.9	2.	2.	7.	27.	24.	18.	13.	7.
2000-2400	6.8	27.8	.1	5.	3.	7.	20.	28.	16.	12.	8.
				Mockingbird Gap 400 m							
0000-0400	6.1	28.6	.5	7.	3.	5.	15.	27.	15.	13.	16.
0400-0800	5.4	27.8	.2	10.	4.	3.	15.	29.	10.	11.	19.
0800-1200	4.8	26.2	.0	10.	6.	4.	14.	23.	8.	13.	22.
1200-1600	5.7	27.6	.5	3.	5.	8.	24.	21.	13.	13.	13.
1600-2000	6.6	27.1	.2	2.	3.	8.	28.	24.	17.	13.	5.
2000-2400	6.8	28.3	.5	6.	2.	8.	20.	27.	17.	13.	9.

Table 4. Frequency distribution of sodar wind direction for each altitude and time of day (continued)

	Wind Speed (m/s)			Wind Direction Frequency (%)							
Hours (MST)	Mean	Max	Min	N	NE	E	SE	S	SW	W	NW
Mockingbird Gap 450 m											
0000-0400	6.2	26.9	.2	6.	3.	4.	15.	25.	18.	13.	15.
0400-0800	5.4	26.4	.1	9.	4.	4.	14.	27.	13.	12.	17.
0800-1200	4.9	24.2	.2	9.	6.	5.	12.	26.	9.	15.	19.
1200-1600	5.4	27.7	.7	3.	5.	8.	21.	25.	13.	14.	12.
1600-2000	6.4	26.7	.7	3.	2.	8.	25.	27.	17.	13.	4.
2000-2400	6.5	28.5	.4	4.	2.	8.	18.	29.	15.	13.	11.
Mockingbird Gap 500 m											
0000-0400	6.3	26.6	.2	5.	5.	3.	13.	27.	19.	12.	17.
0400-0800	5.4	27.9	.2	9.	3.	5.	15.	26.	13.	14.	16.
0800-1200	4.9	23.4	.1	9.	6.	4.	9.	28.	10.	18.	17.
1200-1600	5.3	27.8	.4	5.	4.	9.	18.	29.	12.	13.	9.
1600-2000	6.3	27.0	.7	3.	2.	9.	24.	28.	16.	13.	5.
2000-2400	6.5	28.4	.6	5.	3.	7.	17.	29.	15.	15.	9.
Mockingbird Gap 550 m											
0000-0400	6.2	26.5	.1	4.	5.	3.	13.	28.	19.	12.	15.
0400-0800	5.3	23.2	.5	8.	3.	7.	16.	26.	14.	14.	12.
0800-1200	4.9	15.3	.0	7.	7.	5.	9.	29.	12.	19.	13.
1200-1600	5.1	27.7	.3	5.	4.	10.	16.	31.	12.	12.	8.
1600-2000	5.9	27.3	.5	3.	3.	12.	20.	30.	15.	14.	5.
2000-2400	6.3	28.2	.5	4.	3.	8.	17.	29.	16.	15.	9.
Mockingbird Gap 600 m											
0000-0400	6.3	23.6	.3	5.	5.	4.	12.	30.	17.	15.	13.
0400-0800	5.5	23.0	.1	8.	4.	6.	15.	25.	18.	14.	10.
0800-1200	5.0	15.1	.1	7.	7.	6.	8.	28.	15.	19.	11.
1200-1600	4.9	27.5	.2	6.	4.	10.	15.	32.	14.	13.	6.
1600-2000	5.7	27.2	.7	3.	3.	12.	18.	29.	15.	13.	6.
2000-2400	6.2	28.1	.1	3.	2.	8.	15.	30.	18.	14.	10.

Table 4. Frequency distribution of sodar wind direction for each altitude and time of day (continued)

	Wind Speed (m/s)			Wind Direction Frequency (%)							
Hours (MST)	Mean	Max	Min	N	NE	E	SE	S	SW	W	NW
				Mockingbird Gap 650 m							
0000-0400	6.2	24.1	.0	3.	5.	4.	11.	33.	18.	14.	11.
0400-0800	5.6	22.9	.3	5.	3.	6.	15.	27.	22.	13.	8.
0800-1200	5.0	14.6	.2	6.	7.	6.	8.	27.	19.	18.	10.
1200-1600	4.7	27.4	.7	4.	4.	10.	14.	33.	17.	13.	5.
1600-2000	5.4	27.0	.9	4.	4.	10.	20.	23.	21.	14.	4.
2000-2400	5.8	27.4	.2	2.	1.	8.	13.	32.	21.	13.	10.
				Mockingbird Gap 700 m							
0000-0400	6.4	25.4	.1	3.	6.	5.	10.	36.	18.	15.	7.
0400-0800	5.7	17.7	.4	4.	3.	6.	15.	25.	25.	16.	7.
0800-1200	5.3	14.6	.3	5.	4.	8.	9.	26.	22.	18.	9.
1200-1600	4.6	27.5	.6	4.	3.	9.	15.	29.	21.	13.	5.
1600-2000	5.4	26.9	.9	2.	2.	13.	18.	23.	25.	14.	3.
2000-2400	5.6	26.7	.5	1.	2.	7.	12.	37.	24.	9.	9.
				Mockingbird Gap 750 m							
0000-0400	6.4	27.1	.3	2.	3.	7.	10.	35.	20.	17.	5.
0400-0800	6.0	12.8	.6	1.	3.	5.	13.	24.	30.	17.	7.
0800-1200	5.0	13.4	.6	5.	3.	8.	8.	27.	26.	15.	8.
1200-1600	4.1	11.8	.3	3.	3.	11.	19.	22.	25.	12.	6.
1600-2000	4.5	26.5	.6	1.	1.	9.	19.	27.	28.	12.	1.
2000-2400	5.2	14.2	.5	0.	4.	8.	10.	38.	27.	5.	9.

Table 5. Frequency distribution of sodar wind direction

Direction	Frequency (%)	Wind Speed (m/s) Mean	Max	Min
	Mockingbird Gap 50-300 m			
N	5.	7.2	27.8	.0
NE	3.	5.5	20.5	.2
E	6.	4.8	25.1	.1
SE	30.	4.6	13.8	.0
S	18.	5.9	28.2	.1
SW	9.	5.0	18.7	.2
W	10.	6.5	17.8	.1
NW	18.	5.1	28.5	.1
	Mockingbird Gap 350-600 m			
N	6.	7.7	27.9	.1
NE	4.	4.5	21.0	.1
E	6.	5.0	25.0	.1
SE	17.	5.1	14.7	.0
S	27.	6.5	28.5	.2
SW	14.	4.7	23.6	.3
W	13.	6.1	20.4	.1
NW	13.	5.8	28.6	.0

4.3 Comparison of SAMS and Sodar Data

Mockingbird Gap sodar wind data collected 400 and 500 m above the ground were statistically compared with conjunctive Jim Site tower measurements to determine how well the latter agrees with winds expected above the valley floor at the height of the cable. Both systems were operated for 15 days between 16 and 30 Apr 92. The 15-min averaged sodar measurements were first averaged over each hour to match the temporal resolution of the SAMS data. Using the two 1-h averaged data sets, scalar average wind speeds for each hour of the day and frequency distributions of wind speed and direction were computed and are plotted in figures 38 through 43. Agreement between the sodar and tower wind speeds was fairly good, but there were some differences in wind direction. Compared to the Jim Site measurements, the sodar winds blew more frequently from the south and less frequently from the southwest and west.

Mockingbird Gap sodar data from the same two levels were also compared with tower measurements collected on the valley floor at the same site. Forty-nine days of concurrent measurements, collected between 16 Apr and 23 Jun 92, were similarly analyzed. The results are plotted in figures 44 through 49, and, as expected, a much poorer agreement between the two sets of wind speeds was found.

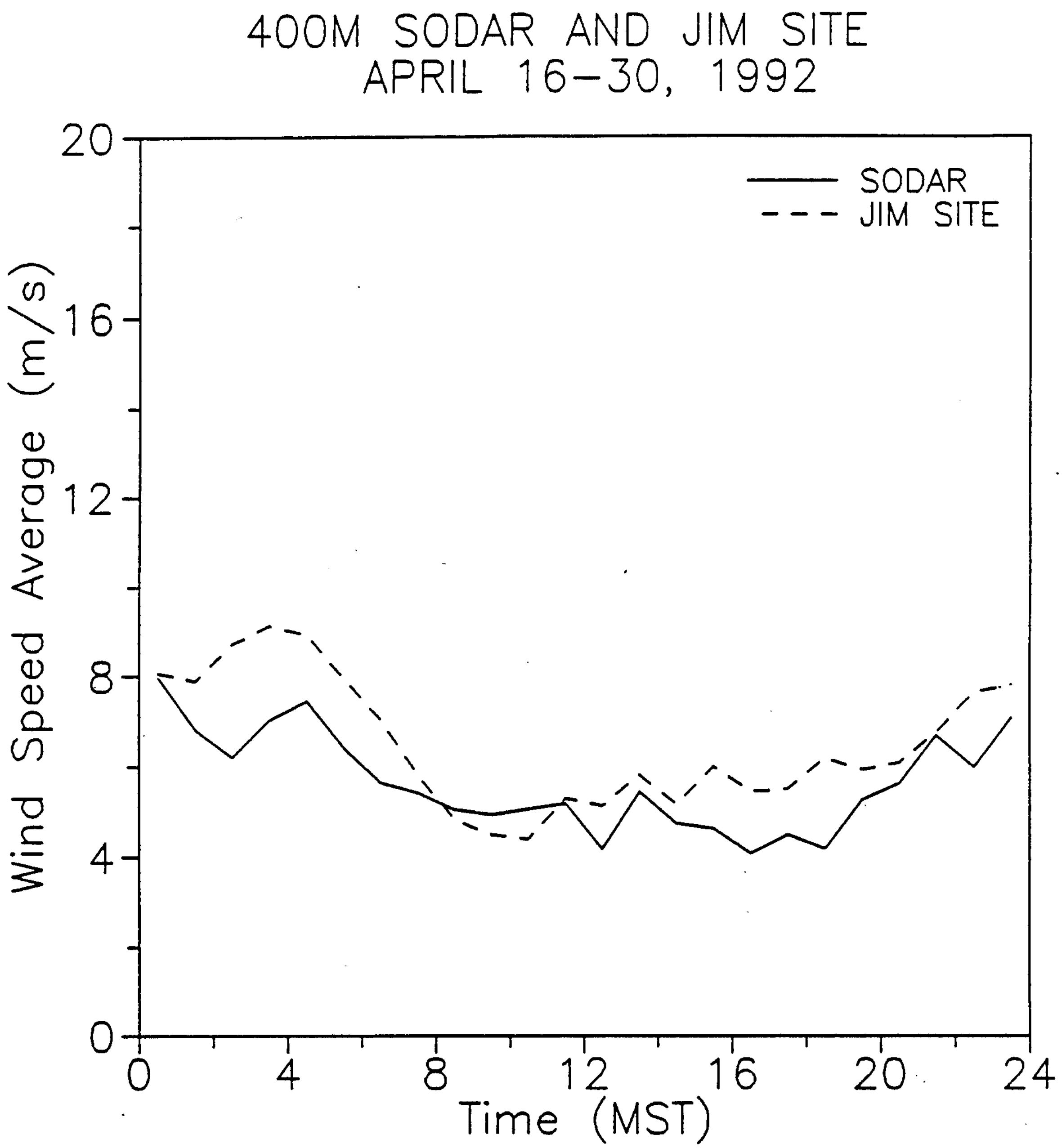


Figure 38. Jim Site and 400-m sodar scalar average wind speeds versus time of day.

