NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO

VERY LARGE ARRAY PROGRAM

VLA TEST MEMORANDUM NO. 130

16 MONTHS OF VLA WIND DATA

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ABSTRACT

Wind records of the past 16 months are analyzed. These records were taken only during VLA operations, and thus are incomplete; only 45% of all days are covered. Missing are all very high winds (stow position).

The five months of February through June were more windy than the remaining seven, July through January. The average wind speed was 8.9 mph for the quiet season and 12.1 mph for the windy one, March having the highest average of 14.1 mph. The daily maximum was on 1/4 of all days above 22 mph for the quiet season, and above 31 mph for the windy one. During March, 83% of all days had a daily maximum above 22 mph, but only 12% during December.

All strong winds above 34 mph came from a narrow azimuth range, 258° average ± 22° standard deviation (SW - WNW). There were 96 daily maxima above 22 mph; they lasted for a duration of 7.6 hours ± 3.5 hours; except for 6 outsiders, they all occurred early after noon, at 14:06 MST ± 1.6 hours. High winds at night above 22 mph, maxima or not, occurred only during 13% of all nights.

A limit of 18 mph had earlier been used for design specification and structural analysis. The daily maximum surpassed this limit on 63% of all days. However, regarding the strong regularity of high winds, only 16% of all time is lost above 18 mph in the quiet season, and 25% in the windy one.

The future tests should record complete weather data whenever tilt readings are taken, and especially so during stow position. The wind tests should start as soon as possible; March has the highest maxima and more windy nights.

1. THE DATA

From John Spargo I got the weather data for a period of 16 months, from Sept. 21, 1979 to Jan. 26, 1981. Unfortunately, the coverage is rather incomplete. The whole period contains 494 days, but only 225 days are covered completely enough to be counted. Thus:

$$\text{fraction of coverage} = 225/494 = 45\% \qquad (1)$$

For the future tests which are planned, it would be very important to obtain a complete coverage of weather data, in some way or the other. Tilt and deformation readings are of no use if the weather data are missing.

Not only are the present data incomplete, they are biased, too. The data were recorded only when the VLA was operating, which means that all very high winds are missing, whenever the telescopes had to go to stow position. Actually, the highest maximum on these 225 recorded days is only 45 mph, whereas hand-written notes of Bill Horne during 83 days of his tiltsensor readings show a maximum of 75 mph (May 8, 1979). For the future tests it would be important to have wind records especially for highest winds in stow position.

Can we still do statistics? The answer is yes, if we keep in mind that the present results describe the wind not in general but during telescope operations, and that any detailed results may be quite a bit off the normal because the one year observed may not be typical, and because 45% is not a good coverage.

The available data are a large and useful collection. A typical example is shown in Fig. 1 (omitting the air temperature). Each cross in the plots represents one or more integrations over about three minutes. The evaluation of these data is made a bit tedious by three facts: first, the scales are somewhat unusual, 1 speed unit = 5 m/s, and 1 azimuth unit = 36 degrees. Second, they are plotted versus day number and IAT, instead of calendar day and MST (we want to see day and night, sunshine, etc.). Third and mainly, almost a dozen of different time scales are used on the different plots. Maybe all this is the reason why these data have not found the use they deserve, and it would be essential if this could be changed for the future tests.

Our first question is: which questions should we ask? We are interested in the average and the maximum wind speeds and in their distribution, we would like to know seasonal differences if there are any; and when winds are high enough to degrade the observations, we want to know the duration and the wind direction. We should look out for any obvious regularities which could help the scheduling of observations.

Regarding the average speed, I decided to read for each day its daily average (whole day), just by eyeball-inspection and rounded to integer m/s, see Fig. 1a. Regarding the maxima, I have read each day the second highest cross, v_m in Fig. 1b, because there is frequently a single high outsider as the one on May 24, and also in general the observer is not so much bothered by a single gust of short duration.

For all days with stronger winds, where $v_m \geq 10$ m/s = 22 mph, I have in addition read the duration d of this maximum, at a level of $v_m - 3$ m/s as shown in Fig. 1b, the time MST of its occurrence, and the average azimuth of the maximum, see Fig. 1c.

2. DIFFERENT SEASONS

First, we ask for the average speed and the distribution of higher winds, if possible, as a function of the time of year. A summary is given in Table 1 and Fig. 2. The average wind speed is 9.6 mph; the highest monthly average is 14.1 mph in March and May, while the lowest average is a factor of two down, 6.7 mph in December. Regarding higher winds, they occur most frequently in February, March and May, while July, August and December are very quiet. The absence of high winds is much more striking for the quiet months than their lower average is. However, all these statements would need a good deal more data.

