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FINAL REPORT

RECENT TRENDS IN WIND DIRECTION ✓
AND SPEED IN KUWAIT

EES - 71

AL-THABIA

Y. Abdal, D. Al-Ajmi, R. Al-Thabia, M. Abuseil

ENVIRONMENTAL SCIENCES DEPARTMENT
ENVIRONMENTAL AND EARTH SCIENCES DIVISION

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KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH
P.O. BOX 24885
13109 - SAFAT - KUWAIT

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Wind direction and speed are critical features in Kuwait because they are associated with dust and sand storms, which occur mainly during summer. Wind speed and direction data of June, July and August for the period 1957-85 were collected from the Meteorological station at Kuwait International Airport.

The wind direction data were grouped in four main sectors, i.e., NE, SE, SW and NW. The data were used to calculate the frequency of wind direction and speed, and to construct wind roses for different periods of the 29 years.

The wind analysis showed that NW winds were predominant. NW winds had the highest frequency of occurrence for the period of 1962-1985, and NNW winds had the highest frequency during the period of 1957-1961. The analysis also showed that moderate wind speeds (8-18 mile/hour) had the highest frequency during the period 1957-1985 especially with the NW direction, however, the result does not show any major trend in the wind direction and speed.

KEY WORDS

أهم المصطلحات

Wind direction, Meteorological station, Kuwait International Airport, Wind roses, Trend, Frequency.

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تعتبر سرعة الرياح واتجاهاتها من العناصر المناخية التي تتسبب في نشاط العواصف الترابية وتساقط ذرات الغبار وخاصة في فصل الصيف في دولة الكويت ، ونظرا لأهميتها فقد جمعت المعلومات عن سرعة الرياح واتجاهاتها المسجلة في مطار الكويت الدولي خلال شهر يونيو ويوليو وأغسطس للفترة ما بين ١٩٥٧ - ١٩٨٥ ميلادي .

المعلومات التي جمعت تعتمد على معدل سرعة واتجاه الرياح في خلال الساعة مقاسة على ارتفاع ١٠ متر من سطح الأرض .

كما تم حصر اتجاه الرياح في أربع مجموعات رئيسية وهي كالآتي:-
شمال شرقي ، جنوب شرقي ، جنوب غربي ، شمال غربي

ولقد دلت نتائج الدراسة على أن مجموعة الرياح الشمالية الغربية هي السائدة على المجموعات الأخرى وخاصة أن اتجاه الشمال الغربي هو السائد على الاتجاهات الأخرى في المجموعة نفسها . ولقد أثبتت الدراسة أيضا أن اتجاه الرياح من الشمال الغربي كان مسيطرا خلال الفترة ما بين ١٩٦٢ - ١٩٨٥ بينما الاتجاه من الشمال شمال غربي كان المسيطر في الفترة ما بين ١٩٥٧ - ١٩٦١ . أما بالنسبة لسرعة الرياح فلقد أثبتت الدراسة أن السرعة المحددة ما بين ٨ - ١٨ ميل في الساعة هي السائدة في خلال الأعوام التي أجريت عليها الدراسة .

KEY WORDS
أهم المصطلحات
اتجاه الرياح - سرعة الرياح - الرياح السائدة - العواصف الترابية

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Introduction

This study deals with wind speed and direction not just as natural phenomena, but also in terms of their influence on the human environment, i.e., structures and landscape. Therefore, this report is addressed to those who are interested in exploring the role of the wind in design and in finding innovative ways to improve the quality of life.

Wind speed and direction are critical features in Kuwait because they are associated with dust storms and mobile sand phenomena. Summer winds cause environmental problems such as fine surface sediments and sand sheets in the desert, as well as severely polluting the air and reducing visibility, which affects air navigation.

The analysis of wind data would be very useful to determine trends in wind speed and direction and to predict sand and dust storms in Kuwait, and to plan environmental protection accordingly.

As the frequency of dust occurrence is highest in summer (Safar, 1980), wind data analysis at the peak of this season is of critical importance for the study of dust storms and mobile sand phenomena.

The study of climatic trends requires long records of representative climatological data. The Kuwait International Airport (KIA) weather station has daily meteorological data from 1957 and, for the purpose of creating the 1957-1985 averages, these data were entered in KISR's Computer.

The aim of this study is to describe the trends in wind direction and speed in Kuwait during the dusty season (June, July and August) in the 29 year period 1957 - 1985.

Wind Measurements

The instrument used at Kuwait International Airport to measure wind direction and speed is the electrical anemograph. A wind vane is mount-

ed on a tower at a height of 10 m above ground level. The continuous fluctuations of wind direction and speed can be visualized, at time intervals of one hour or less, from the traces recorded on the anemograph's chart. Fig. 1 shows a typical daily anemograph chart.

To obtain hourly averages of wind directions or speeds a simple interpolation can be performed on the anemograph chart. The wind direction fluctuations are recorded on a time scale at the top of the chart. The wind speeds are recorded on the bottom of the chart.

The wind directions are observed in degrees on a compass scale which refers to the direction from which the wind is blowing. The wind speed is measured in different units such as knot, miles per hour (mph), etc. The wind speed data used in this study were recorded in miles per hour.

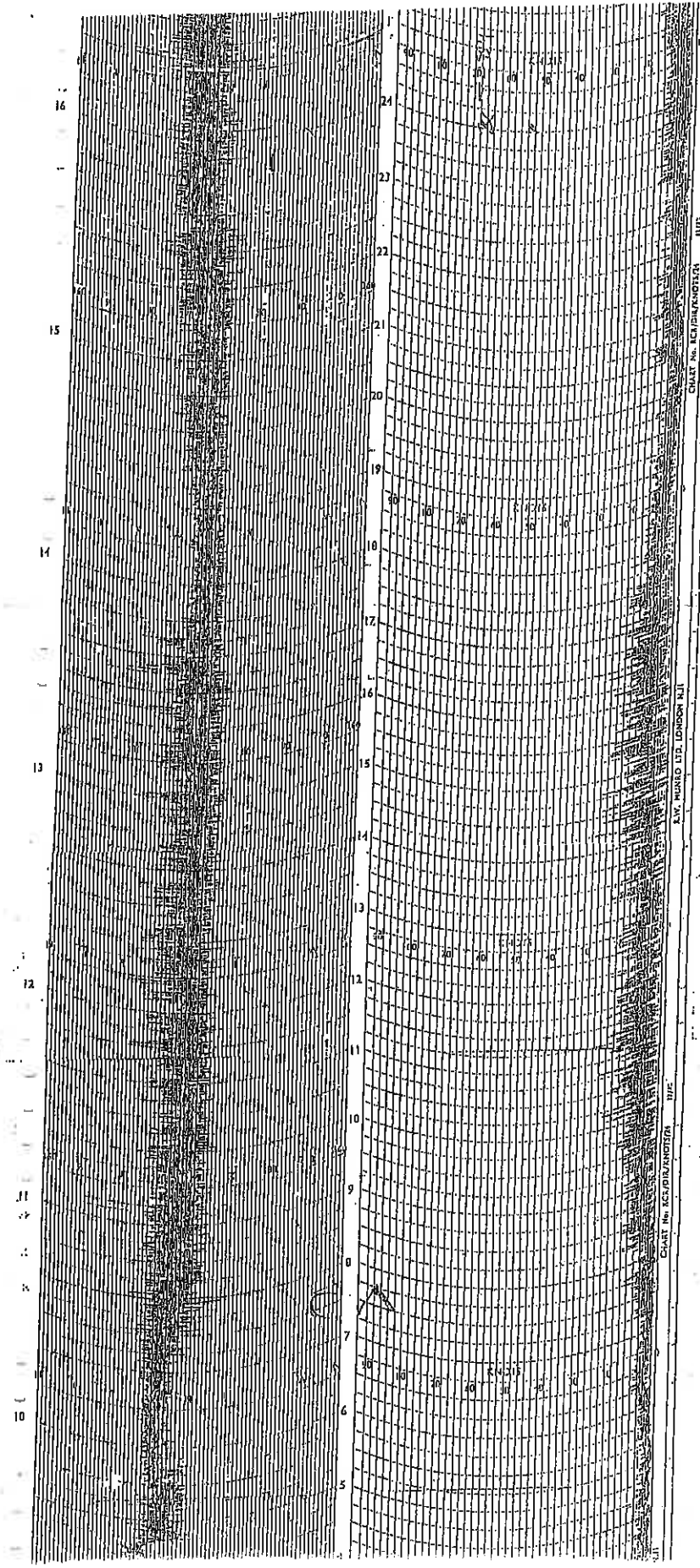
Data Collection

Investigations were made on the availability and reliability of surface wind data. In Kuwait, only the meteorological station at Kuwait International Airport (KIA) was set to record daily meteorological data, including surface wind data. The KIA also had the longest continuous period of records. It was decided that for the purpose of this study only the surface wind data from KIA would be used.

Two types of surface wind data records were available from KIA. The first is the average of the last ten minutes of each hour, which was used for aviation purposes; the second is the hourly average, which was used for climatological records.

In view of this, a computer test run was made for the records of four years (1978-1981) to compare the ten-minute averages with the averages for whole hours. The results are shown in tables 1 and 2, respectively.