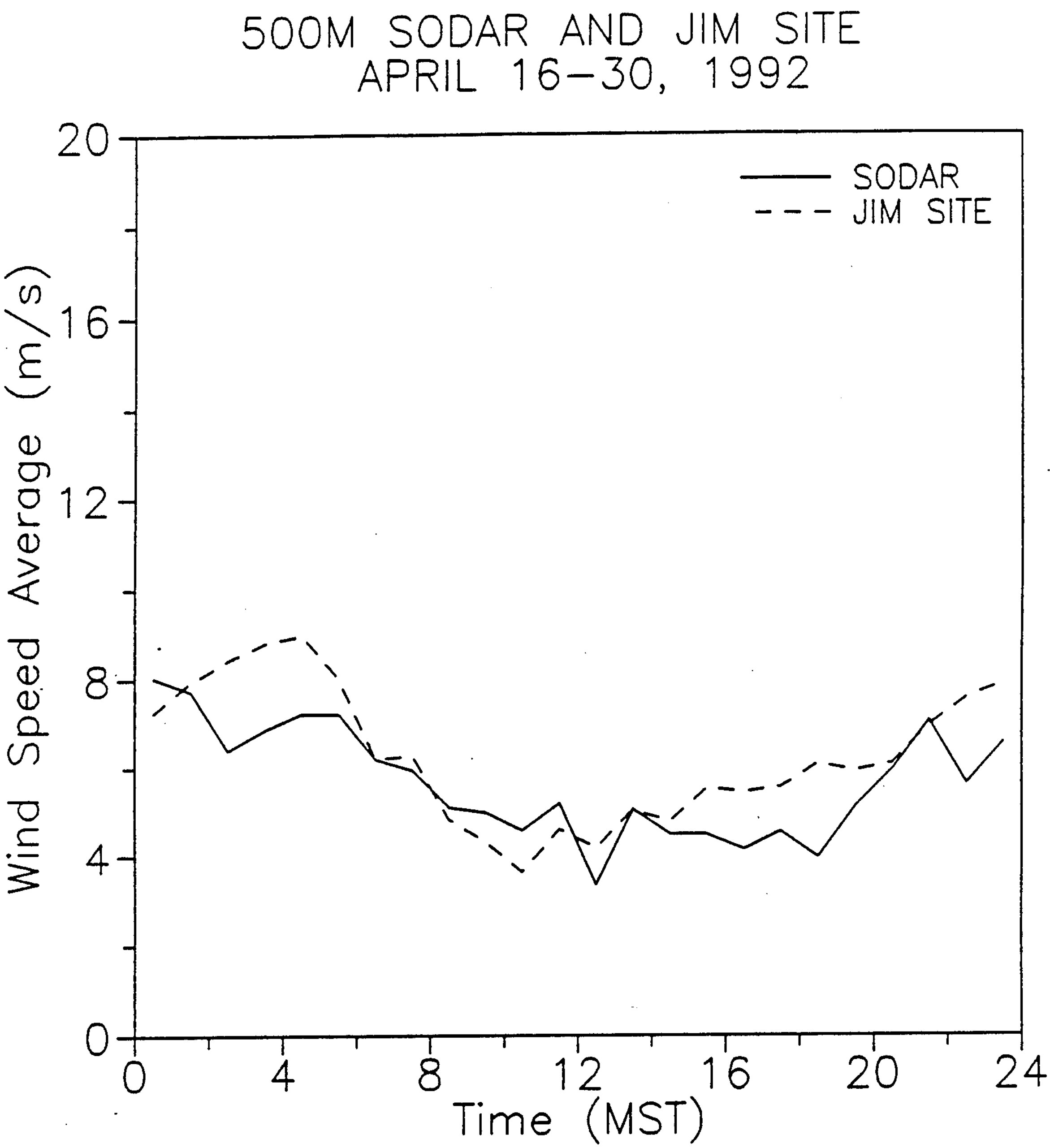


Figure 39. Jim Site and 500-m sodar scalar average wind speeds versus time of day.

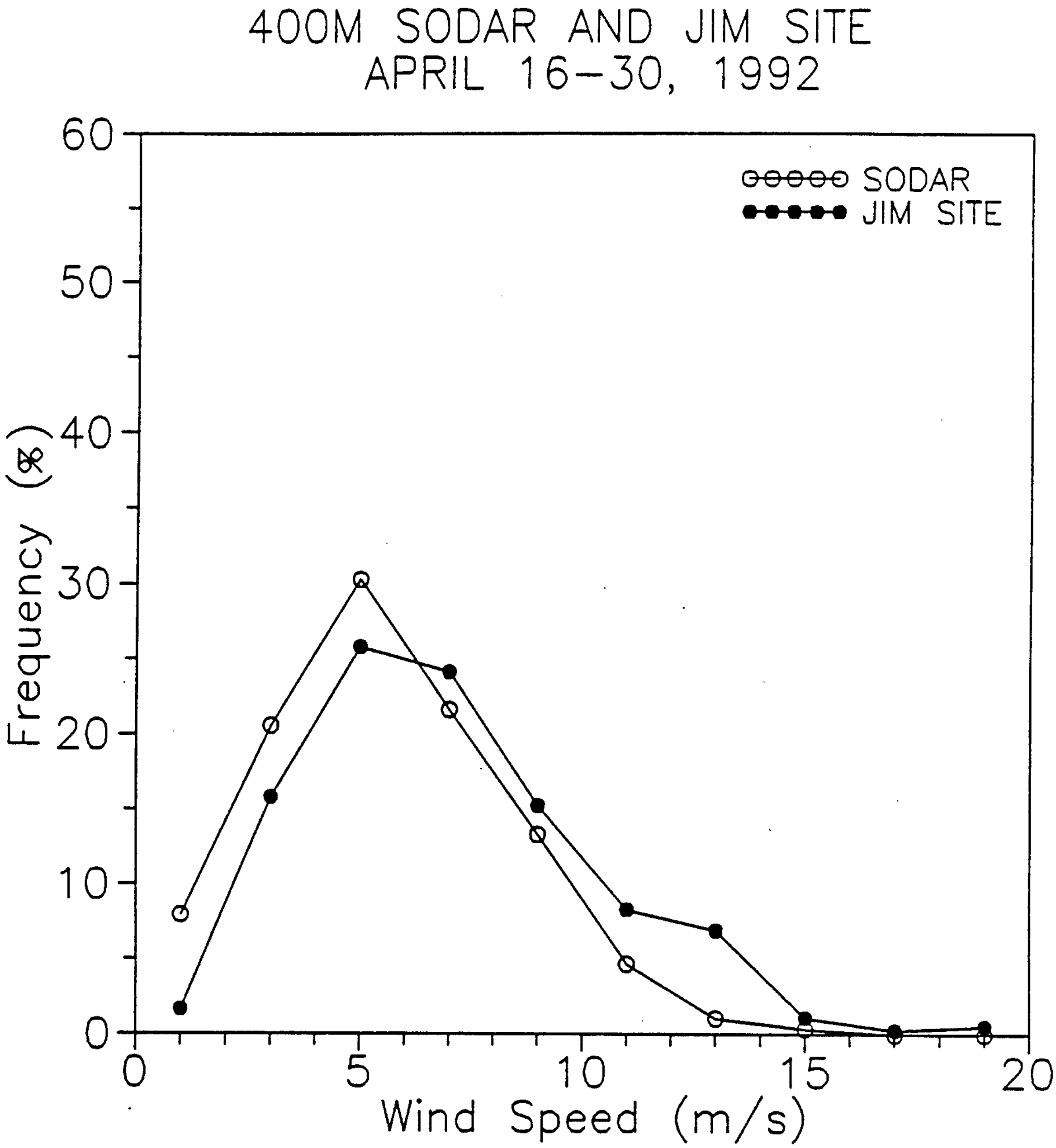


Figure 40. Frequency distribution of Jim Site and 400-m sodar wind speeds.

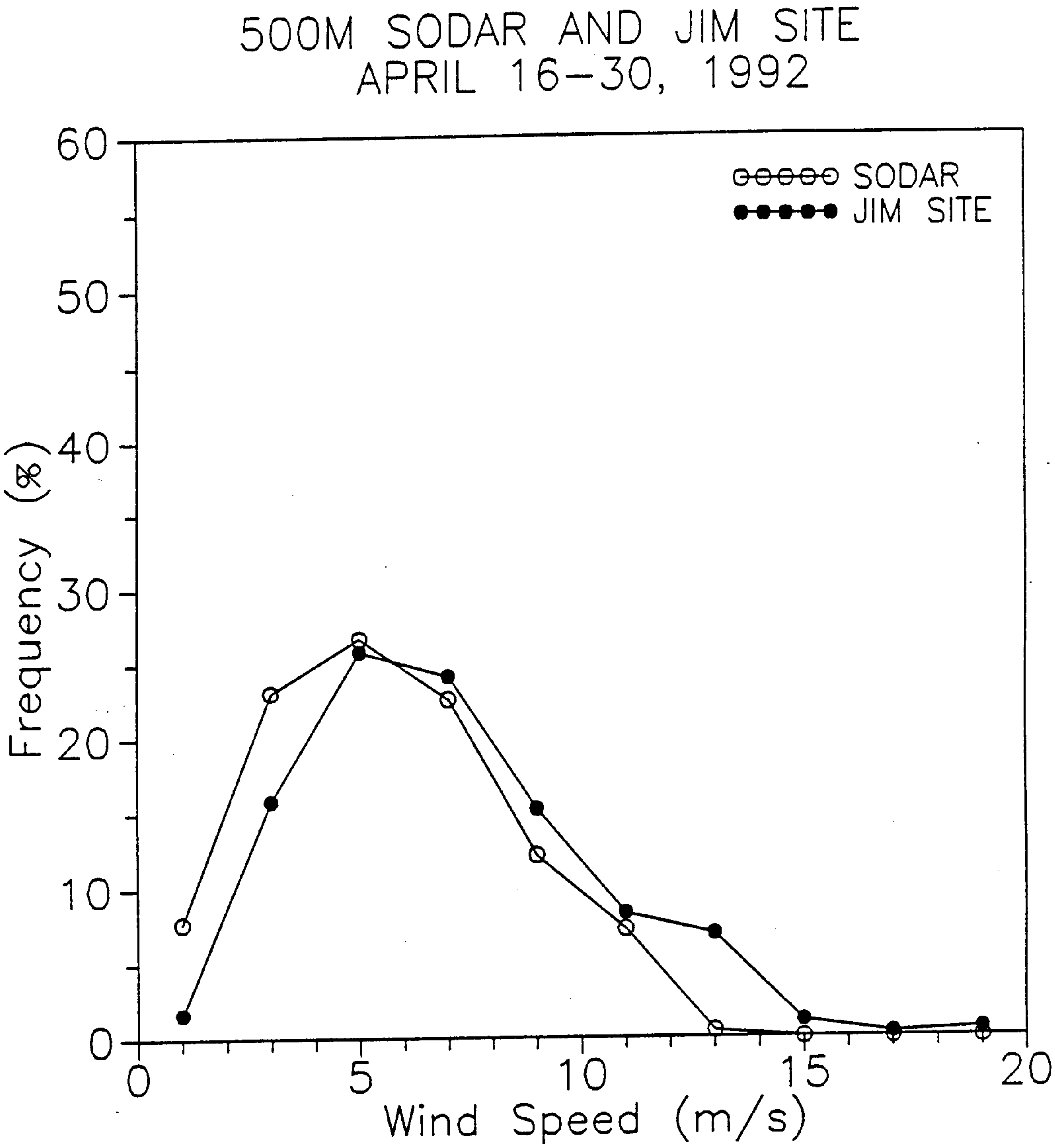


Figure 41. Frequency distribution of Jim Site and 500-m sodar wind speeds.