For simplicity, we just want to divide the whole year into two consecutive parts, windy and quiet, and we may pick the 5 months February to June as the windy part, and the remaining 7 months as the quiet part, as shown in Table 1 and Fig. 2. This may be an oversimplification but it shall be used in the following.

Table 1. Seasonal values of average speed, and distribution of high winds.

Month	days covered	v_{av}		percentage of days where daily max is above				
		m/sec	mph	10 m/s 22 mph	13 m/s 29 mph	16 m/s 36 mph	19 m/s 43 mph	
Jan	28	4.2 ± 0.3	9.4	36	7	0	0	
Feb	14	4.9 .6	11.0	43	29	7	7	windy
Mar	18	6.3 .4	14.1	83	50	28	6	windy
Apr	15	4.5 .3	10.1	53	7	0	0	windy
May	18	6.3 .5	14.1	72	50	11	6	windy
Jun	18	5.2 .4	11.6	78	39	11	0	windy
Jul	11	4.1 .3	9.2	45	0	0	0	
Aug	12	3.9 .2	8.7	25	0	0	0	
Sep	15	4.2 .4	9.4	33	7	0	0	
Oct	23	4.6 .5	10.3	35	22	13	0	
Nov	27	3.8 .3	8.5	30	7	7	4	
Dec	26	3.0 ± 0.2	6.7	12	0	0	0	
total	225	4.6 ± 0.4	9.6	45	18	7	2	

Regarding the future tests, we have suggested in Memo 129 to plan two different runs, one for thermal deformations and one for wind deformations. The present results mean that we should do the wind run as the first one, and we should start just as soon as possible, because March is the windiest of the year. It would be a pity to miss it.

3. DISTRIBUTION FUNCTIONS

A good way of representing distributions is to plot the cumulative distribution (percentage below given limit) on probability paper, as done in Fig. 3 for the daily average and in Fig. 4 for the daily maximum. A one-dimensional Gaussian would give an exact straight line. Since the wind follows a two-dimensional distribution, the plots must fall off below the straight line for small v (no negative v, for example). And because of our bias, omitting stow position, the plot should steepen for the highest maxima. Figs. 3 and 4 follow these expactations well enough.

Table 2. Seven quiet and 5 windy months.

months	v_{av}		3rd quartile		90% level	
	m/s	mph	of v_{av}	of v_m	of v_{av}	of v_m
Jul - Jan, 7	4.0 ± 0.2	8.9	11 mph	22 mph	13 mph	27 mph
Feb - Jun, 5	5.4 ± 0.4	12.1	15	31	19	36
whole year, 12	4.6 ± 0.4	9.6	13	26	16	31

Some results, regarding average and high winds, are shown in Table 2. The difference between quiet and windy periods is significant and may be somewhat useful. As an upper cut-off or observational limit, I mostly prefer to use the third quartile (1/4 of time lost); a more stringent limit is the 90% (1/10 of time lost).

The design specifications and the structural analyses have used $v \leq 18$ mph = 8 m/sec as the upper limit for precision observations. What does that mean? From Figs. 3 and 4 we read that the daily average and daily maximum are below this limit for the following fraction of all days:

	v_{av}	v_m	
Quiet, Jul - Jan	97%	50%	F(v) in percent of all days, for $v \leq 18$ mph (2)
windy, Feb - Jun	87%	20%	

If only the average would matter, then the 18 mph seems to be too stringent, it is about the 90% level and is only seldom passed. But since for most observations the maximum matters more than the average, the 18 mph seems too lenient, being surpassed half of all days even during the quiet period, and 4/5 of all days during the windy one. However, not all of a day is lost if it contains only a single maximum of short duration. This will be discussed in the next section.

4. REGULARITIES

Three regularities have been mentioned by the VLA staff: strong winds come mostly from SW to W, they occur mostly early afternoon, and they are of limited duration. All three are well confirmed by the present data.