Significant differences were observed between the two sets of averages. For example, the total frequency percentage of N winds was 2.5 for the last-ten-minute averages and 9.2 for the hourly averages; for NW



synoptic chart for 24 hours at Kuwait International Airport

KISRX 20752

Table 1. FREQUENCY (%) OF WIND OCCURRENCE ACCORDING TO WIND SPEED AND WIND DIRECTION
ANALYSIS OF WIND DATA 1978 - 1981 (HOURLY AVERAGE)

MONTH	SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	MSW	N	MNW	NW	NNW	CALM	MISS	TOTAL
JUN	CALM																	32.3		32.3
	<0.5	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.6	0.1	0.1			1.7
	0.5-5	1.3	1.3	0.7	1.4	0.6	0.7	0.2	1.4	0.8	1.1	0.7	3.3	2.8	11.3	4.4	3.6			35.6
	5-10	1.3	1.3	0.9	1.2	0.5	0.6	0.1	0.0	0.1	0.1	0.0	0.5	3.3	8.8	3.0	2.2			23.8
	10-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	3.9	0.8	0.0			5.3
	>25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0
JUL	MISS																	1.3		1.3
	TOTAL	2.5	2.5	1.6	2.7	1.1	1.4	0.4	1.5	0.9	1.2	0.8	4.0	6.9	24.5	8.3	6.0	39.6		100.0
	CALM																	16.4		16.4
	<0.5	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.2	0.2	0.6	0.1	0.0			1.9
	0.5-5	0.7	1.1	1.2	3.2	2.5	2.4	2.0	4.8	1.5	0.9	0.9	3.8	3.9	15.4	3.5	1.7			49.5
	5-10	0.1	0.1	0.1	1.2	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.4	2.0	12.7	3.3	0.8			23.3
AUG	10-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.7	0.0			6.5
	>25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0
	MISS																	2.4		2.4
	TOTAL	0.3	1.2	1.3	4.5	4.6	2.9	2.2	5.0	1.6	0.9	1.0	4.4	6.1	34.4	7.7	2.6	18.8		100.0
	CALM																	9.9		9.9
	<0.5	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.7	0.8	0.0			3.1
AUG	0.5-5	0.4	0.3	0.9	1.3	1.6	1.4	1.7	3.4	2.2	0.6	0.9	6.0	7.1	13.4	9.0	1.8			52.2
	5-10	0.0	0.0	0.0	0.7	1.6	0.5	0.1	0.1	0.0	0.0	0.0	0.1	3.5	17.8	5.1	0.3			29.8
	10-25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.4	0.0			3.4
	>25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			0.0
	MISS																	1.6		1.6
	TOTAL	0.5	0.4	0.9	2.1	3.3	2.1	1.9	3.7	2.3	0.8	1.0	6.3	10.8	34.8	15.3	2.2	11.5		100.0

Table 2. FREQUENCY (%) OF WIND OCCURRENCE ACCORDING TO WINDSPEED AND WIND DIRECTION
ANALYSIS OF WIND DATA 1978 - 1981 (LAST 10 MINUTES)

MONTH	SPEED (M/S)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM MISS ΔVAR.	TOTAL	
JUN	CALM																			
	1-11	4.3	2.3	1.5	1.0	3.2	1.2	0.6	1.9	3.0	1.2	0.9	1.0	5.4	5.2	6.9	5.6	9.3	5.3	
	12-22	3.3	1.5	0.5	0.5	1.1	0.9	0.4	0.2	0.2	0.3	0.2	0.1	0.7	4.0	10.3	10.1		45.7	
	23-33	3.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.8	3.5	4.7		34.8	
	>34	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2		9.9	
	MISS																			0.4
	VARIABLE																			0.1
TOTAL		9.2	3.7	2.0	1.6	4.3	2.2	1.1	2.2	3.2	1.5	1.1	1.0	6.2	10.1	20.8	20.6	9.3	100.0	
CALM																			10.9	
JUL	1-11	1.9	1.3	0.7	1.5	4.0	2.3	1.4	2.7	5.0	1.7	0.8	1.2	5.8	5.3	7.3	4.7		47.5	
	12-22	1.6	0.2	0.1	0.1	1.1	2.5	0.2	0.1	0.1	0.0	0.0	0.0	0.7	2.8	11.8	9.6		30.7	
	23-33	3.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	4.5	5.0		10.3	
	>34	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2		0.3	
	MISS																			0.3
	VARIABLE																			0.0
	TOTAL		3.5	1.5	0.8	1.6	5.1	4.9	1.7	2.7	5.0	1.7	0.8	1.2	6.5	8.7	23.6	19.6	11.2	100.0
CALM																			11.2	
AUG	1-11	1.2	0.4	0.5	0.5	1.6	1.9	1.0	1.7	4.8	1.8	0.3	1.2	6.8	8.6	9.7	6.1		48.9	
	12-22	1.4	0.0	0.0	0.0	0.6	1.5	0.3	0.2	0.1	0.0	0.0	0.0	0.3	4.4	12.7	10.9		32.6	
	23-33	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.1	2.6		7.3	
	>34	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	
	MISS																			0.0
	VARIABLE																			0.0
	TOTAL		3.3	0.5	0.5	0.5	2.2	3.5	1.4	1.9	4.9	1.9	0.3	1.2	7.1	13.5	26.5	19.6	11.2	100.0

winds the figures were 8.3 and 20.8; and for NWW winds they were 6.0 and 20.6, respectively. These discrepancies are attributed to the fact that wind speed and direction vary widely within one hour, which means that the average for the last ten minutes (i.e., only about 17% of the total time) is not representative. It was therefore decided to use only the hourly averages for this study.

The data available at KIA for the period 1957-1985 were collected. The wind direction data are recorded on anemograph charts, and to obtain hourly averages the wind directions were interpolated to degrees.

Wind direction data were grouped into 16 sectors (Table 3). Three additional categories were added for "calm" readings (no wind), "variable" readings (wide fluctuations within the hour) and missing data.

Wind speed data were grouped on the basis of Beaufort wind scale (Table 4). For the purpose of this study the scale was reduced to five categories (Table 5).

Finally, the data were stored in KISR's computer on a monthly and annual basis.

Table 3. Wind Direction and the Coded Degrees

Sector	Interpolated Wind Direction (Degrees)
N	349 - 11
NNE	12 - 33
NE	34 - 56
ENE	57 - 78
E	79 - 101
ESE	102 - 123
SE	124 - 146
SSE	147 - 168
S	169 - 191
SSW	192 - 213
SW	214 - 236
WSW	237 - 258
W	259 - 281
WNW	282 - 303
NW	304 - 326
NNW	327 - 348

Table 4. The Beaufort Scale for Wind Speed on Land

Beaufort Number	Seaman's Description of Wind	Terms Used By U.S. Weather Bureau	Velocity (mph)	Velocity (knots)	Estimating Velocities on Land
0	Calm	Calm	Less than 1	Less than 1	Smoke rises vertically
1	Light air	Light	1-3	1-3	Smoke drifts; wind vanes unmoved
2	Light breeze		4-7	4-6	Wind felt on face; leaves rustle; ordinary vane moved by wind
3	Gentle breeze	Gentle	8-12	7-10	Leaves and small twigs in constant motion; wind extends light flag
4	Moderate breeze	Moderate	13-18	11-16	Raises dust and loose paper; small branches are moved
5	Fresh Breeze	Fresh	19-24	17-21	Small trees in leaf begin to sway; crested wavelets form on inland water
6	Strong Breeze	Strong	25-31	22-27	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty
7	Moderate gale		32-38	28-33	Whole trees in motion; inconvenience felt in walking against the wind
8	Fresh gale	Gale	39-46	34-40	Breaks twigs off trees; generally impedes progress

Table 4 Cont'd.

Beaufort Number	Seaman's Description of Wind	Terms Used By U.S. Weather Bureau	Velocity (mph)	Velocity (knots)	Estimating Velocities on Land
9	Strong gale	Gale	47-54	41-47	Slight structural damage occurs
10	Whole gale	Whole gale	55-63	48-55	Trees uprooted; considerable structural damage occurs
11	Storm		64-75	56-65	
12	Hurricane	Hurricane	Above 75	Above 65	

Table 5. Wind Speed Categories Used in This Study

Category	Wind Speed (mph)
Calm	0
Light	1 - 7
Moderate	8 - 18
Strong	19 - 31
Gale	≥ 32

Data Analysis

The frequency percentages of wind direction and wind speed were calculated for each of the three months (June, July and August) for 29 years.

Wind Direction

The frequency percentages of winds from each of the 16 sectors defined in Table 3 were calculated for each year. The results are shown in Tables A1, A2 and A3 in Appendix A. These tables, as well as Table 6, show that four directions, i.e., N, NNW, NW and WNW, were among the prevailing wind directions in most of the 29 years.

On the basis of these observations, the decision was made to consider these four wind directions as one sector.

Therefore, for the purpose of this study, it was decided to group the sixteen wind directions into four main sectors clockwise as follows.

1. Northeast sector, consisting of the following:
 - * North Northeast (NNE)
 - * Northeast (NE)
 - * East Northeast (ENE)
 - * East (E)
2. Southeast sector, consisting of the following:
 - * East Southeast (ESE)
 - * Southeast (SE)
 - * South Southeast (SSE)
 - * South (S)
3. Southwest sector, consisting of the following:
 - * South Southwest (SSW)
 - * Southwest (SW)
 - * West Southwest (WSW)
 - * West (W)
4. Northwest sector, consisting of the following:
 - * North (N)
 - * North Northwest (NNW)