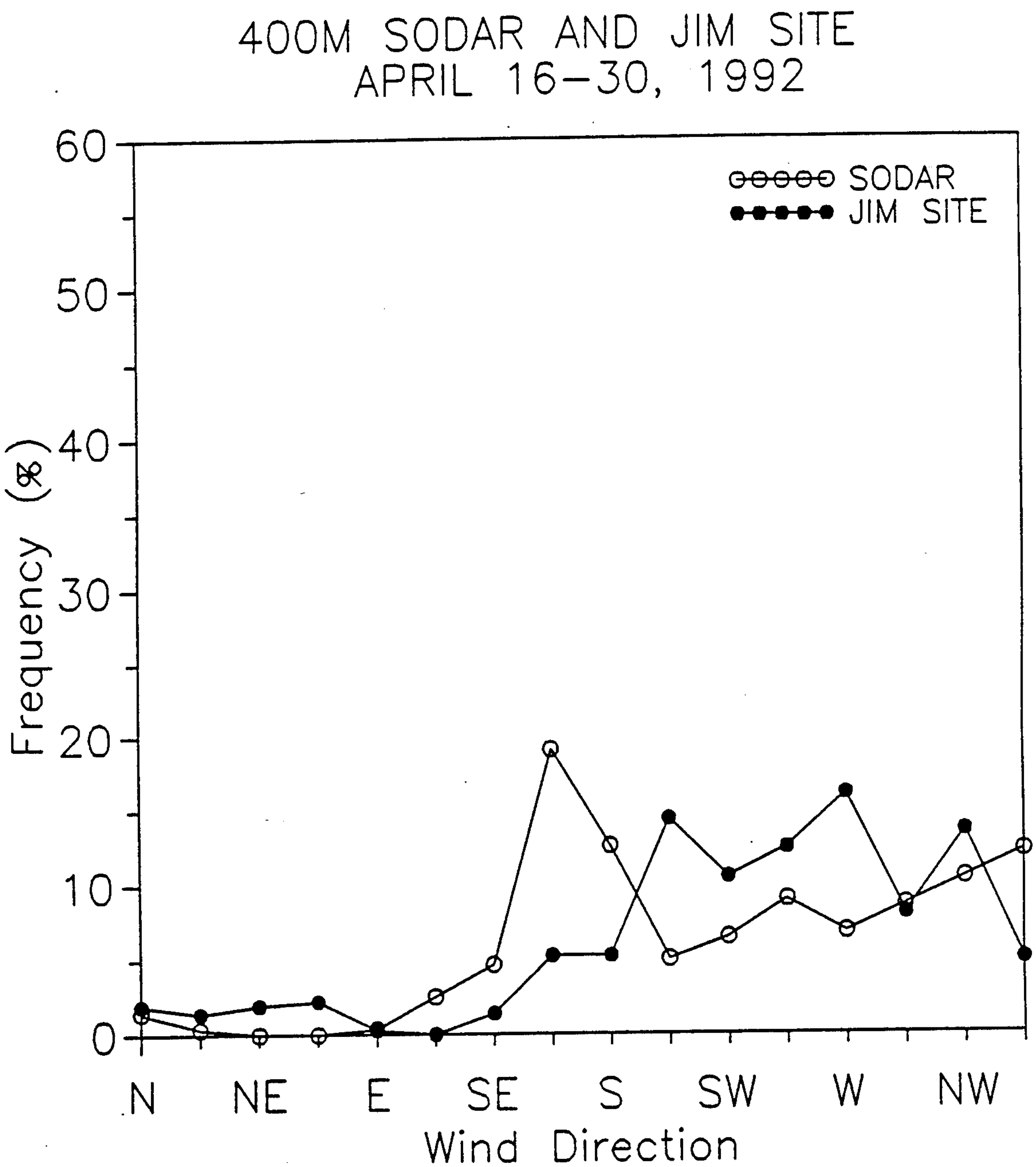


Figure 42. Frequency distribution of Jim Site and 400-m sodar wind directions.

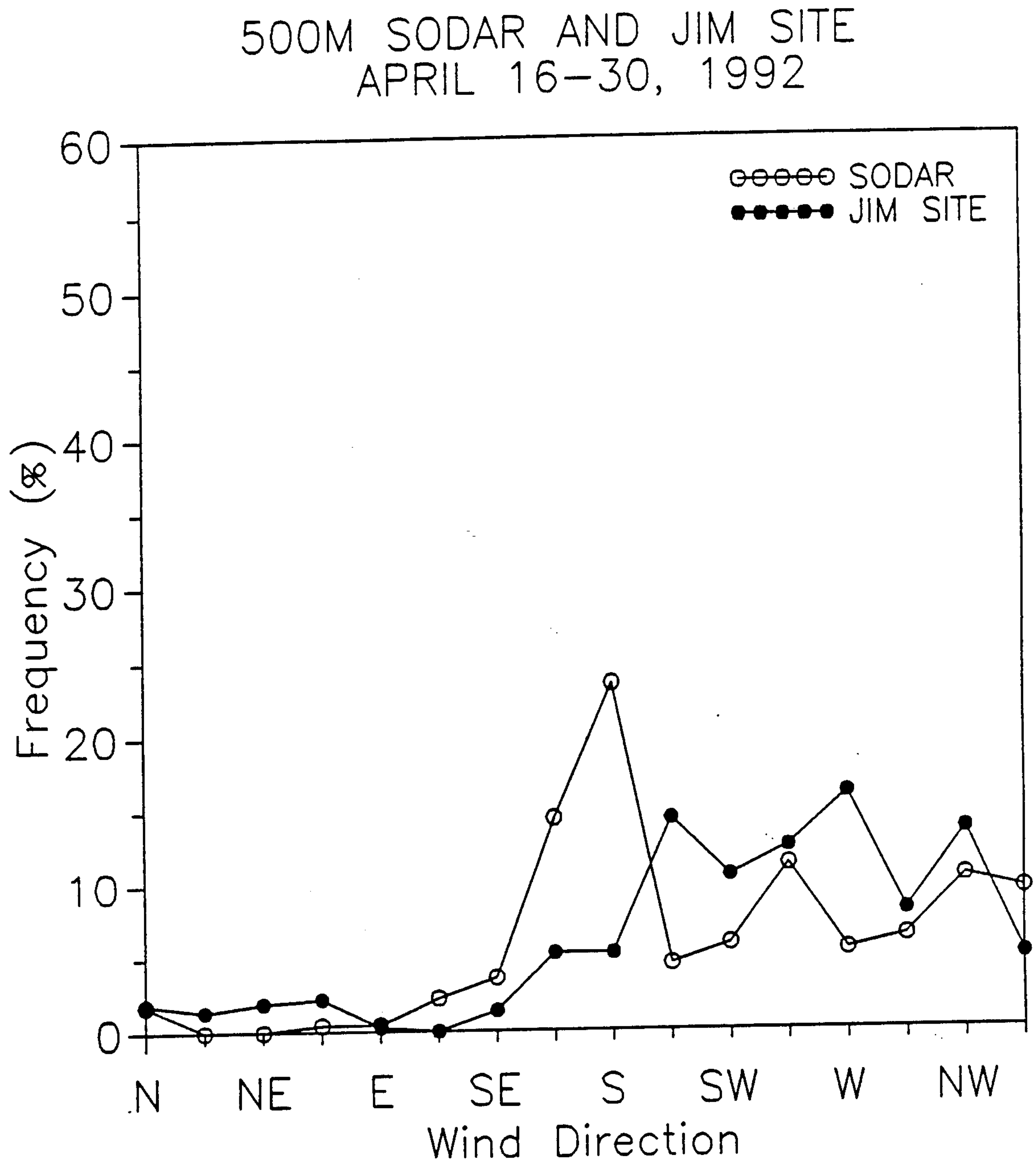


Figure 43. Frequency distribution of Jim Site and 500-m sodar wind directions.

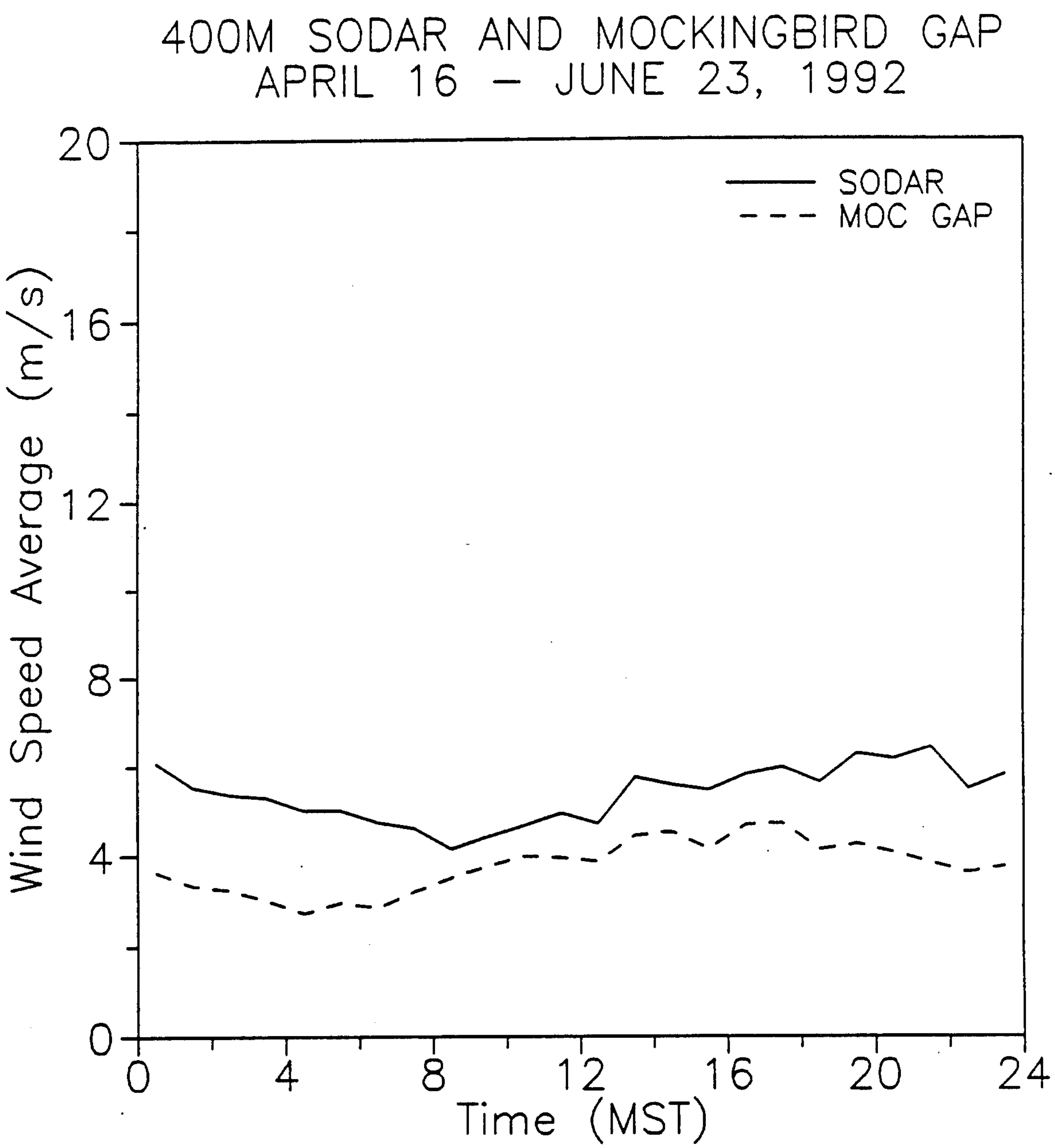


Figure 44. Mockingbird Gap and 400-m sodar scalar average wind speeds versus time of day.