Wind direction α and daily maximum v_m are plotted in Fig. 5 for all 96 days where $v_m \geq 10$ m/sec = 22 mph. The directional clustering is very obvious and is strongest pronounced for the highest winds. Above 15 m/sec = 34 mph, we have only one outsider at 118°; and for the remaining 19 days we obtain the average direction, its mean error, and the standard deviation from the average, as

$$\begin{aligned} \text{direction of strong winds} \quad & \alpha = 258° \pm 5°, \\ \text{standard deviation} \quad & \sigma = 22°. \end{aligned} \tag{3}$$

We have looked for seasonal variations of α; there is a weak indication of a correlation which would need more data for confirmation. It seems that the different clusterings of Fig. 5 are preferably (but not exclusively) produced during the following months

WNW	Oct - Mar	
WSW	Apr - May	(4)
SE	Jun - Aug	

Fig. 6 shows duration and time of occurrence of all stronger winds. The regularity especially of the latter is really amazing. All 96 days with $v_m \geq 10$ m/sec yield for the duration

$$\begin{aligned} \text{average} \quad d &= (7.6 \pm 0.4) \text{ hours}, \\ \text{standard deviation} \quad \sigma &= 3.5 \text{ hours}. \end{aligned} \tag{5}$$

And omitting the six outsiders of Fig. 6b, the remaining 90 days give

$$\begin{aligned} \text{time of occurrence} \quad t &= (14{:}06 \pm 0{:}10) \text{ MST}, \\ \text{standard deviation} \quad \sigma &= 1.6 \text{ hours}. \end{aligned} \tag{6}$$

I have also noted each case where high winds ≥ 10 m/sec were recorded during nights, maxima or not. The total number is

$$\text{high winds at night} = 30 \text{ nights} / 225 = 13\% \text{ of all nights}. \tag{7}$$

As for seasonal variations, d and t do not show any. But it seems that higher winds at night occur more frequently during the six months Oct - Mar, which is another reason for starting the wind-deformation tests as soon as possible. High winds at night are essential for the distinction between wind and Sun.

Now we come back to the time loss caused by high winds, regarding the specified limit of 18 mph = 8 m/sec. In the last column of (2) we have the fraction $F(v_m)$ of all <u>days</u> where $v_m \leq 18$ mph. If the high regularity of the maxima is used in the (general and private) scheduling of observations, we may calculate the fraction of all <u>time</u> with high winds. This time loss then is $(1 - F)\ d/24^h$, and with d from (5):

$$\text{fraction of time lost above 18 mph} = \begin{cases} 16\% \text{ for Jul - Jan,} \\ 25\% \text{ for Feb - Jun.} \end{cases} \qquad (8)$$

This is a nice result. It shows that the 18 mph limit used in specifications and analysis actually is the recommended third quartile even during the windy months, and the 84% level for the quiet months.

Several correlations were looked for but not found, for example, all possible correlations between any two of: v_m, d, MST, α. Some of these cases are shown in Figs. 5 and 6.

I had hoped that high winds would mostly come from overcast skies (when observations at shortest wavelengths are hindered anyway), but this seems not to be the case. I do not have records about cloudiness, but the records about ambient air temperature may be used as an indicator: the difference between daily maximum and nights is large on sunny days, up to 26 °C in winter and about 18 °C in summer, and mostly about 5 °C for overcast sky. A rough inspection showed that high winds occur independent of cloudiness. At least there is no obvious correlation.