Table 6. Prevailing Wind Directions

Year	June					July					August				
1957	N	NNW	NW	WNW	E	N	NNW	NW	WNW	E	N	NNW	NNE	E	SE
1958	N	NNW	NW	WNW	SE	NNW	N	NW	SE	NNE	NNW	N	NW	SE	E
1959	N	NNW	NW	WNW	S	NNW	WNW	NW	N	W	NNW	NW	WNW	N	W
1960	NNW	NW	WNW	N	W	NW	WNW	WNW	ESE	S	NNW	NW	WNW	W	N
1961	NW	NNW	WNW	N	SSE	NW	WNW	NNW	W	E	NW	NNW	N	E	S
1962	NW	WNW	W	NNW	N	WNW	NN	W	NNW	E	S	E	WNW	NW	SSW
1963	NW	NNW	WNW	N	W	NW	WNW	WNW	W	N	NW	WNW	NNW	W	E
1964	NW	NNW	WNW	N	W	WNW	NW	W	E	S	WNW	NW	WNW	W	SSW
1965	NW	NNW	WNW	N	NE	NW	WNW	W	N	WNW	NW	NNW	E	WNW	S
1966	NW	WNW	NNW	W	N	NW	WNW	NNW	NNW	W	N	NW	WNW	W	N
1967	NW	WNW	W	E	SW	WNW	NW	W	E	S	NW	W	WNW	S	N
1968	NW	WNW	NNW	SW	W	NW	SW	NE	WNW	SE	NW	WNW	W	NE	NNW
1969	NW	S	NNW	NE	N	NW	WNW	SW	W	NNW	NW	WNW	SW	SE	W
1970	NW	NNW	N	W	WNW	NW	NNW	N	W	WNW	NW	NNW	W	N	WNW
1971	NW	NNW	WNW	N	W	NW	WNW	NNW	W	N	NNW	NW	WNW	N	W
1972	N	NW	NNW	NNE	E	NNW	NW	N	WNW	W	N	NW	NNW	W	WNW
1973	NW	NNW	N	WNW	W	NW	NNW	WNW	W	S	NW	NNW	N	WNW	ENE
1974	NW	N	NNW	NE	WNW	NW	WNW	W	S	N	NW	WNW	NNW	W	N
1975	NW	WNW	W	N	NNW	NW	WNW	W	E	S	NW	WNW	W	E	S
1976	NW	WNW	NNW	S	N	WNW	W	NW	WSW	ENE	WNW	W	NW	WSW	NNW
1977	NW	WNW	NNW	W	ENE	NW	WNW	W	NNW	WSW	NW	WNW	NNW	W	S
1978	NW	WNW	W	NNW	E	NW	WNW	ESE	E	W	NW	WNW	W	NNW	S
1979	NW	NNW	N	NE	NNE	NW	NNW	N	WNW	S	NW	NNW	ESE	WNW	S
1980	NW	NNW	N	W	WNW	NW	NNW	N	W	S	WNW	NW	SSW	W	WNW
1981	NNW	NW	N	WNW	W	NW	WNW	W	NNW	E	NW	NNW	WNW	S	N
1982	NW	NNW	N	W	S	NW	NNW	WNW	W	N	NW	WNW	W	NNW	N
1983	NW	NNW	N	W	E	NW	NNW	N	W	WNW	NW	NNW	WNW	W	N
1984	NW	NNW	WNW	W	S	NNW	NW	W	WNW	N	NW	WNW	NNW	W	N
1985	NW	NNW	WNW	W	N	NW	WNW	NNW	W	N	NW	E	S	NNW	N

- * North West (NW)
- * West Northwest (WNW)

Monthly Wind Direction Frequency. Figures 2a, 2b and 2c present the frequency distribution of the four wind direction sectors in June, July and August, respectively. The figures show that, with only one exception the Northwest sector has the highest frequency in each of the three months for the last 29 years.

A comparison of the three figures shows that the frequency of the Northwest wind has some stability during the month of June (Fig. 2a), and less stability during July and August (Figs. 2b and 2c). The August frequencies were particularly unstable from 1957 to 1968: both the highest and the lowest values in the 29 years were recorded during this period.

The other three sectors showed some stability during the months of June and July with some exceptional years such as 1962, 1976 and 1979 .

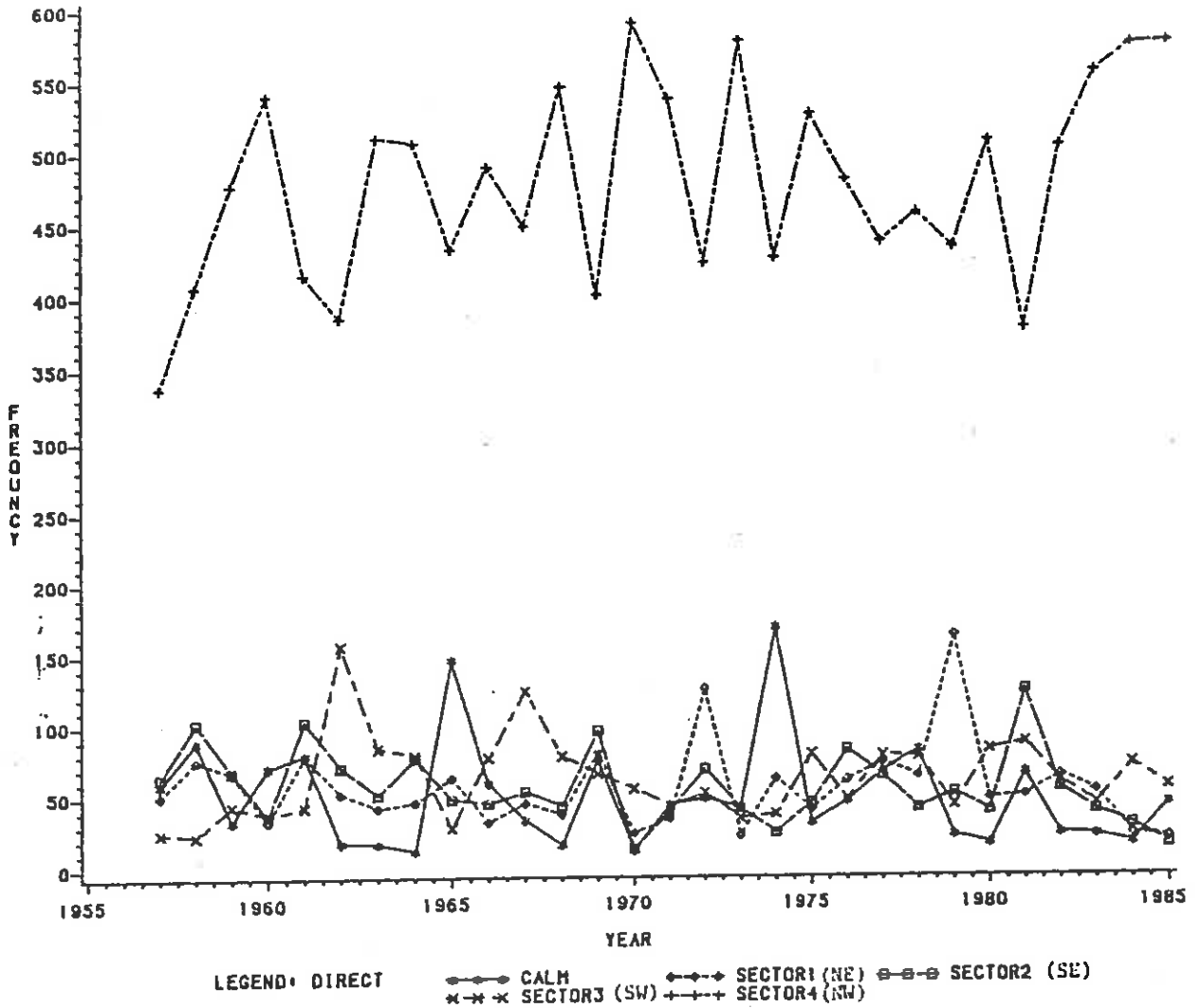
The Southeast and Southwest sectors had the highest frequencies during the month of August 1962 and 1967, respectively (Fig. 2c). During this month, the frequencies of these sectors were unstable and varied from year to year, especially during the early years (1957 to 1968).

Calms were less frequent in June (Fig. 2a) and more frequent in August (Fig. 2c). This category was not included in the analyses of the study because it does not contribute to dust storms and sand mobility.

Overall Wind Direction Frequency for the Three-Month Period. Figures 3a to 3d present the frequency of wind from the four sectors during the whole three-month period. Fig. 3a shows that the frequency of the Northwest sector was lowest in August 1962 and 1985, and highest in July 1959, 1971 and 1983. It also shows that August had the highest fluctuations and June had the lowest.

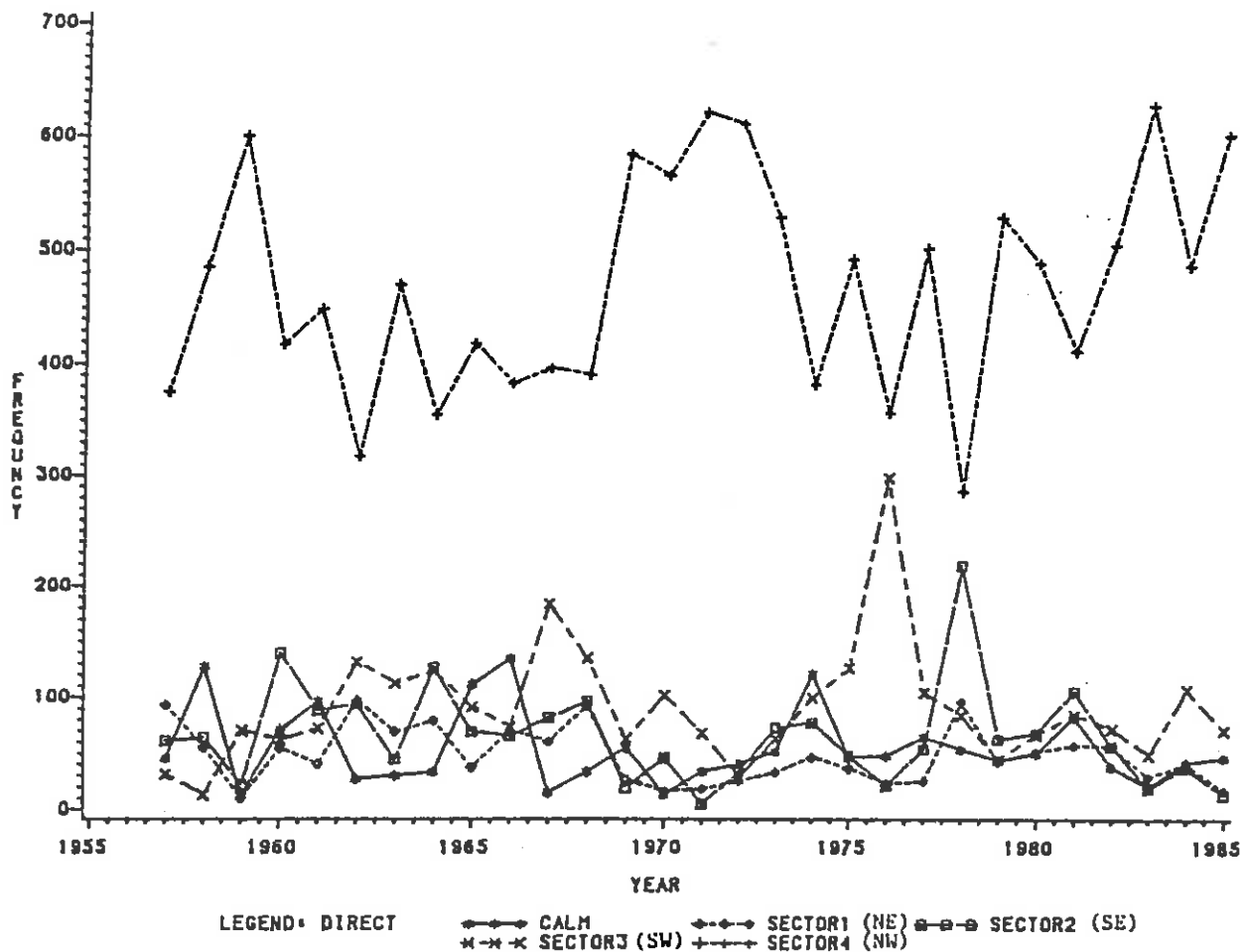
Winds from the Southwest sector were more frequent in August, except in 1962, 1977, and 1981 when higher frequencies were observed in June and July (Fig. 3b).