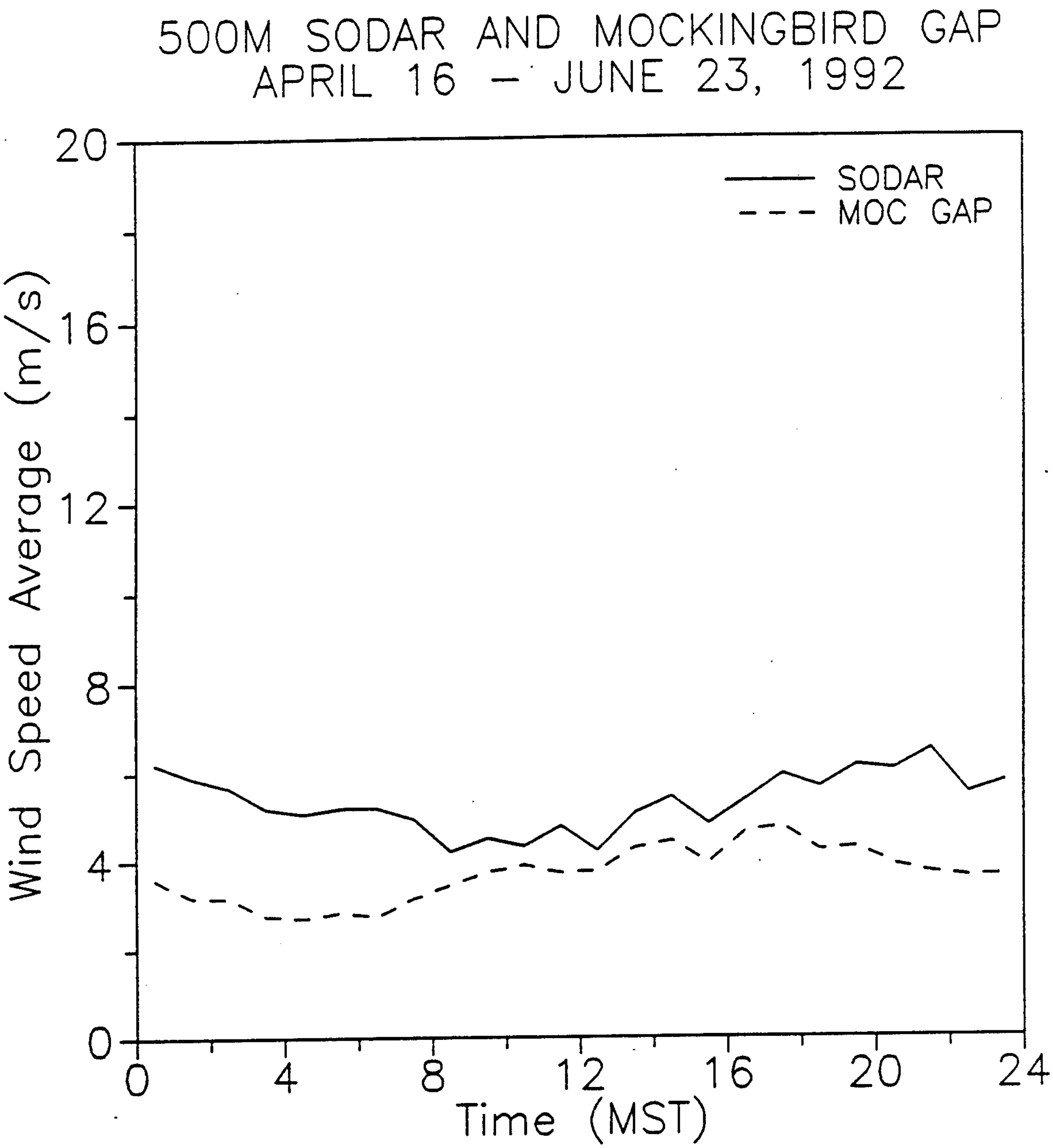


Figure 45. Mockingbird Gap and 500-m sodar scalar average wind speeds versus time of day.

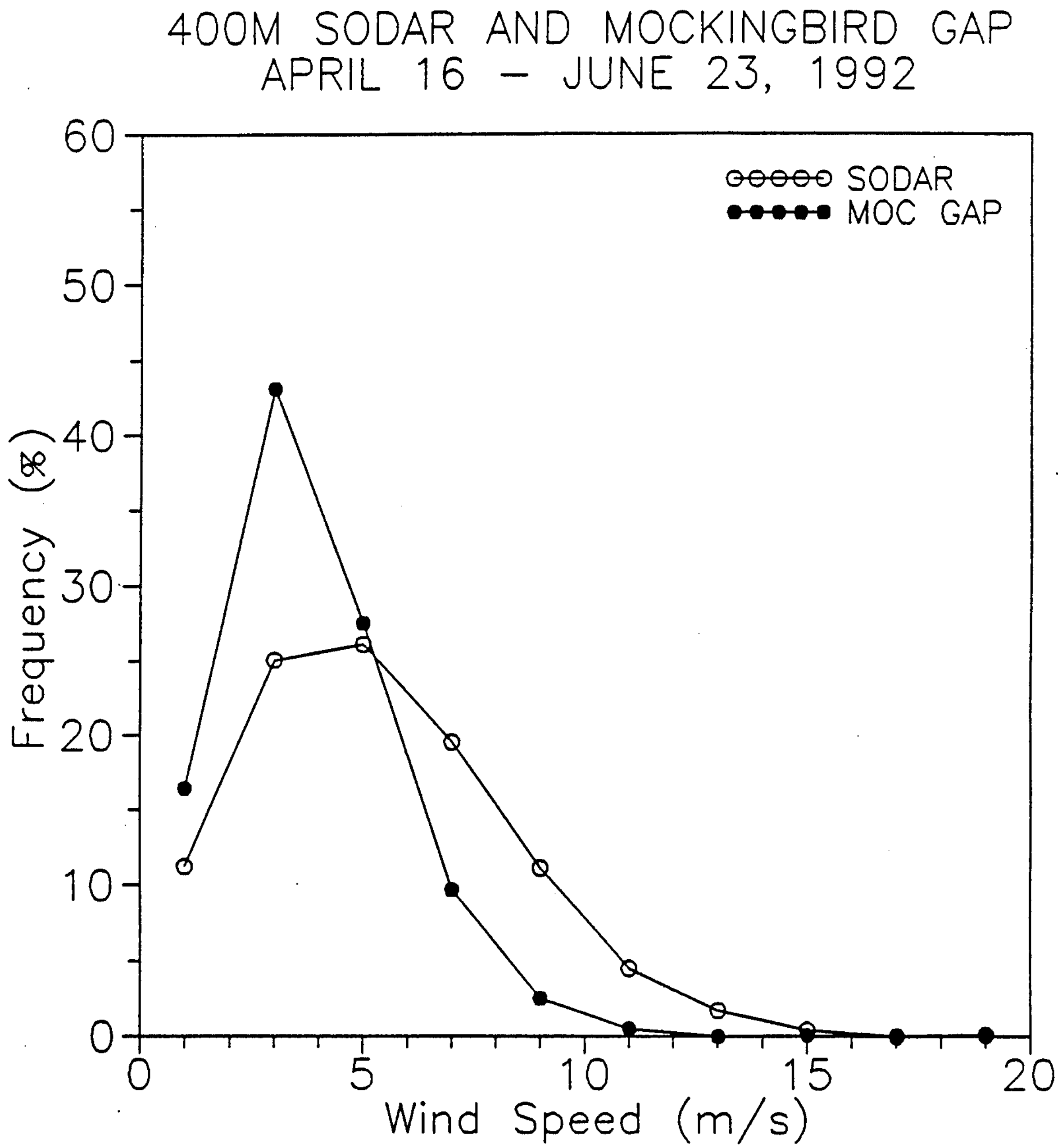


Figure 46. Frequency distribution of Mockingbird Gap and 400-m sodar wind speeds.

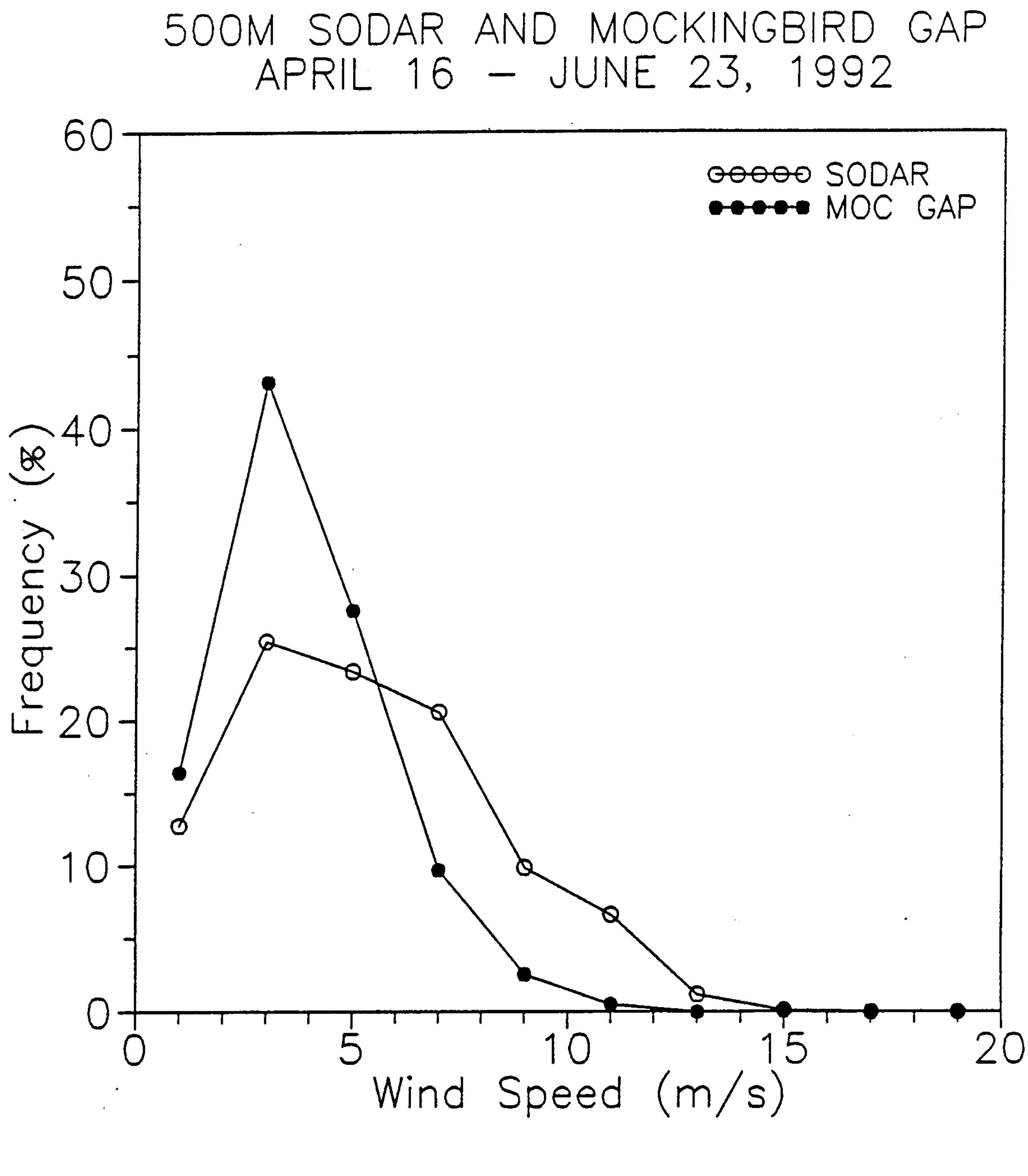


Figure 47. Frequency distribution of Mockingbird Gap and 500-m sodar wind speeds.