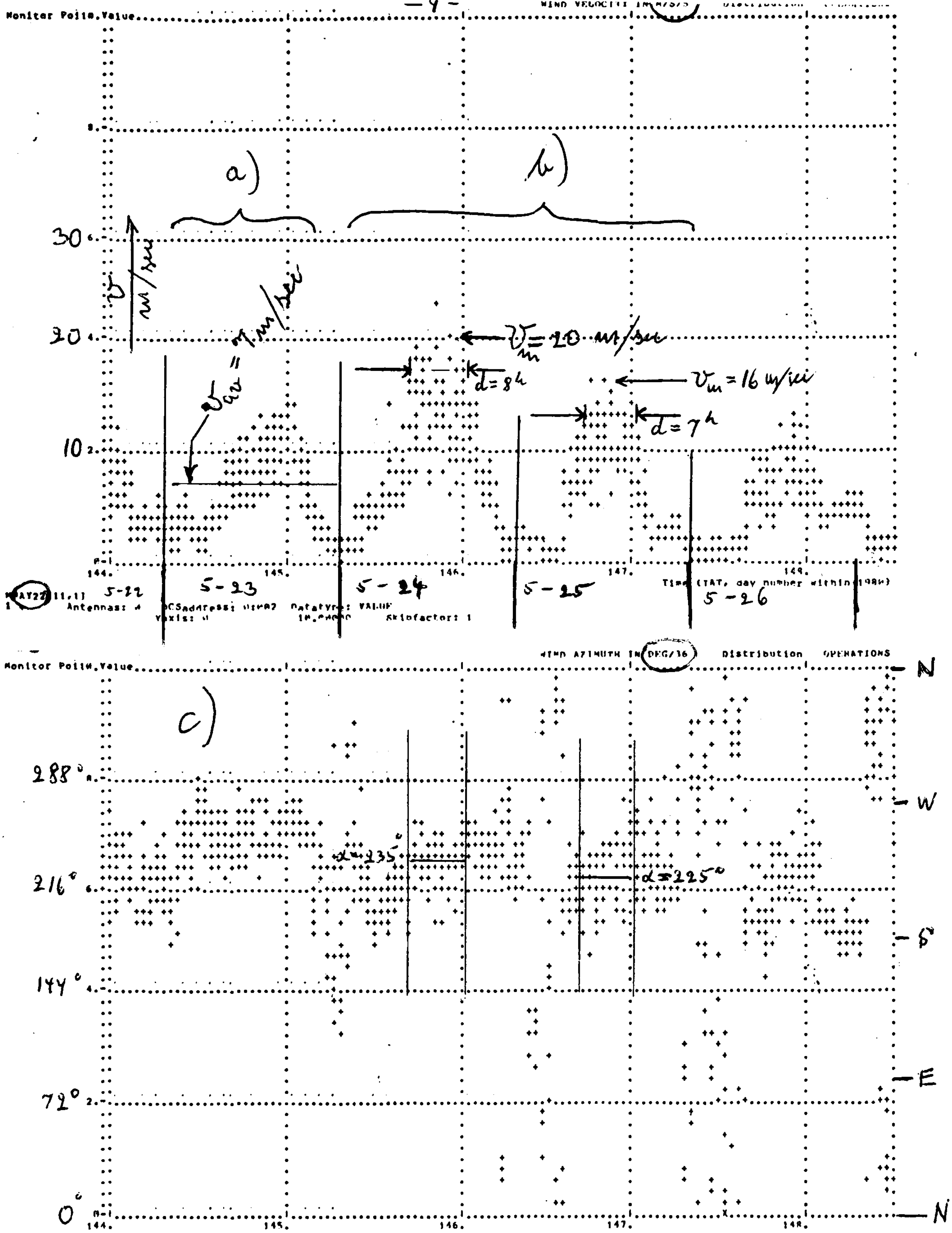


Fig. 1. VLA wind data, May 22-26, 1980. Showing examples for v_{av} and v_m.

a) v_{av} = daily average wind speed (meter/sec);

b) v_m = second highest speed of day; d = duration of v_m - 3 m/sec;
Almost all strong winds occur ≈ 14:00 MST, very quiet periods in between.

c) α = average azimuth during d; strong winds mostly from SW to W.