Similar results were obtained for the Northeast and Southeast sectors. The frequency of Northeast winds varied from one month to another



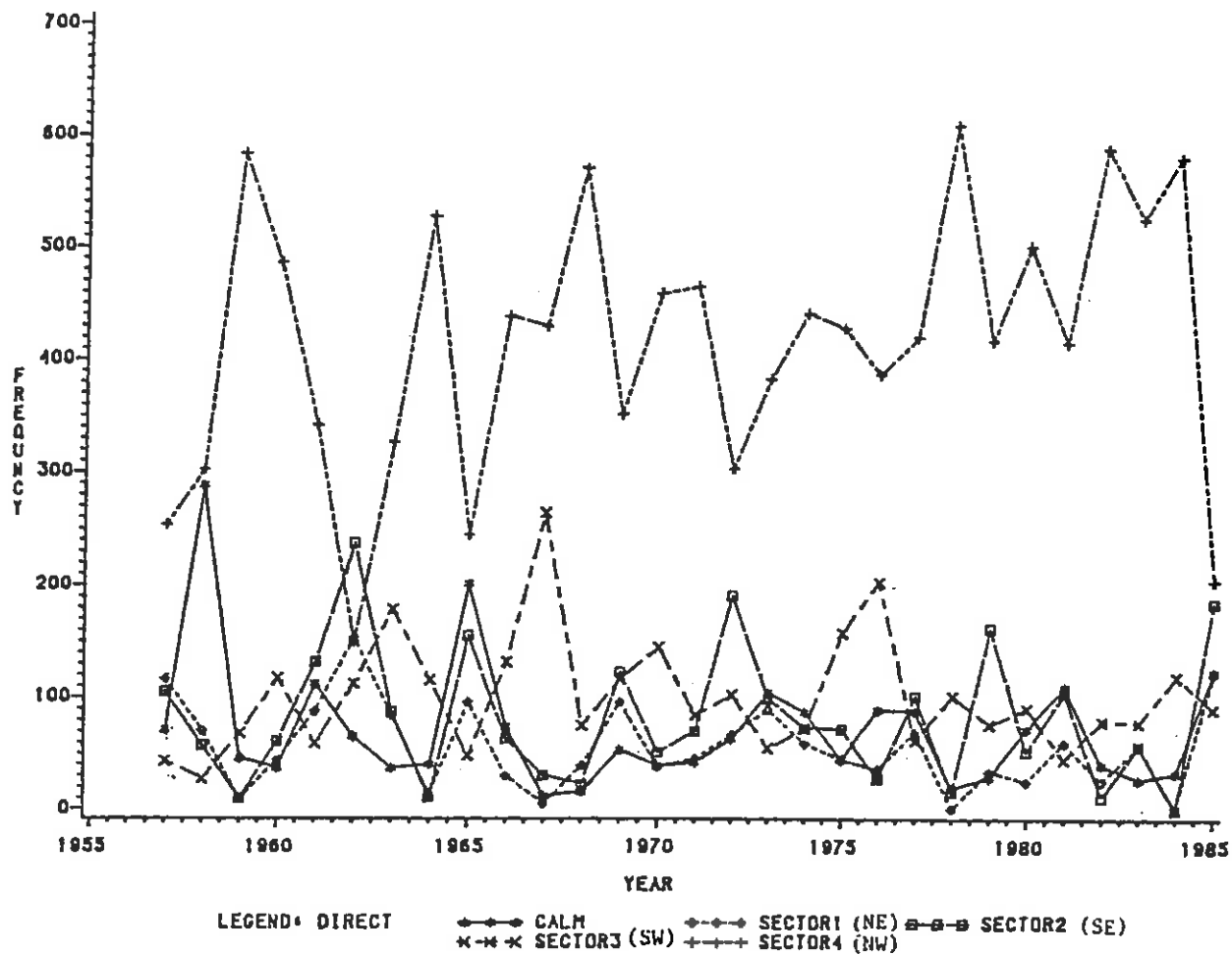
KISRX 20753

Fig. 2a. Frequency distribution of the four main wind direction sectors for June (1957 - 1985).



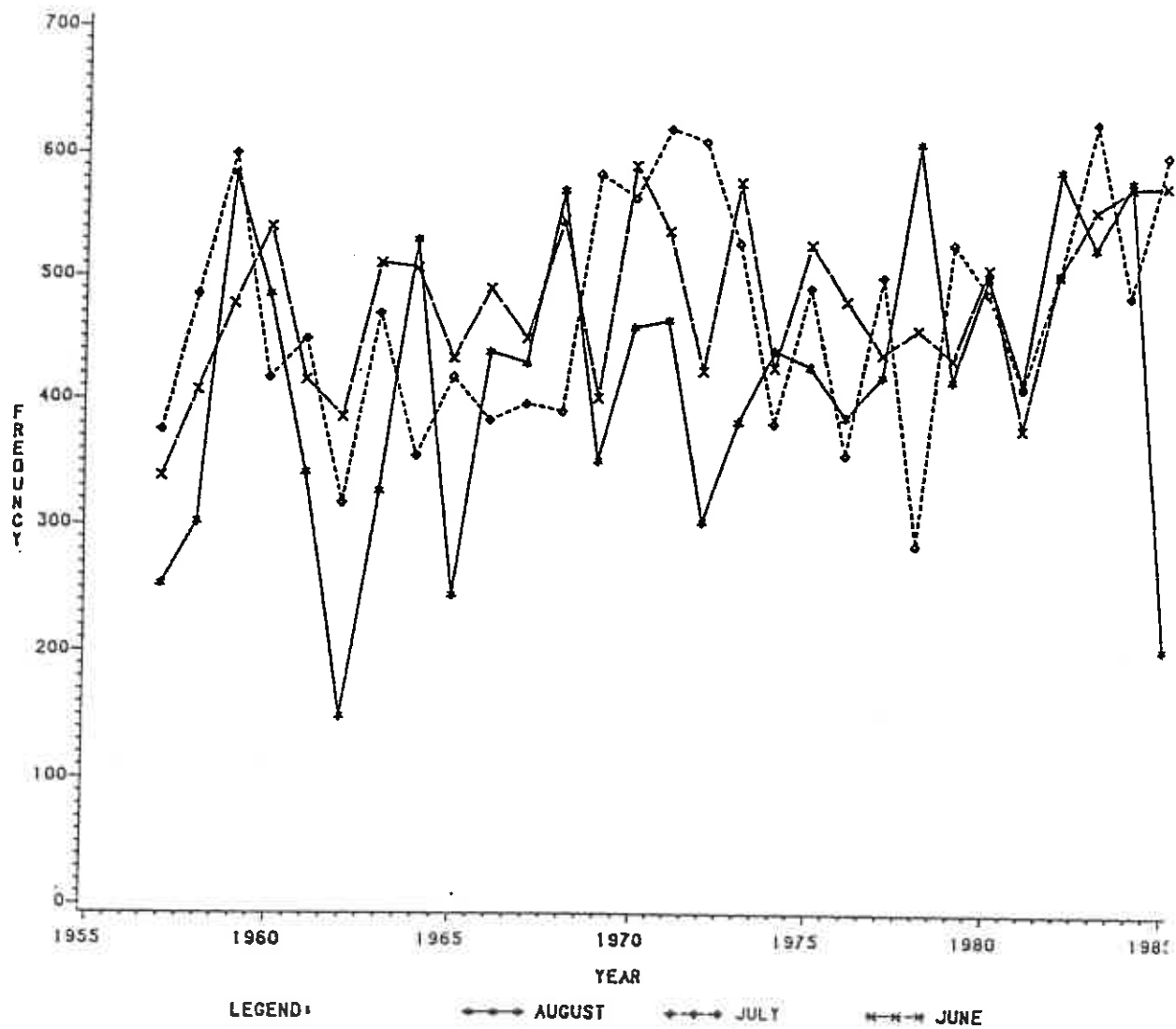
KISR 20754

Fig. 2b. Frequency distribution of the four main wind direction sectors for July (1957 - 1985).