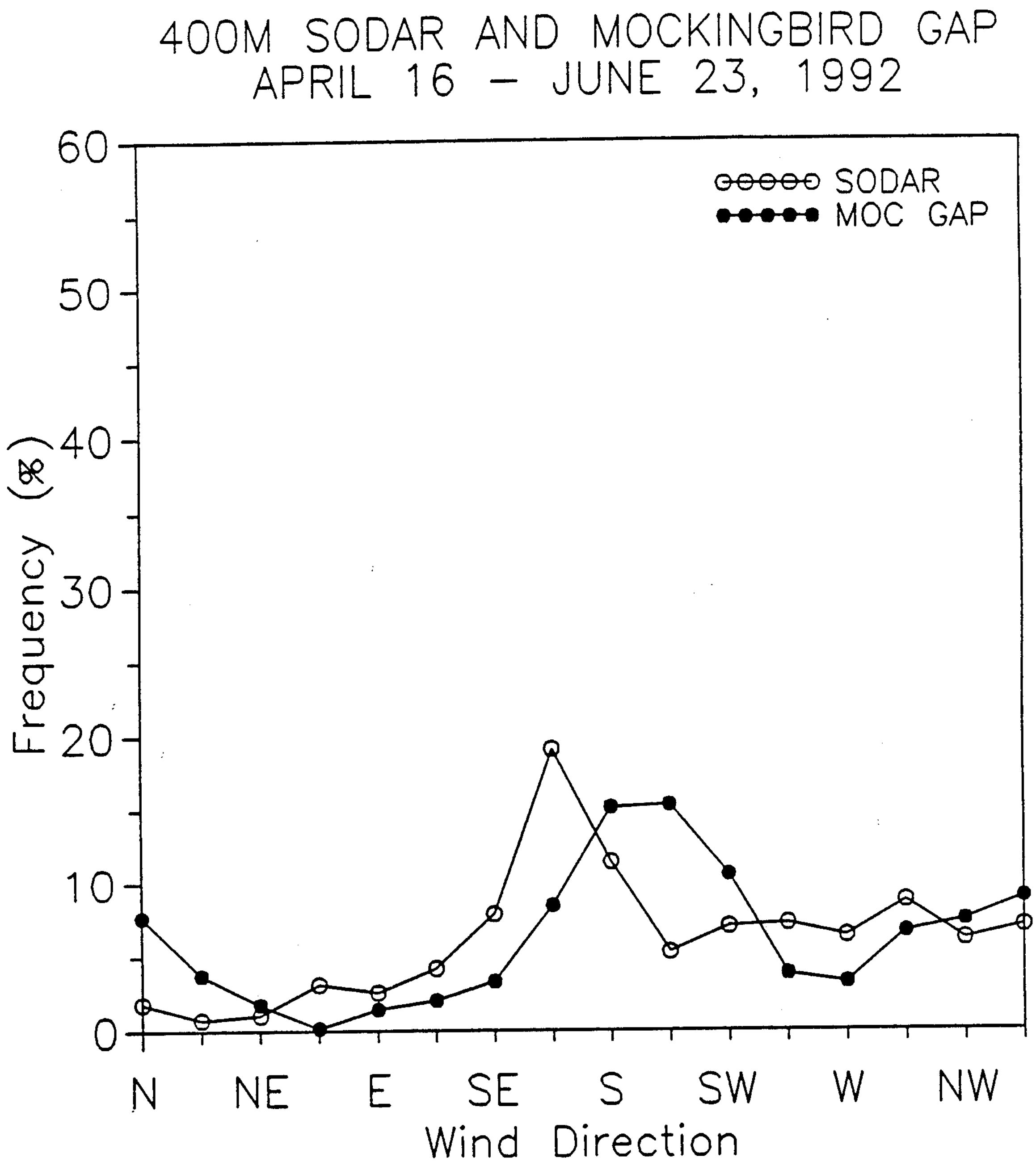


Figure 48. Frequency distribution of Mockingbird Gap and 400-m sodar wind directions.

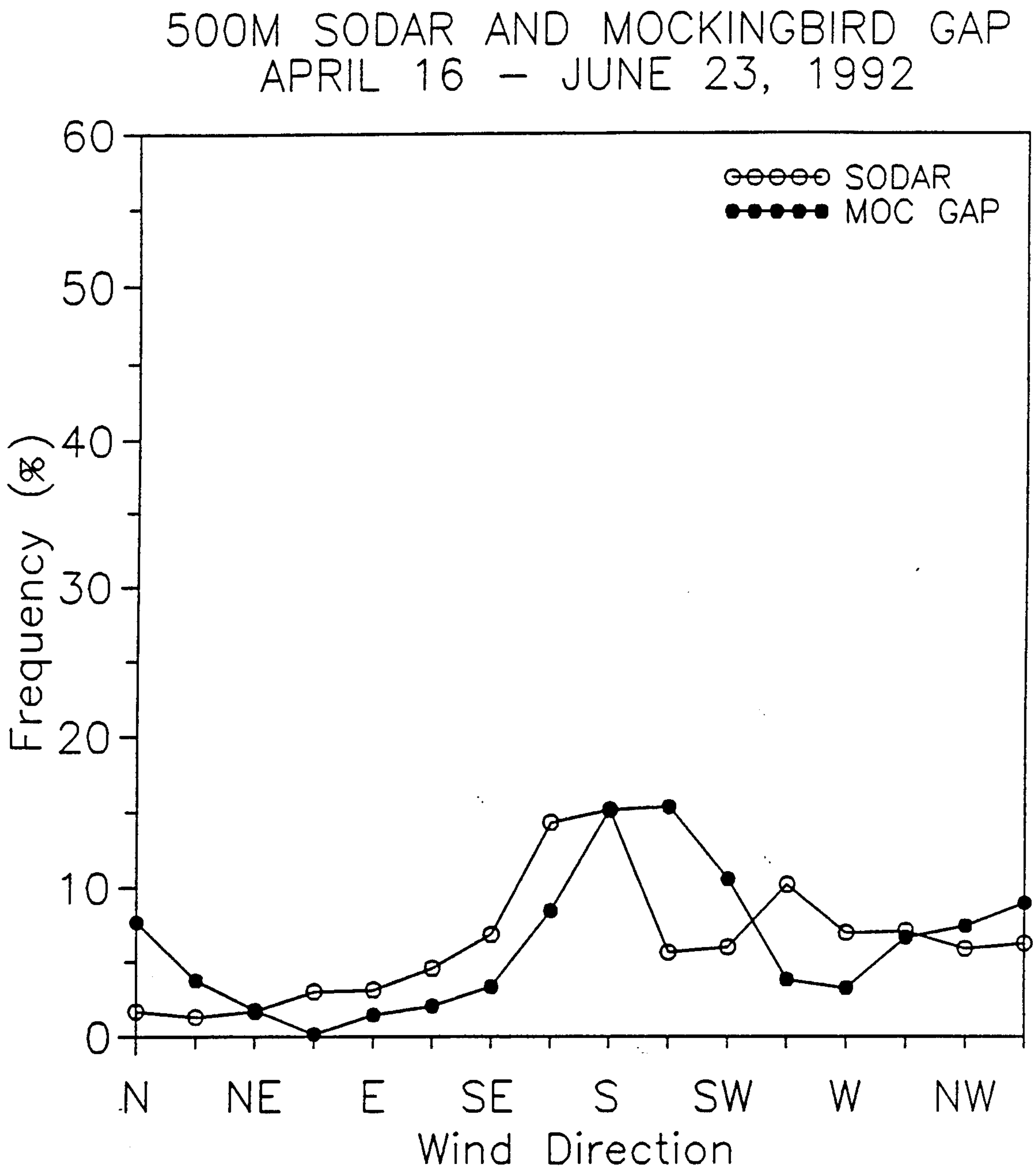
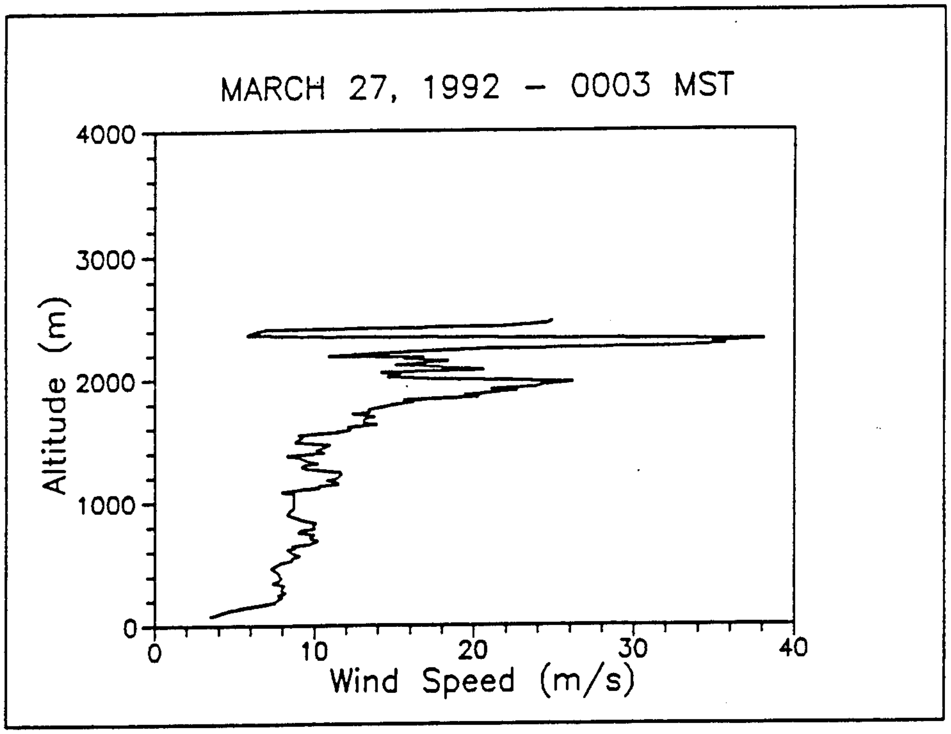


Figure 49. Frequency distribution of Mockingbird Gap and 500-m sodar wind directions.

5. Rawinsonde Data

Vertical profiles of wind speed and direction, determined by the seven rawinsonde flights, are plotted in figures 50 through 56. The winds were computed from balloon positions 40 s apart. The ascent rate of the sondes varied between 2 and 4.5 m s^{-1}, so the vertical resolution of the measurements ranged between 80 and 180 m. In the area of greatest interest, within the first few hundred meters of the surface, most winds were from the southeast with magnitudes between 5 and 10 m s^{-1}.