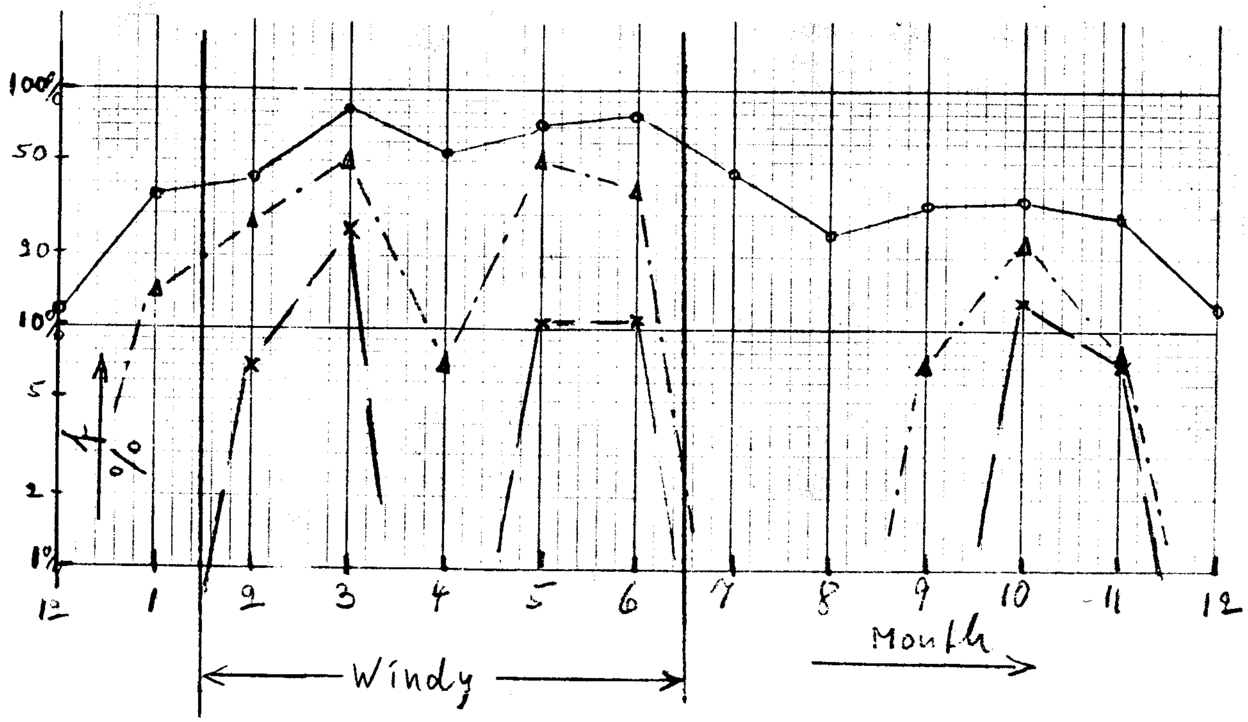


Fig. 2. Selection of "windy" part of year, February through June.

Shown is the percentage of days where the daily maximum speed is above a given limit (Sept. 21, 1979 to Jan. 26, 1981):