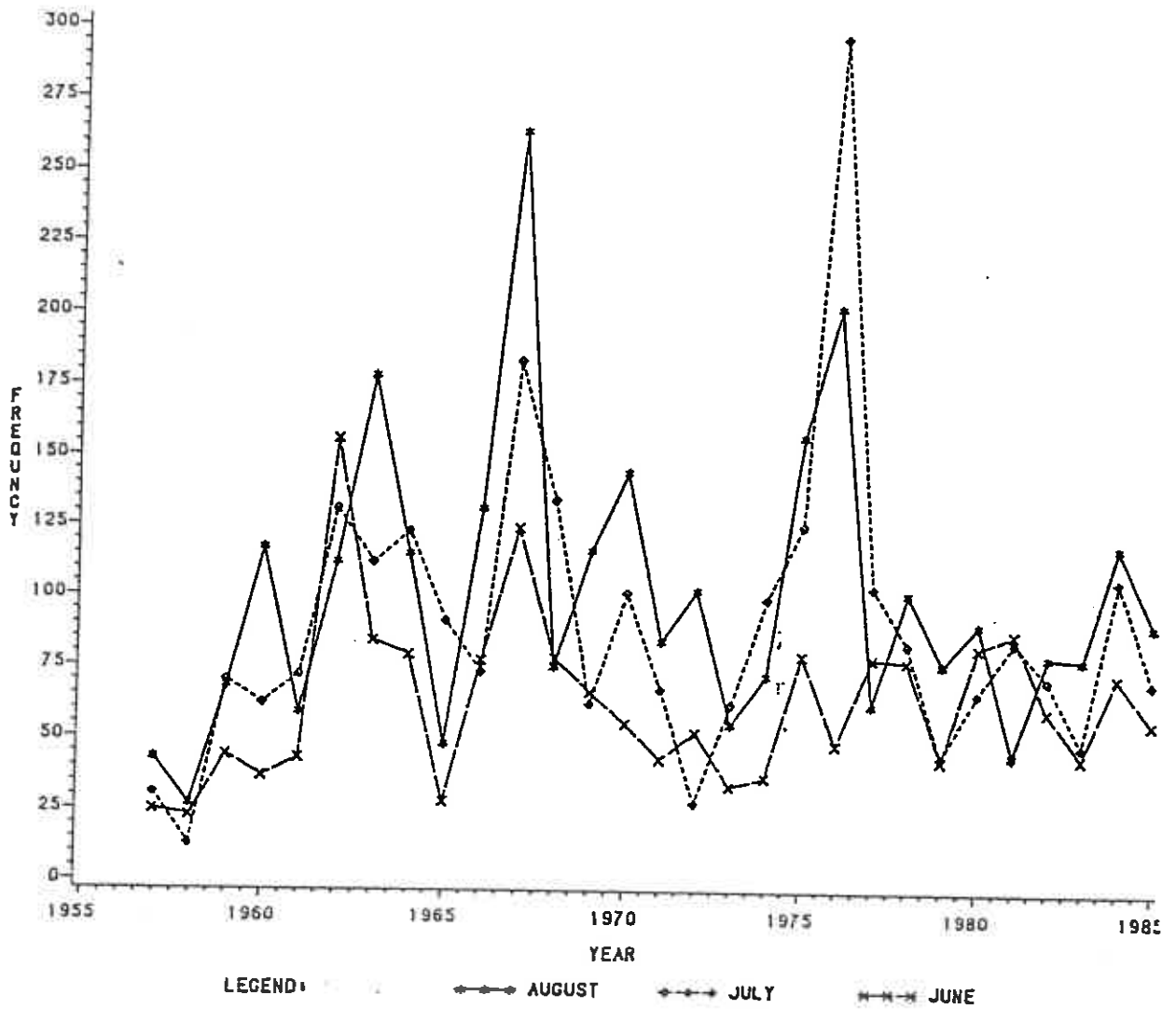
KISRX 20755

Fig. 2c. Frequency distribution of the four main wind direction sectors for August (1957 - 1985).



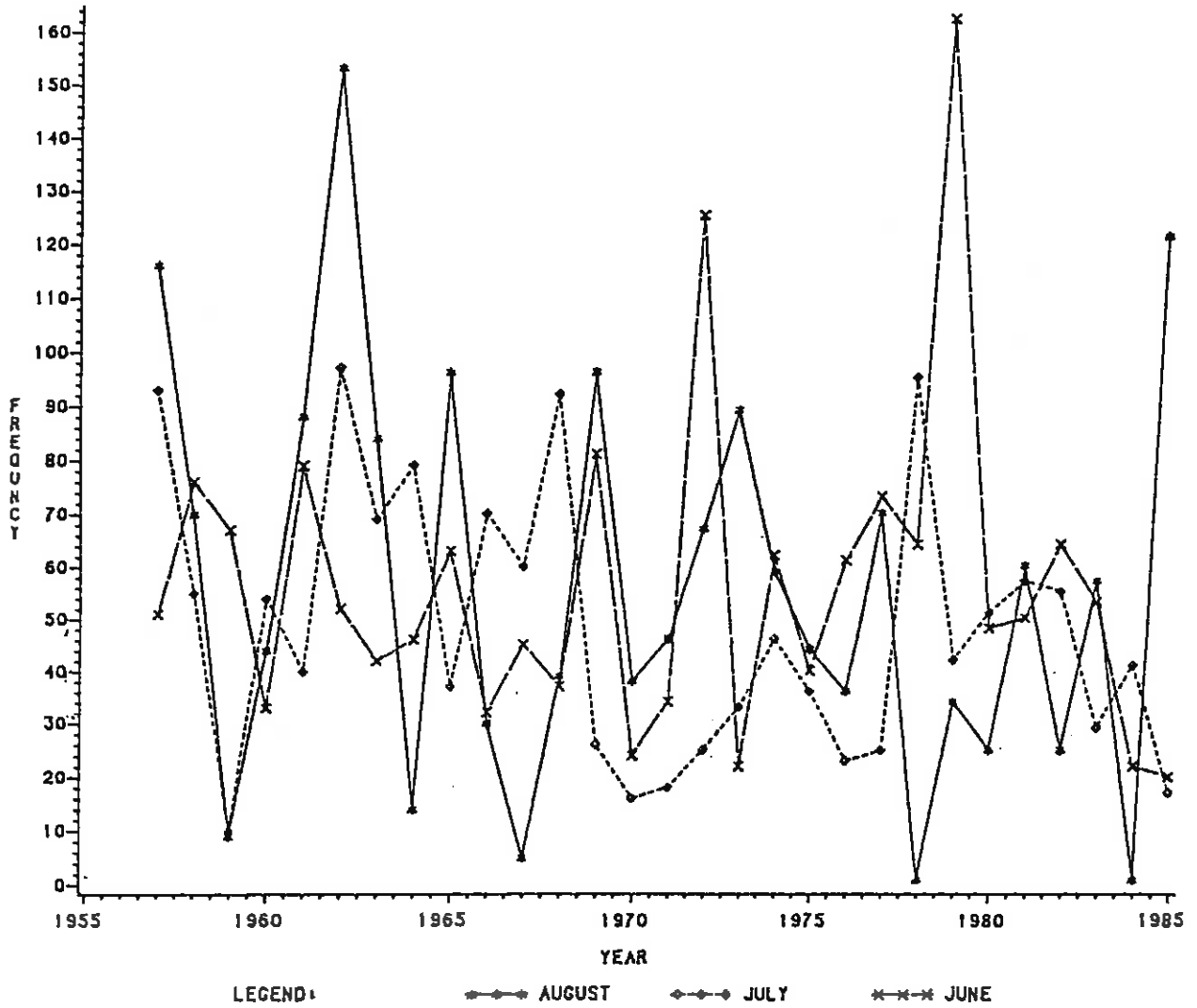
KISRX 20756

Fig. 3a. Overall average frequency distribution of the NW wind sector (1957-1985).



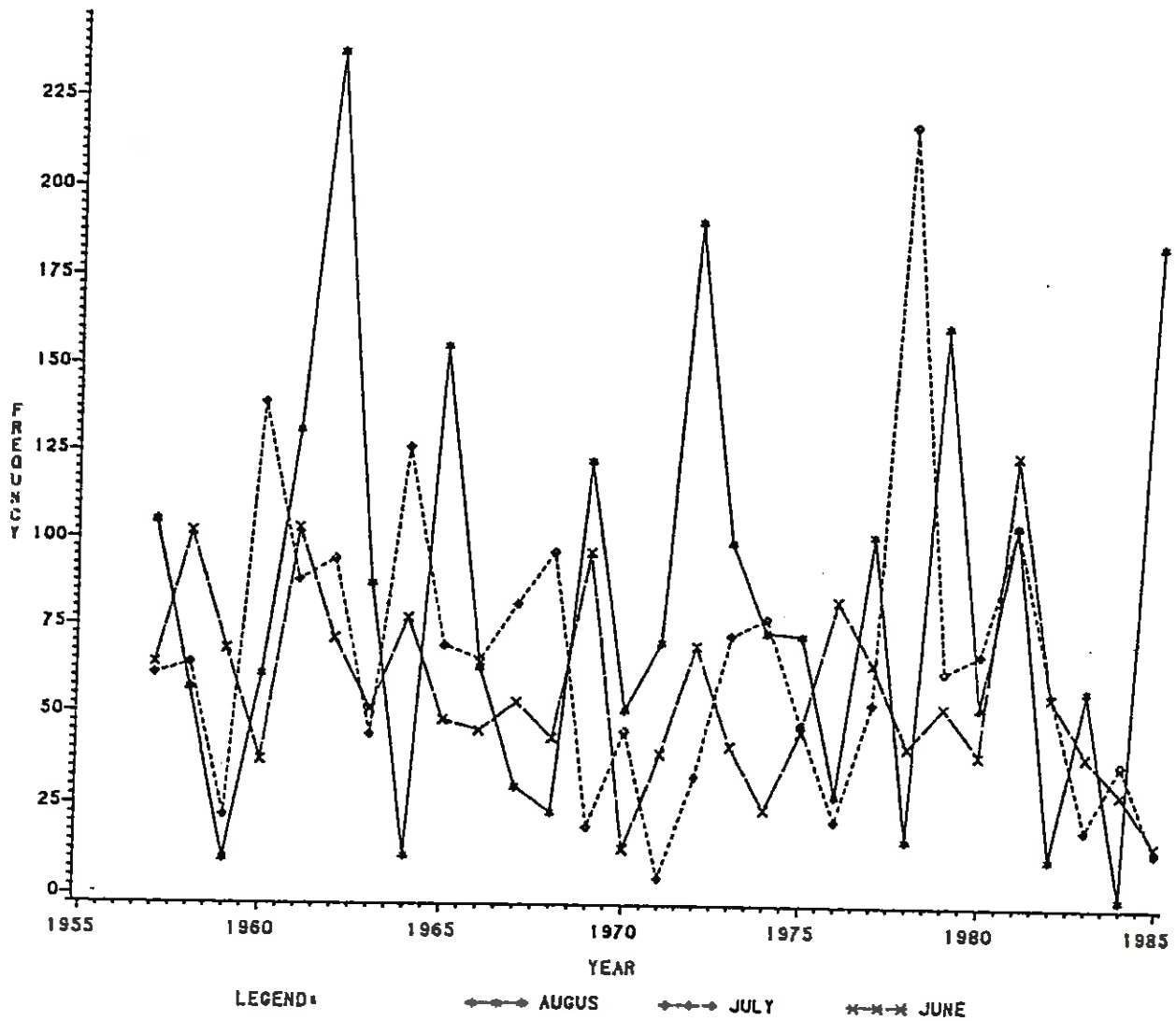
KISRX 20757

Fig. 3b. Overall average frequency distribution of the SW wind sector (1957 - 1985).