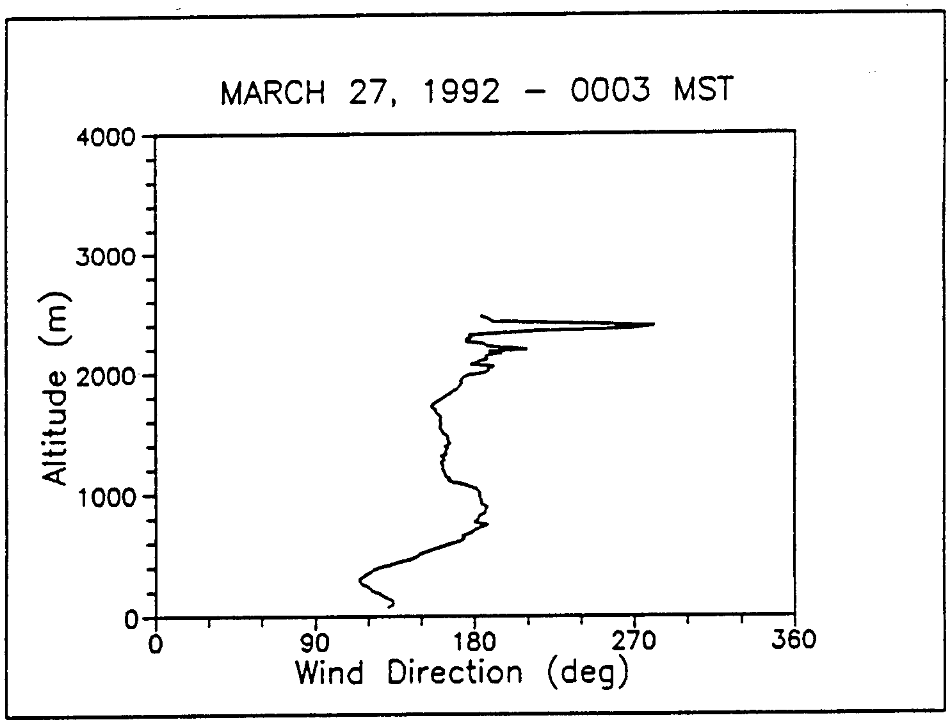
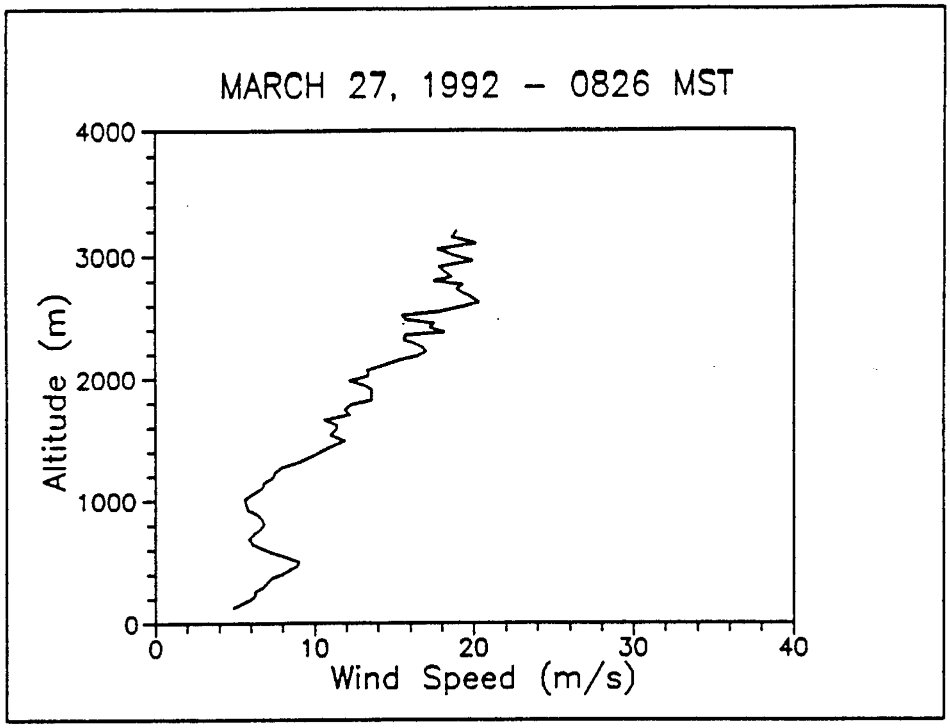


Figure 50. Wind speed and direction profiles from rawinsonde released at Yaw Line on 27 Mar 92 at 0003 MST.



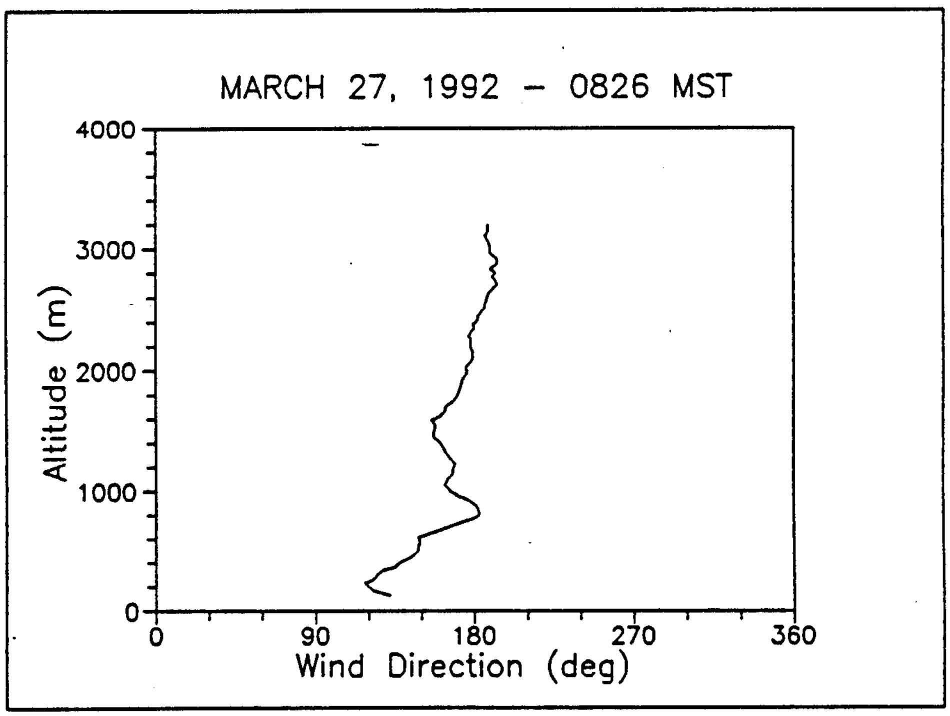
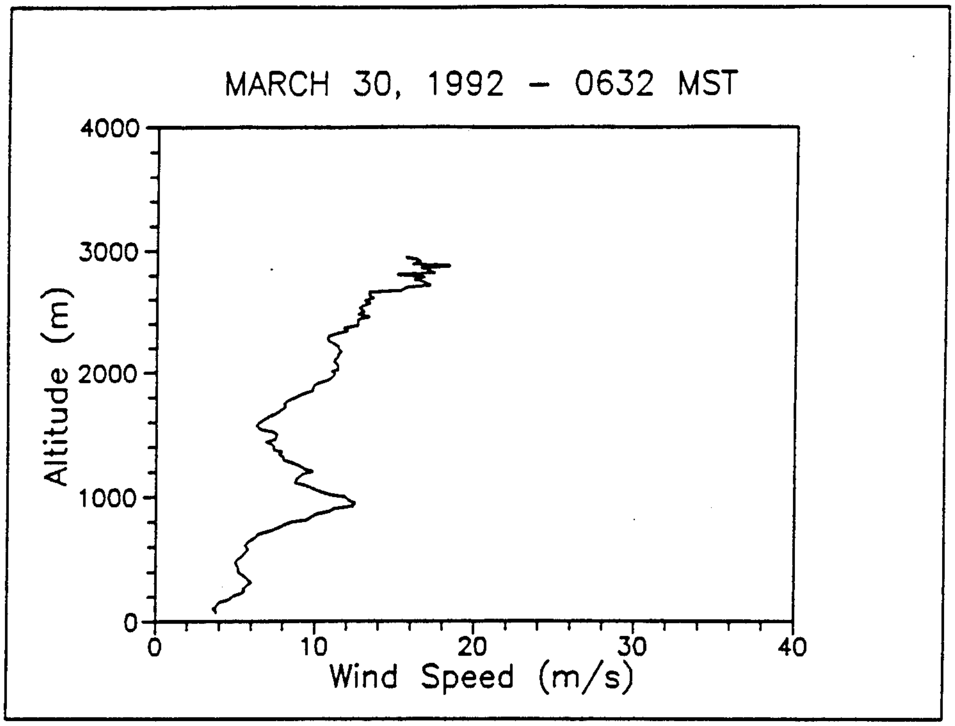


Figure 51. Wind speed and direction profiles from rawinsonde released at Yaw Line on 27 Mar 92 at 0826 MST.



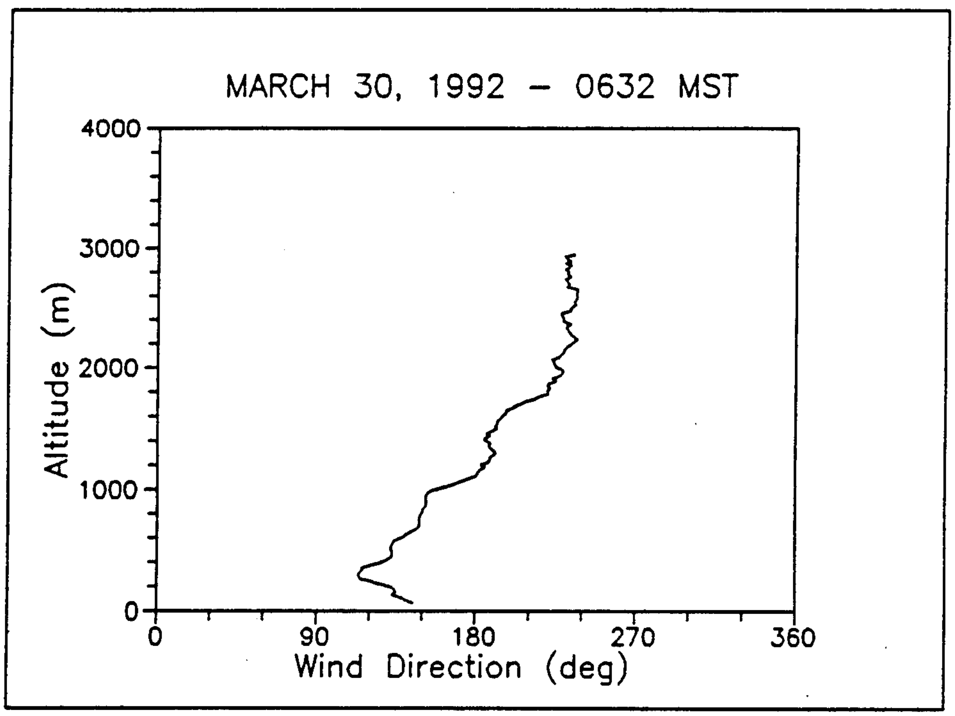
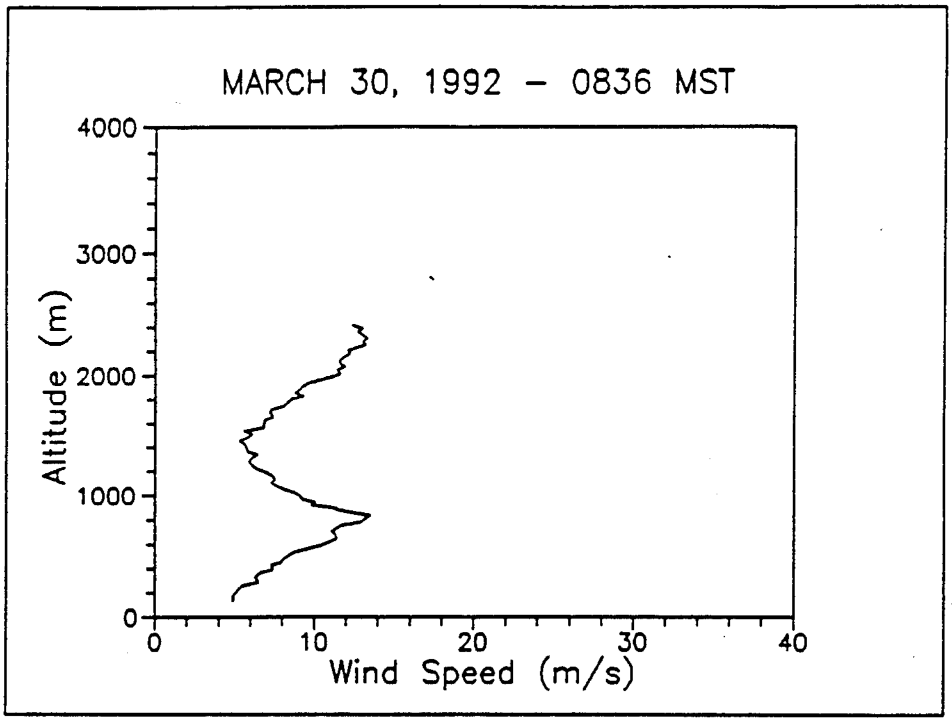