o———o	$v_m \geqq$ 10 m/sec =	22 mph
Δ— - —Δ	13	29
x—— —x	16	36

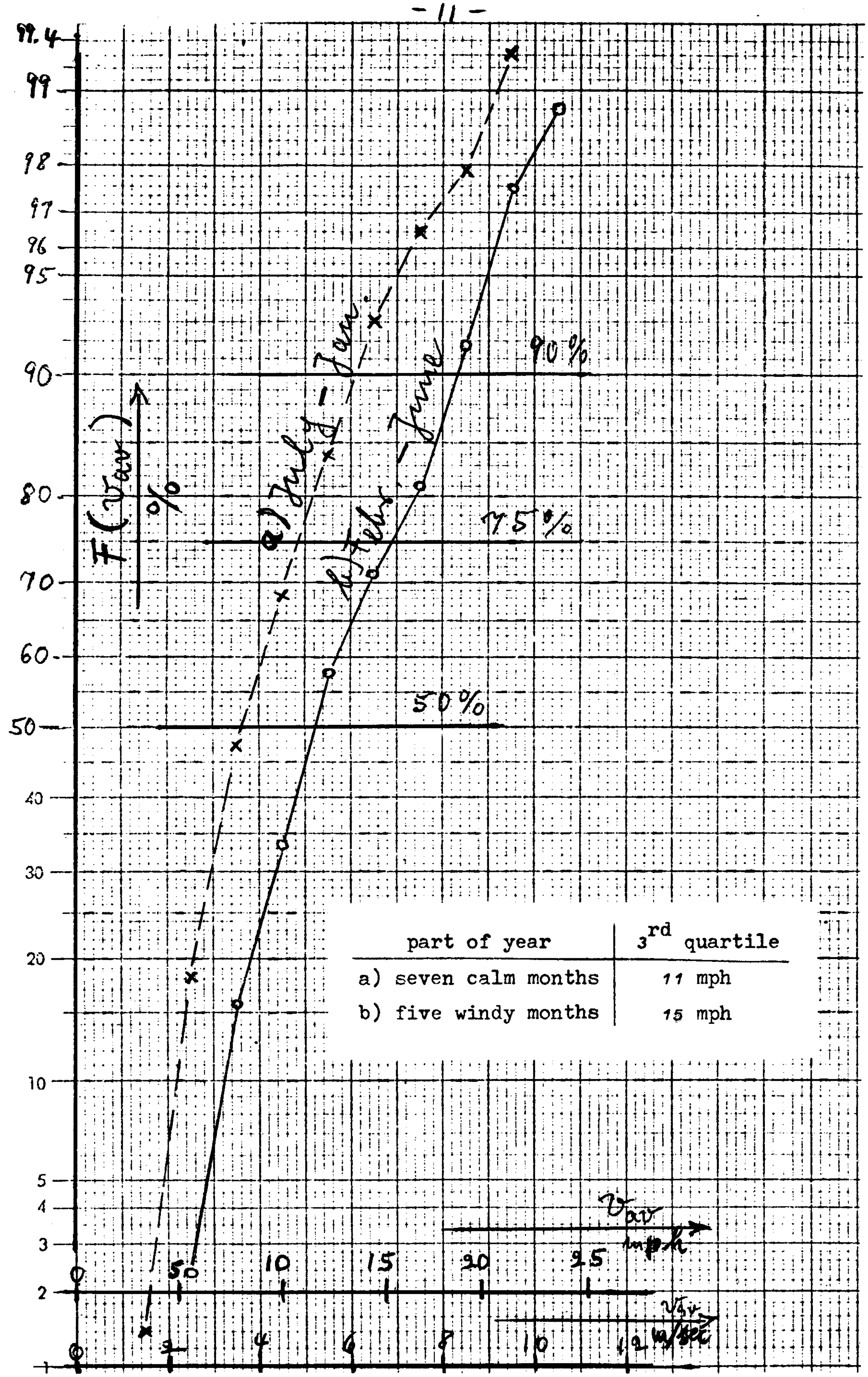
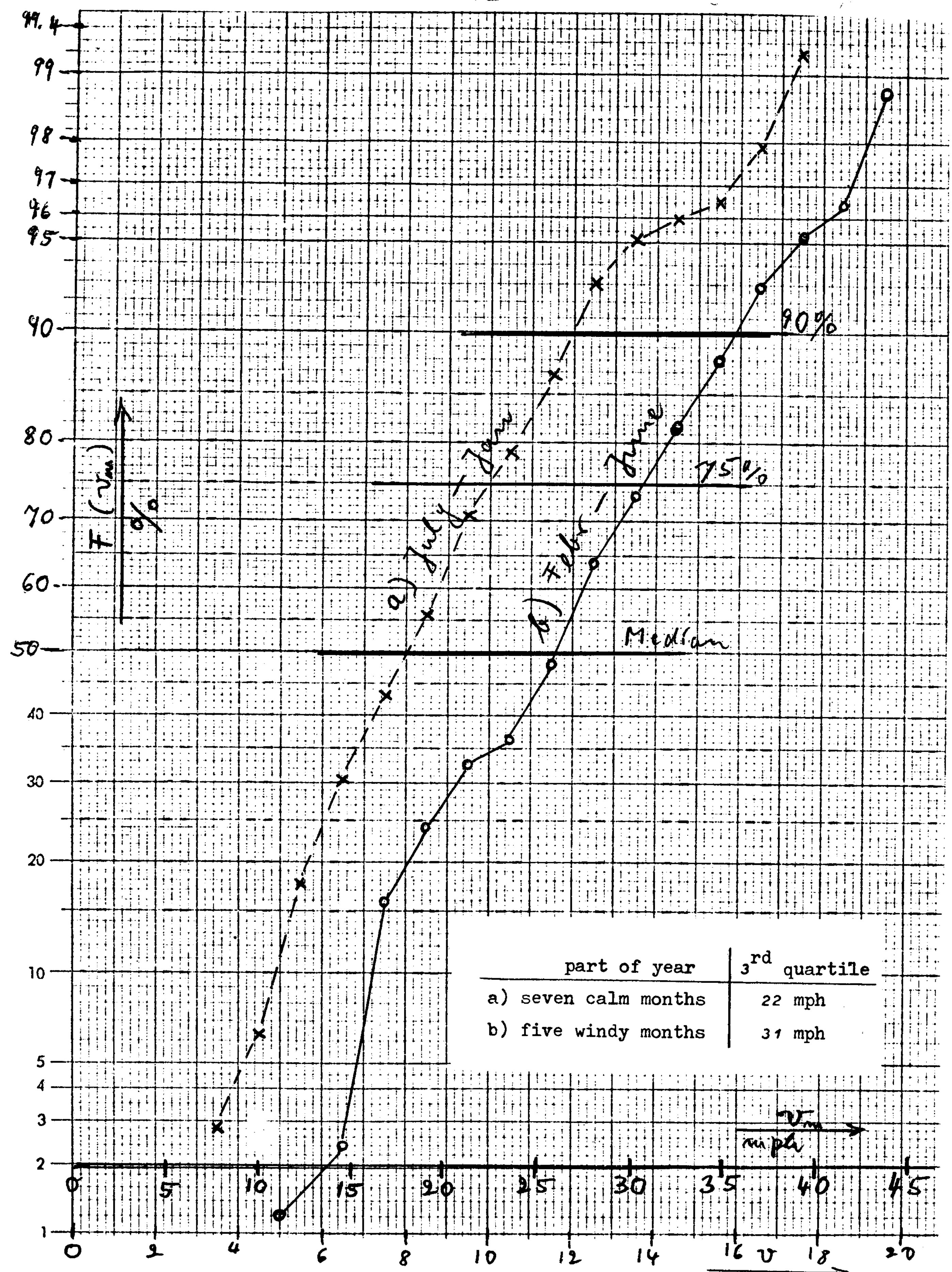


Fig. 3. Cumulative distribution of daily averages (Sept.21, 1979 to Jan.26, 1981). On this paper, a Gaussian would be a straight line.



part of year	3rd quartile
a) seven calm months	22 mph
b) five windy months	31 mph

Fig. 4. Cumulative distribution of daily maxima (Sept. 21, 1979 to Jan. 26, 1981). On this paper, a Gaussian would be a straight line.