KISR X 20758

Fig. 3c. Overall average frequency distribution of the NE wind sector (1957 - 1985).



KISR 20759

Fig. 3d. Overall average frequency distribution of the SE wind sector (1957 - 1985).

with some extreme years such as 1962, 1972, 1979 and 1985 (Fig. 3c). The frequency of Southeast winds was higher in August, when it also showed an apparent peak cycle approximately every three or four years.

In order to test the changes in the monthly frequency means of the three month for the four wind direction sectors, Table 7 was used to test whether there were significant differences among the wind means during the three months. The results of this table showed that the frequency means of Southwest sector during the three months were significantly different at 0.05 level, and F-ratio was 5.20 (P 0.05).

The table also shows that the Northwest sector has the highest monthly hourly mean frequency, and the lowest variation coefficient during June, $\bar{X} = 477.7$ and C.V = 0.14 respectively. The Northeast sector has the lowest monthly hourly mean frequency and higher variation coefficient during July, $\bar{X} = 47.9$ and C.V = 0.53. The coefficient variation was used to compare variation between wind sectors and to measure the relative consistency of average frequency occurrence.

Wind Direction Frequency within Each Sector.

The Northwest Sector. Wind direction frequencies within the Northwest sector during the months of June, July and August are presented in Figs. 4a to 4c.

In June, the NW wind was the prevailing wind in this sector (Fig. 4a). It had a fairly smooth linear frequency trend during the first period from 1957 to 1968, increasing gradually to a maximum in 1968. This trend was rapidly reversed in the following four years (1969 to 1972).

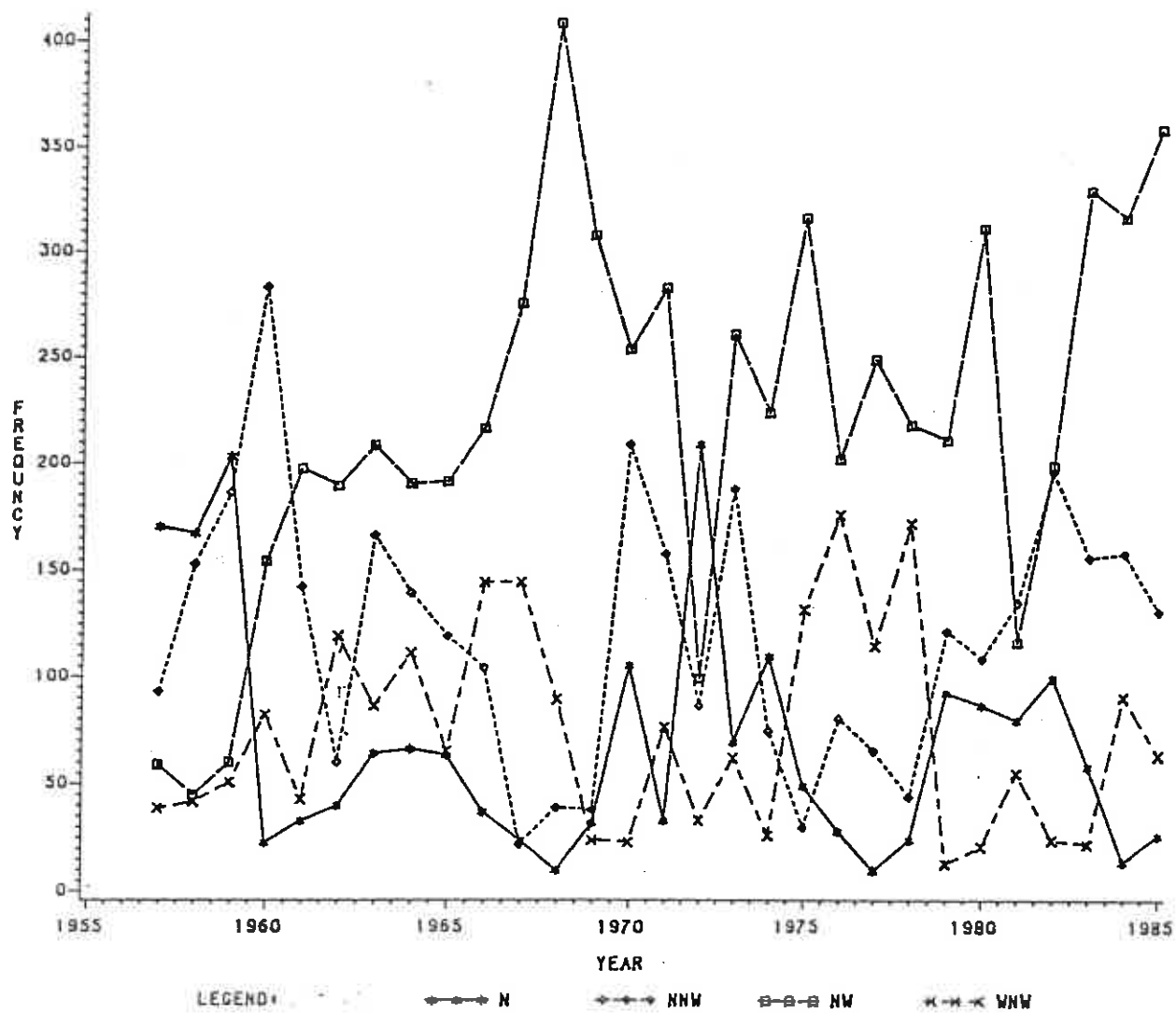
This trend was rapidly reversed in the following four years (1969 to 1972). The correlation coefficient (r) between the frequency monthly means and the period between 1957 to 1968 in June was found to be significant at 0.05 level, and $r = 0.65$. When the t-test was used to test the significance of this correlation between these two observation, it was found that the t-value was 4.44, and the correlation coefficient was significant. The t-value is calculated by the formula

$$t = r \frac{N-2}{1-r^2}$$

Table 7. Summary of the Wind Direction Sectors of the Three Months (1957-1985)

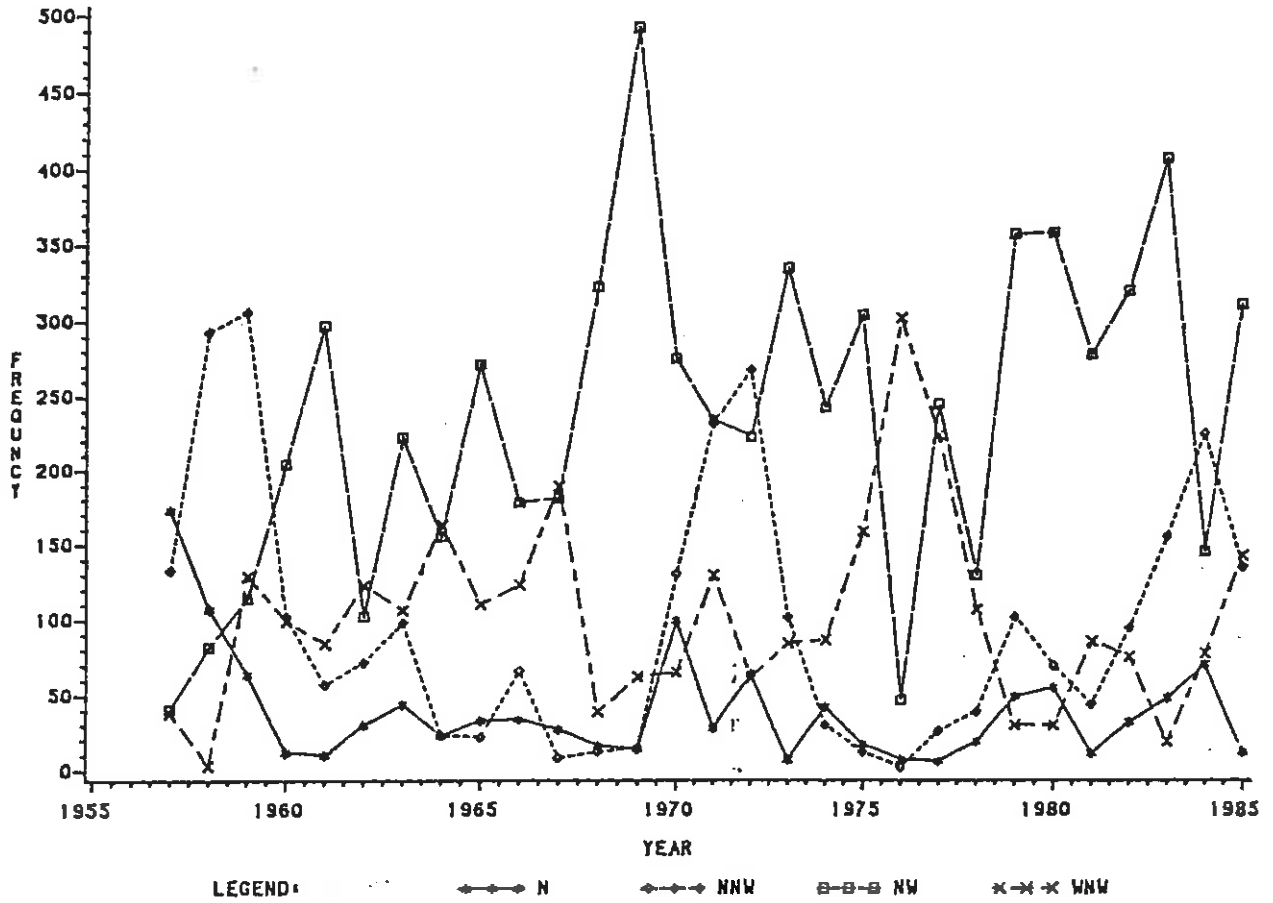
Sector	Month	\bar{X} (h)	SD	CV	Min. Frequency (h)	Max. Frequency (h)	F Ratio
NW	June	477.7	68.2	0.14	338	589	3.29
	July	468.3	96.3	0.20	284	624	
	August	416.9	120.0	0.28	149	604	
SW	June	62.4	29.3	0.47	23	156	5.20
	July	90.0	53.6	0.60	13	296	
	August	100.2	51.5	0.51	27	263	
SE	June	56.2	26.6	0.47	13	124	2.25
	July	65.4	43.9	0.67	5	217	
	August	81.4	60.7	0.75	0	237	
NE	June	56.4	30.2	0.54	20	162	0.61
	July	47.9	25.6	0.53	10	97	
	August	55.8	38.3	0.68	1	153	