Figure 52. Wind speed and direction profiles from rawinsonde released at Yaw Line on 30 Mar 92 at 0632 MST.



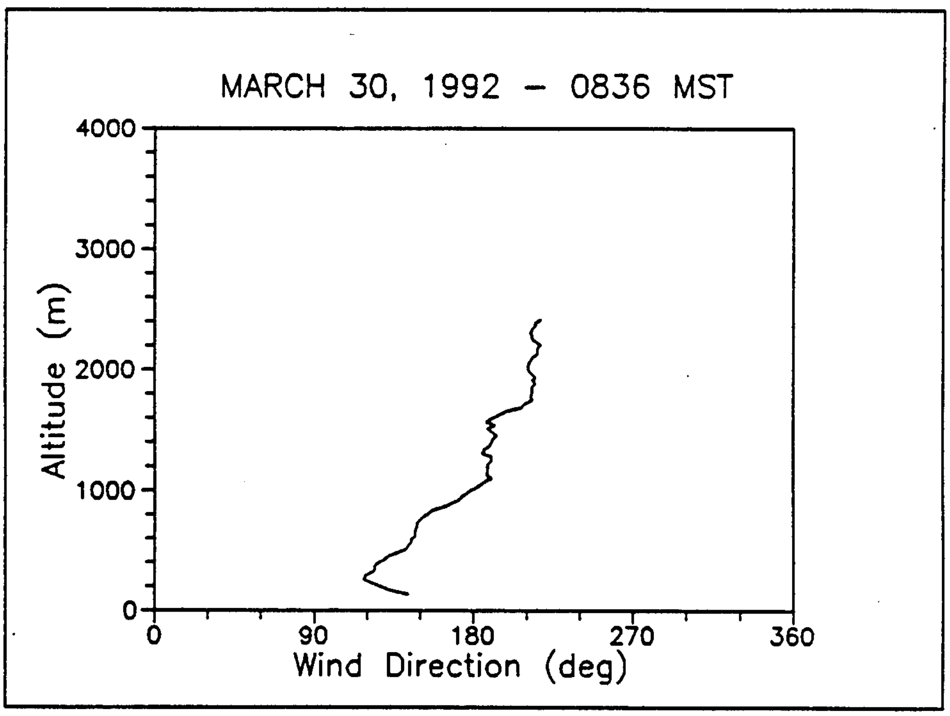


Figure 53. Wind speed and direction profiles from rawinsonde released at Yaw Line on 30 Mar 92 at 0836 MST.

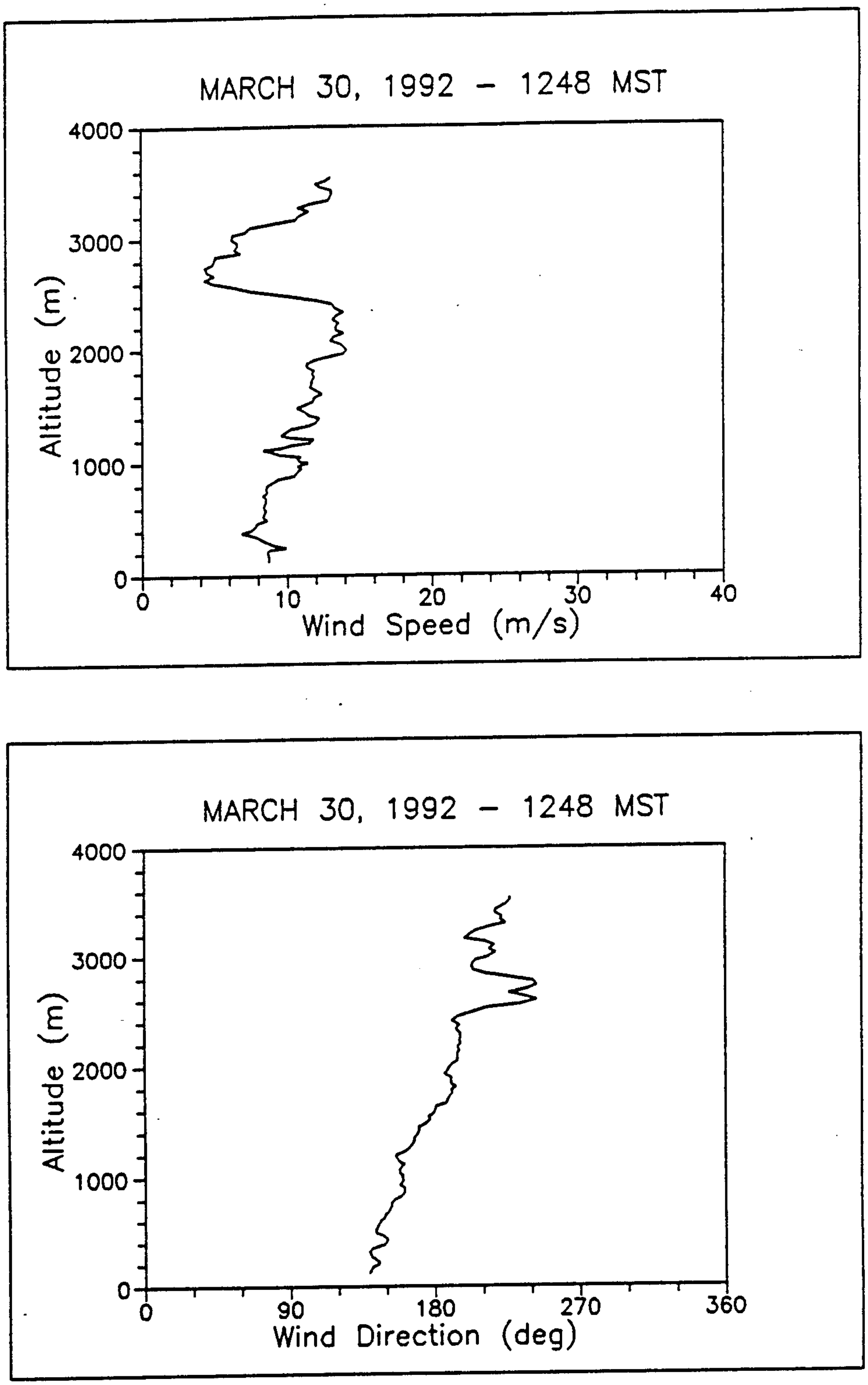
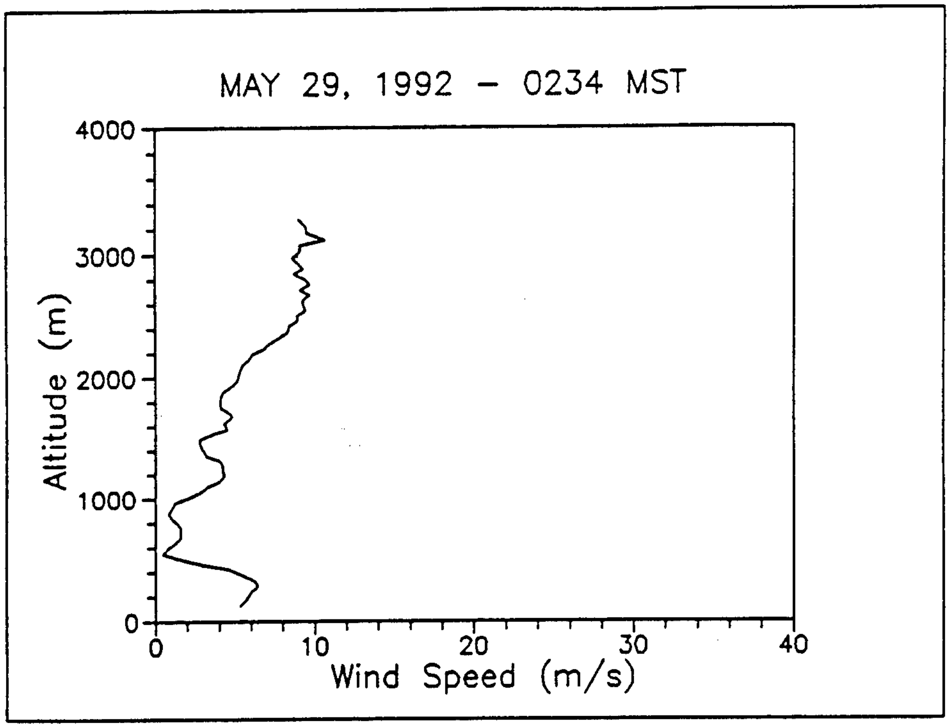


Figure 54. Wind speed and direction profiles from rawinsonde released at Yaw Line on 30 Mar 92 at 1248 MST.