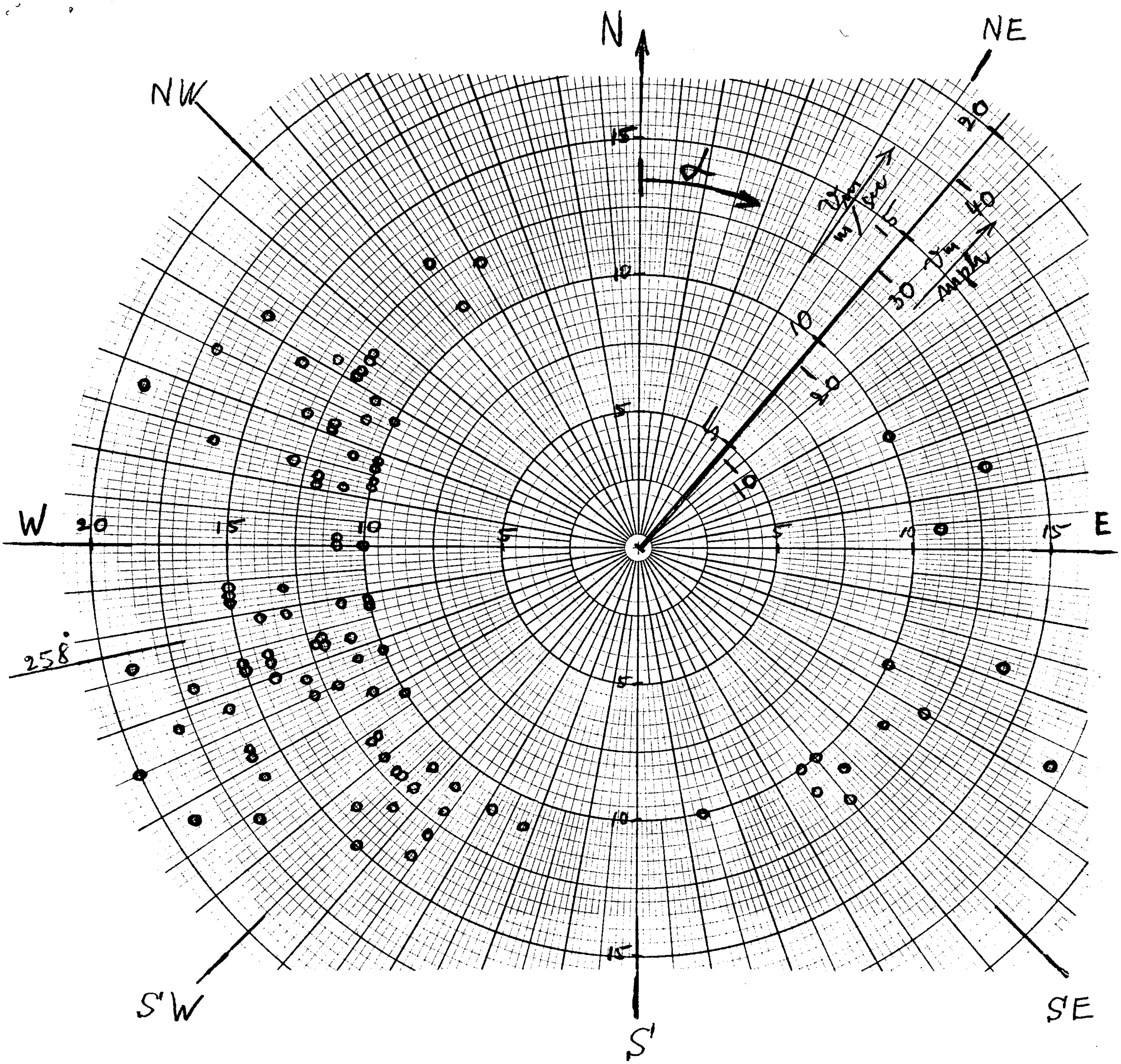
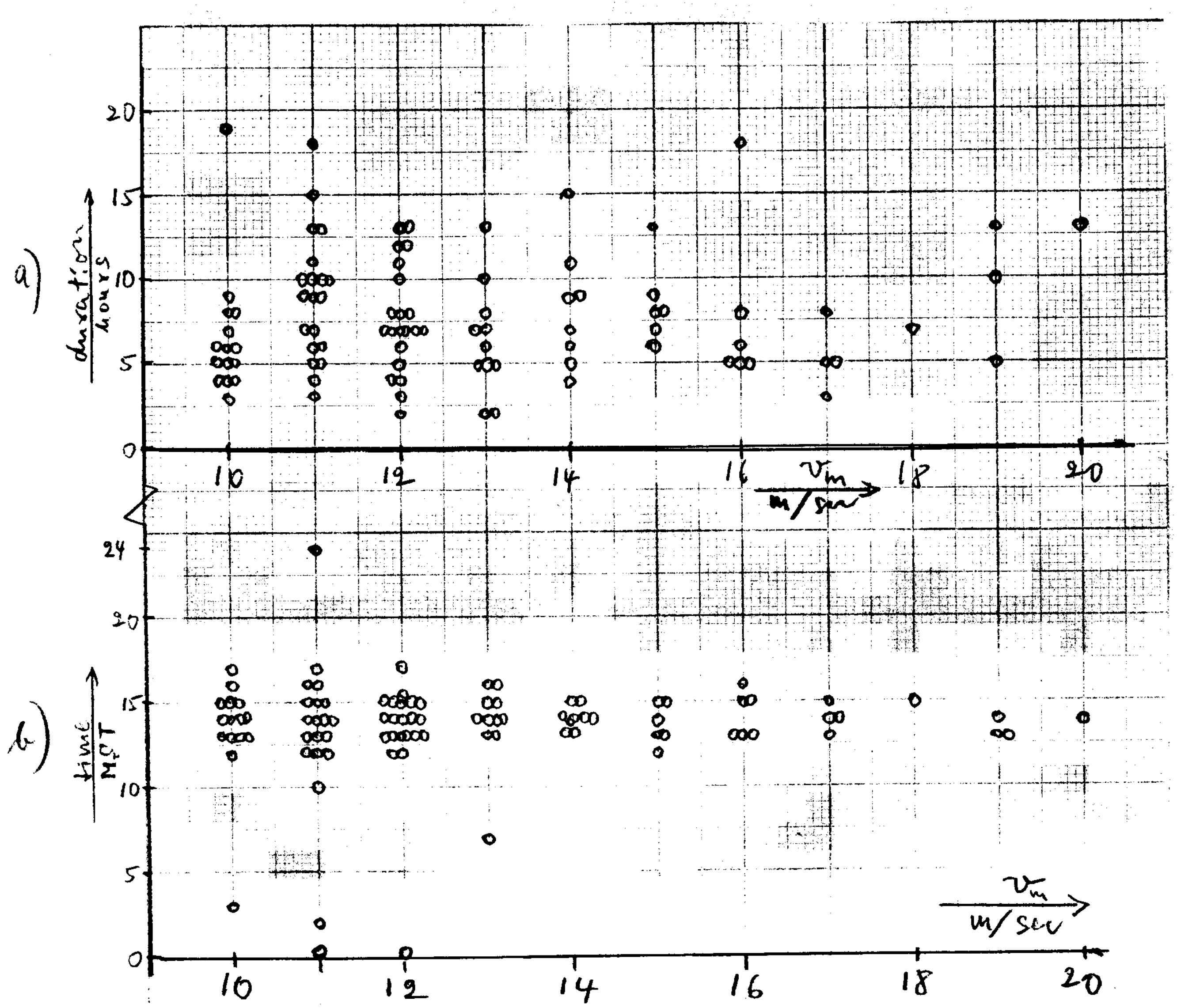


Fig. 5. Wind direction and speed, for all 96 days where $v_m \geq 10$ m/sec = 22.4 mph. Omitting only one outsider, all remaining 19 days where $v_m \geq 15$ m/sec = 34 mph give the average azimuth of strong winds as $\alpha = 258^\circ \pm 5^\circ$, with a standard deviation of only $\sigma = 22^\circ$.



<u>Fig. 6.</u> All 96 days where $v_m \geq 10$ m/sec, showing duration and time of maxima. No correlation.

Almost all higher daily maxima occur between 13:00 and 16:00 MST (only five maxima at night). They mostly last 5 to 13 hours.