\bar{X} = Monthly hourly mean frequency
 SD = Standard deviation
 CV = Coefficient of variation
 F ratio = A statistical test for comparison among average monthly frequency



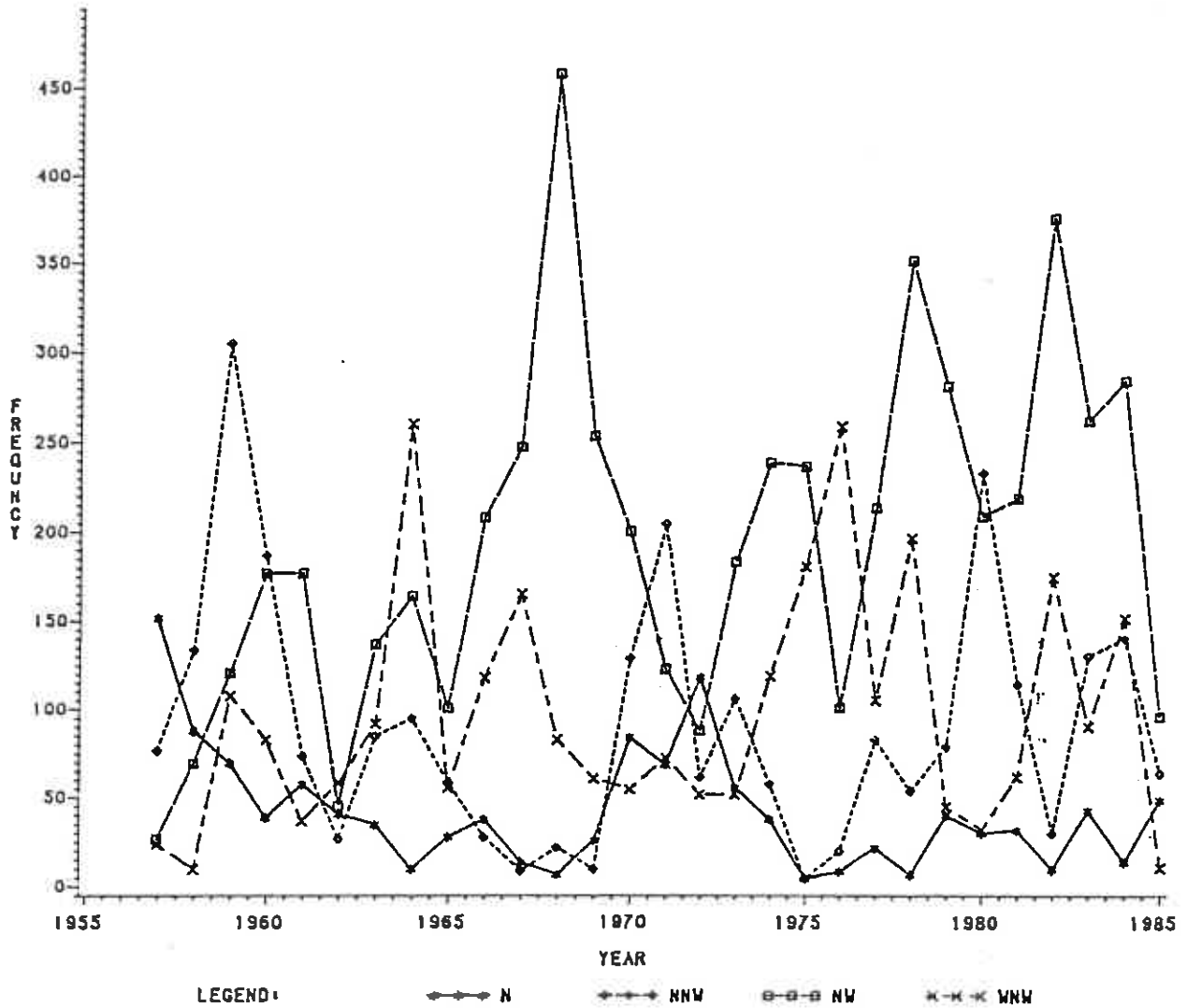
KISRX 20760

Fig. 4a. Frequency distribution of wind direction in the northwest sector during June (1957 - 1985).



KISRX 20761

Fig. 4b. Frequency distribution of wind directions in the northwest sector during July (1957 - 1985).



KISRX 20762

Fig. 4c. Frequency distribution of wind directions in the northwest sector during August (1957 - 1985).

where:

r = correlation coefficient

N = Number of observations

Figure 4a also shows that during the period of 1957 to 1959, the N and the NNW winds were prevailing. The frequency percentage of the N wind ranged between 21.8% in 1957 and 26.1% in 1959 (Table A1, Appendix A). In 1972, the N wind had the highest percentage of occurrence $C = 10.3\%$.

Figure 4b and 4c present the NW sector of July and August. The figures show that the NW winds frequency increased from 1957 to 1961, and again from 1966 to 1969.

The highest frequency of the NW wind occurred in July 1969 when $R = 66\%$ and $C = 7.2\%$ (Table A2, Appendix A), and the lowest in July 1957 ($R = 5.5\%$ and $C = 0.6\%$). For the month of August, the highest frequency was in 1968 ($R = 6.14\%$ and $C = 8.1\%$) and the lowest in 1962 ($R = 6.2\%$ and $C = 0.8\%$).

When the relationships between the NW wind and the other winds in NW sectors was studied, it was found that most of the correlation coefficient were negative or very low (Table 8). For example, in June the correlation coefficient was -0.70 between N and NW, -0.35 between N and W, and 0.48 between N and E. The NW wind had negative correlation coefficients with most wind directions during August. These negative correlation coefficients indicates that an opposite relationship exists between these wind directions. The purpose of the correlation coefficient is to express in statistical terms the degree of relationship between two variables. If the relationship is perfectly positive, r will be 1.00 . If the relationship is perfectly negative, it will be -1.00 . If there is no relationship, r will be zero. If the two observations are related, the coefficient will have a value between zero and -1.00 for a negative relationship, and between zero and 1.00 for a positive relationship (Hays, 1981).

The correlation coefficient between N and NNE were 0.48 , 0.65 , and 0.69 for June, July, and August respectively, and between the WNW and WSW, the correlation was 0.81 in July. These positive coefficients

Table 8. Correlation Coefficients of Wind Directions in the Northwest Sector (N=29 years)

Direction	June				July				August							
	N	NNW	NW	WNW	N	NNW	NW	WNW	N	NNW	NW	WNW	N	NNW	NW	WNW
N	1				1				1				1			
NNW		1				1				1				1		
NW	-0.70	-0.28	1		-0.37	-0.25	1		-	0.22	1		-	0.22	1	
WNW	-0.54	-0.79	0.28	1	-0.49	0.38	0.37	1	-0.12	-0.26	0.37	1	-	-0.12	-0.26	0.37
NNE	0.48	-	-0.37	-0.38	0.65	0.29	-0.39	-0.34	0.69	-	-0.58	-0.46	0.69	-	-0.58	-0.46
NE	-	-0.32	-	-0.39	-	0.24	-	-0.29	0.31	0.23	-	-0.46	0.31	0.23	-	-0.46
ENE	-	-0.15	-0.20	-	-	-0.33	0.28	-	-	-	-0.37	-0.33	-	-	-0.37	-0.33
E	0.48	-0.24	-0.56	-	-	-0.43	-0.34	-	0.24	-0.27	-0.53	-0.51	0.24	-0.27	-0.53	-0.51
ESE	0.34	-	-0.45	-3.8	-0.29	-0.33	-0.28	-	-	-	-0.26	-0.22	-	-	-0.26	-0.22
SE	0.22	-0.26	-0.34	-	-	-0.43	-0.34	-	0.48	0.18	-0.42	-0.40	0.48	0.18	-0.42	-0.40
SSE	0.23	-	-0.43	-	-0.28	-0.33	-	-	0.24	-0.55	-0.60	-0.48	0.24	-0.55	-0.60	-0.48
S	-	-0.18	-	0.27	-	-0.28	-0.22	-	-	0.39	-0.39	-0.42	-	0.39	-0.39	-0.42
SSW	-	-	-	-	-	-0.24	-	-	-	-	0.33	-0.33	-	-	0.33	-0.33
SW	-0.32	-0.54	0.39	-	-0.24	-0.42	-0.33	-	-	-0.30	-	-	-	-0.30	-	-
WSW	-	-0.20	-	0.42	-0.53	-0.44	0.29	0.81	-0.27	-0.14	-0.20	-0.41	-0.27	-0.14	-0.20	-0.41
W	-0.35	-0.38	0.29	0.50	-0.27	-0.37	-0.38	0.37	-0.36	-0.26	0.18	0.63	-0.36	-0.26	0.18	0.63

Note: Coefficients below #0.12 were not included (no correlation)

indicate that the N wind relates highly with NNE during the three months, and the WNW relates highly with WSW, especially in July.