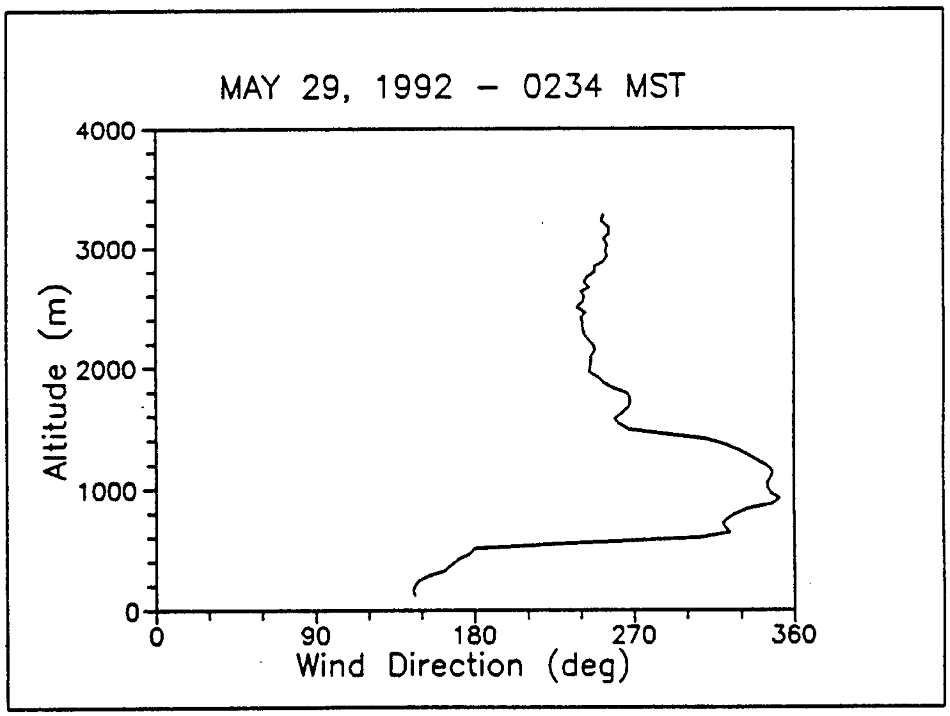


Figure 55. Wind speed and direction profiles from rawinsonde released at Mockingbird Gap on 29 May 92 at 0234 MST.

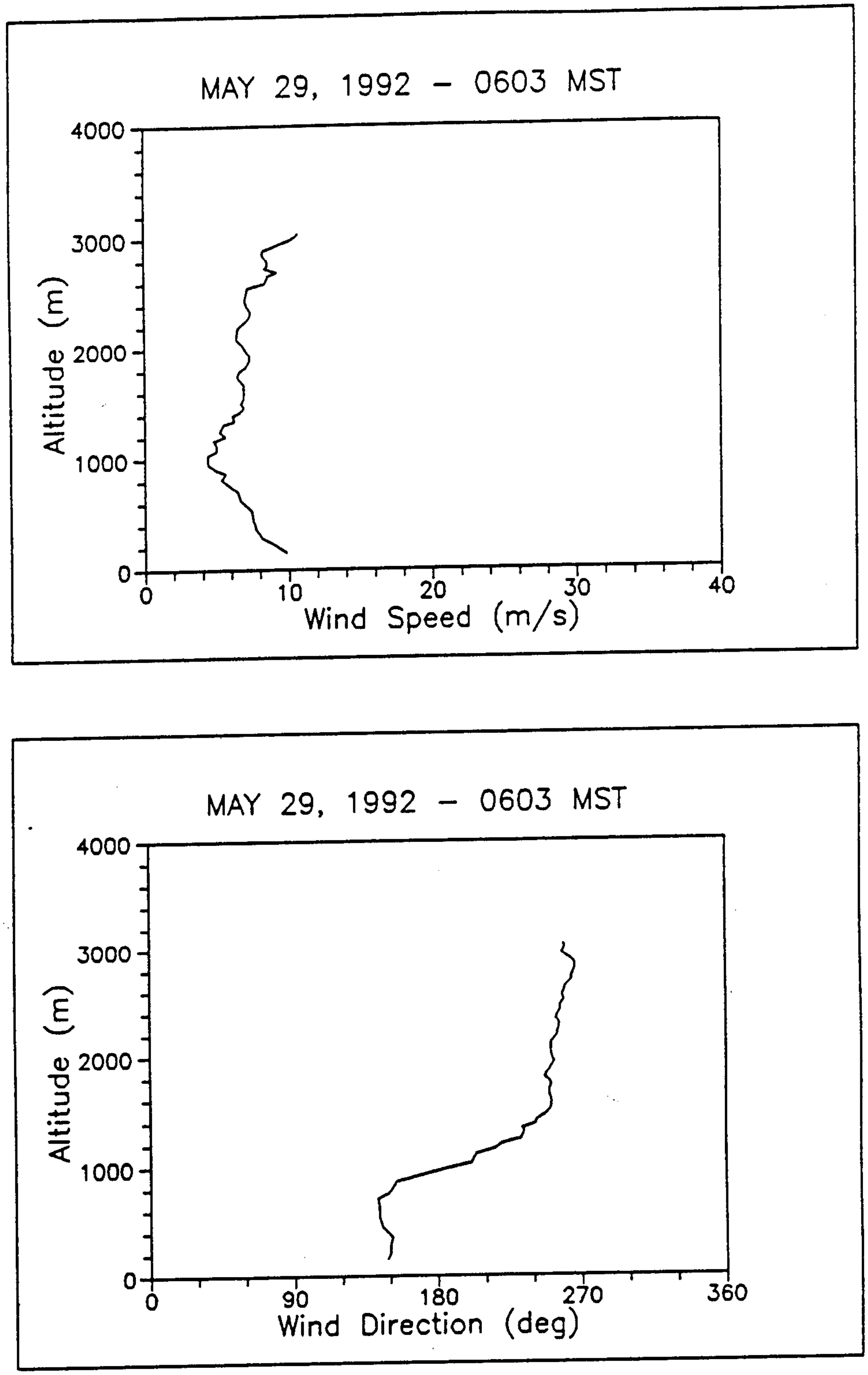


Figure 56. Wind speed and direction profiles from rawinsonde released at Mockingbird Gap on 29 May 92 at 0603 MST.

6. Summary and Recommendations

There was good agreement in wind speed and somewhat less agreement in wind direction among the three SAMS stations situated in the two valleys. As expected, there was poor agreement between the valley winds and the winds collected at the Jim Site SAMS station near the upper anchor of the cable. The wind speeds measured at Jim Site were comparable with concurrent 400- and 500-m sodar data collected at Mockingbird Gap, although, again, there was less agreement in wind direction. Based on these results, it is recommended that a surface station be placed at Jim Site to determine the wind loading on the cable. If wind direction data at the cable or wind data between the cable and the valley are required, an upper-air sensing system and surface station, preferably situated in the same valley, should be installed. The upper-air data could be provided by the sodar used in this study. The sodar collects wind data at regular height intervals up to several hundred meters above the surface continuously for several hours or days without human attention. During the 52 days the sodar operated at Mockingbird Gap, 15-min averaged wind data were successfully collected every 50 m, between 50 and 500 m above the surface at least 75 percent of the time. A sample wind barb cross section using 6 h of sodar data is plotted in figure 57, providing a good view of the vertical and temporal structure of the wind field. The sodar must be operated off a generator or hard power, however, because solar powering was found to be unfeasible.

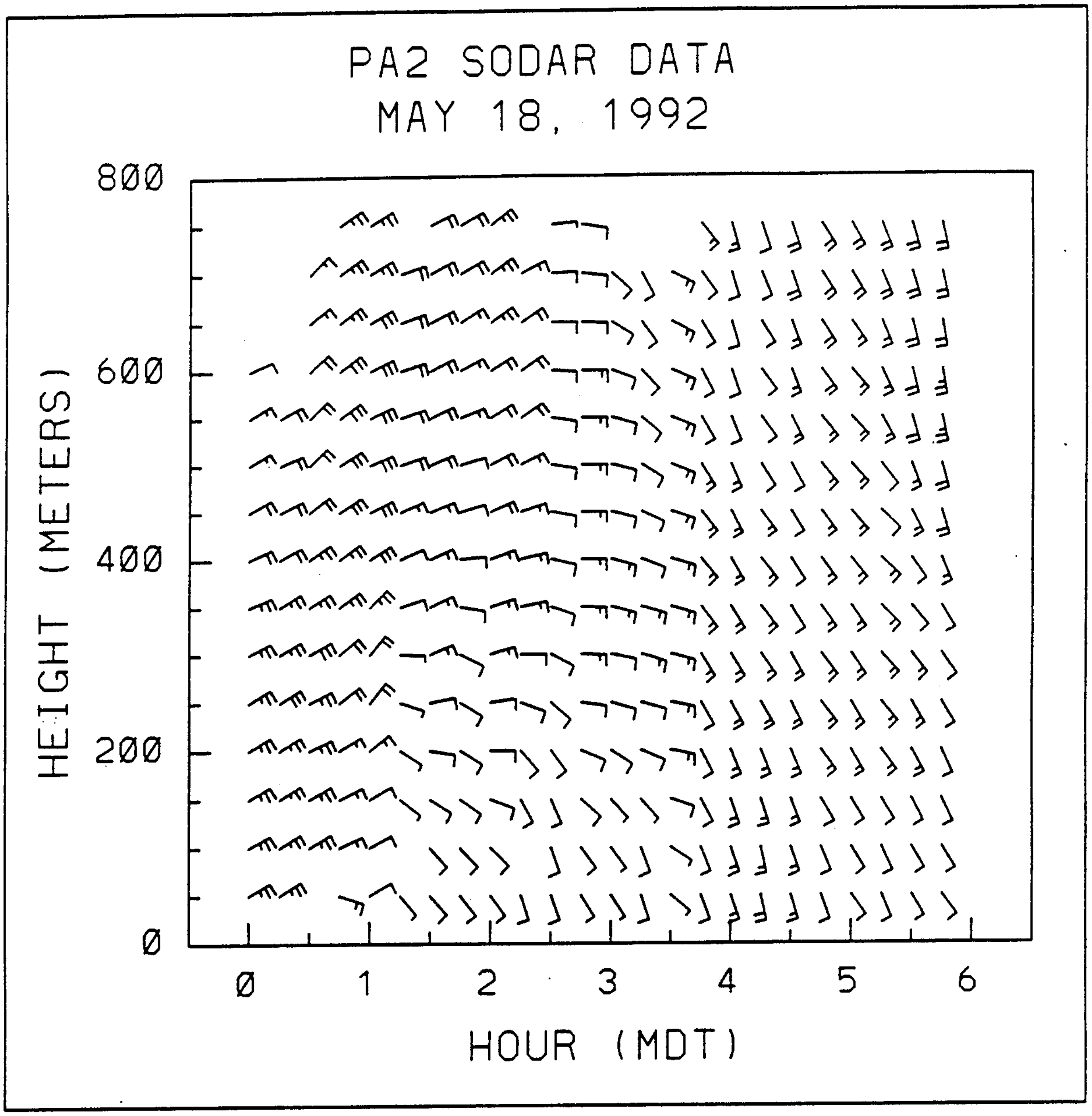


Figure 57. Sample cross section of wind data from sodar (long line = 5 m s^{-1}, short line = 2.5 m s^{-1}).

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1. WSMR, *Aerial Cable Test Capability Final Environmental Impact Statement*, Department of the Army, White Sands Missile Range, NM, 10 October 1991.

2. SNL, WSMR Aerial Cable Briefing, Sandia National Laboratories, Albuquerque, NM, 23 January 1990.

3. Bowers, R. L., *Geology, Hydrology, and Associated Potential Environmental Impacts of the Aerial Cable Test Capability (ACTC) Project, White Sands Missile Range, New Mexico.* Prepared for ACTC Environmental Impact Statement. Special Technical Report 3, Physical Science Laboratory PSL-90/100, December 1990.

Acronyms and Abbreviations

ACTC	Aerial Cable Test Capability
msl	mean sea level
SAMS	Surface Atomospheric Measurement Stations
WSMR	White Sands Missile Range

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Alexandria, VA 22302-1458

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Charlottesville, VA 22901-5396

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