The Southwest Sector. Figures 5a to 5c present the frequency distribution of the wind directions of the Southwest sector for the months of June, July, and August, and the correlation among the wind directions is shown in Table 9. The figures show that the West wind was prevailing in this sector, and that the SW wind had the highest frequency during 1968 and 1969.

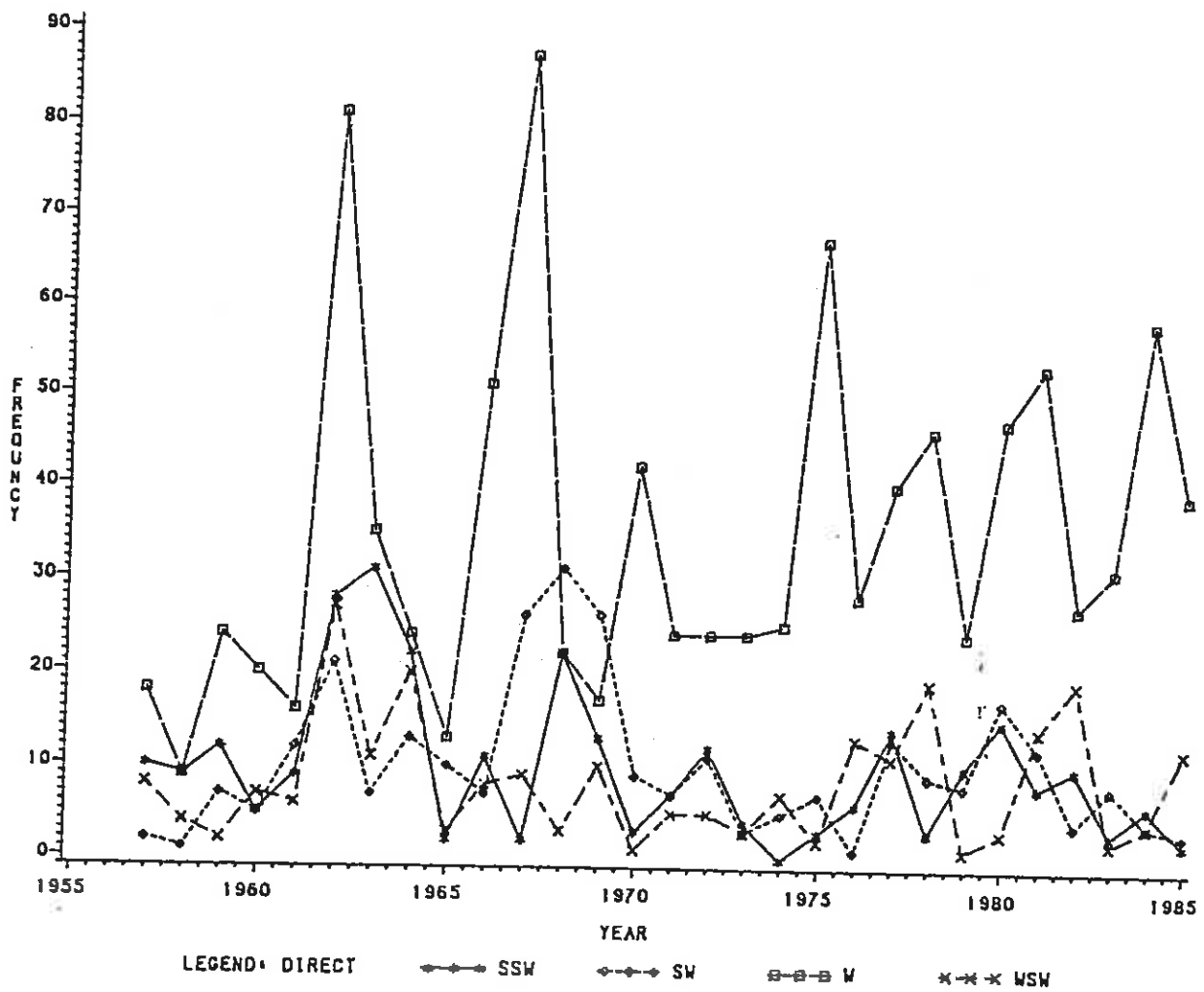
Figure 5a shows that during June the W wind had a lower frequency than in July (Fig. 5b) and August (Fig. 5c), and that its the highest frequency was in June 1967 (R = 12.1%, C = 8.6%, Table A1, Appendix A), July 1976 (R = 33.5%, C = 14.7, Table A2, Appendix A), and August 1967 (R = 32.7%, C = 13.5%, Table A3, Appendix A).

Table 9 shows that the correlation coefficients between SSW and SW were 0.40, 0.68, and 0.39 for the month of June, July, and August respectively, and that the correlation coefficient between SSW and NE increased during July to 0.60.

The Northeast Sector. Figure 6a shows no dominant wind, because there are two wind directions, E and NE, that alternate every two to three years. Fig. 6a also shows that the NNE wind had the highest frequency in June 1972 (R = 8.2% and C = 15.4%, Table A1, Appendix A), whereas E had the highest frequency in July 1962 (Fig. 6b, R = 7.7% and C = 8.9%, Table A2), and NE had the highest frequency in July 1968 (R = 7.0% and 20.2%, Table A2. Fig. 6c shows that the E wind is the dominant wind during August.

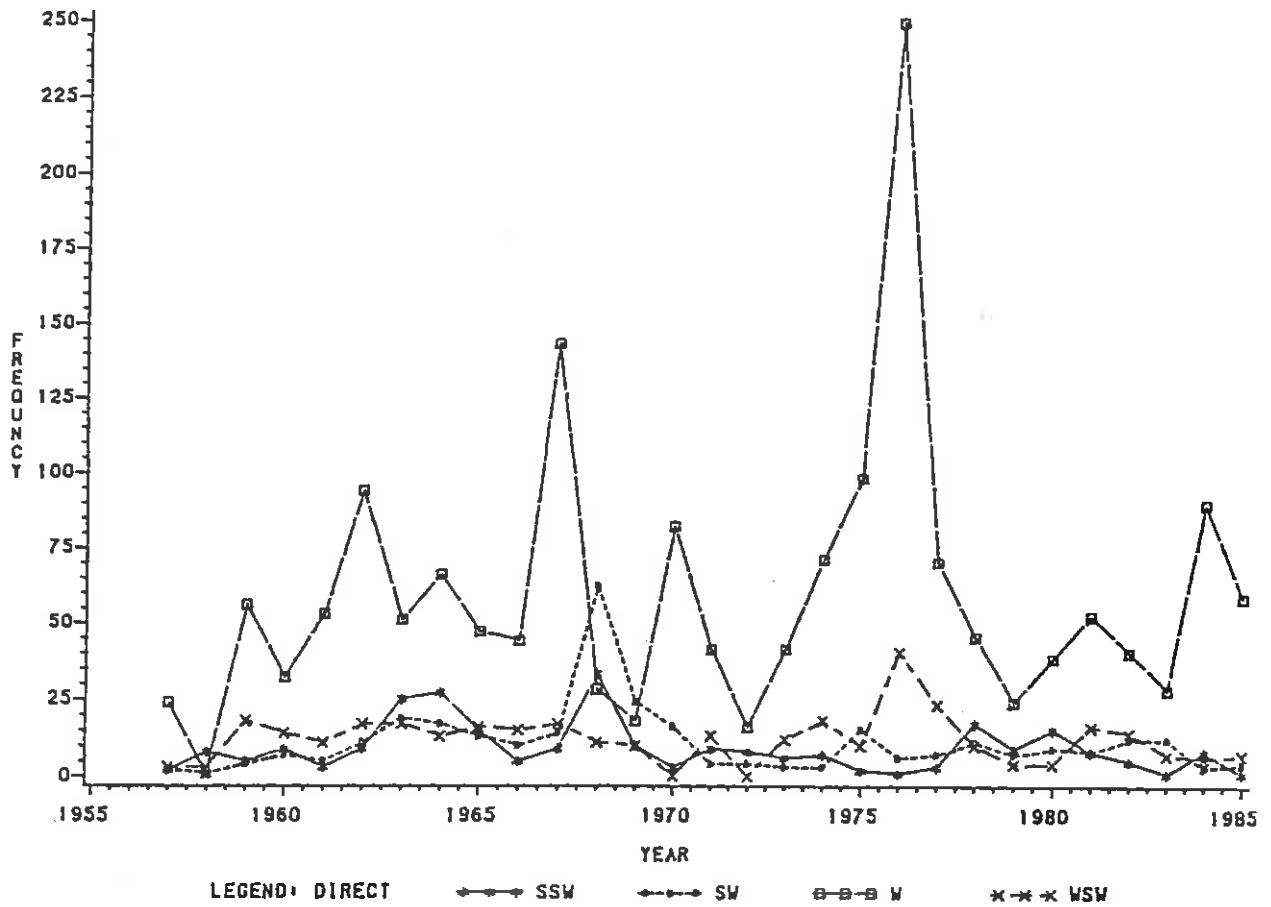
Table 10 shows that there are some positive correlation between NNE and NE (0.49), between NNE and E (0.47), and between NNE and ESE (0.60) during June. The table also showed that the highest positive correlation was 0.91 in August between E and S.

The Southeast Sector. Figs. 7a to 7c present the wind direction within this sector during the three months. The figures show that the S wind was prevailing in June (Fig. 7a) and August (Fig. 7c). The ESE wind's frequency was higher in July (Fig. 7b). Table 11 shows the correlation between the Southeast wind directions. The correlation coeffi-



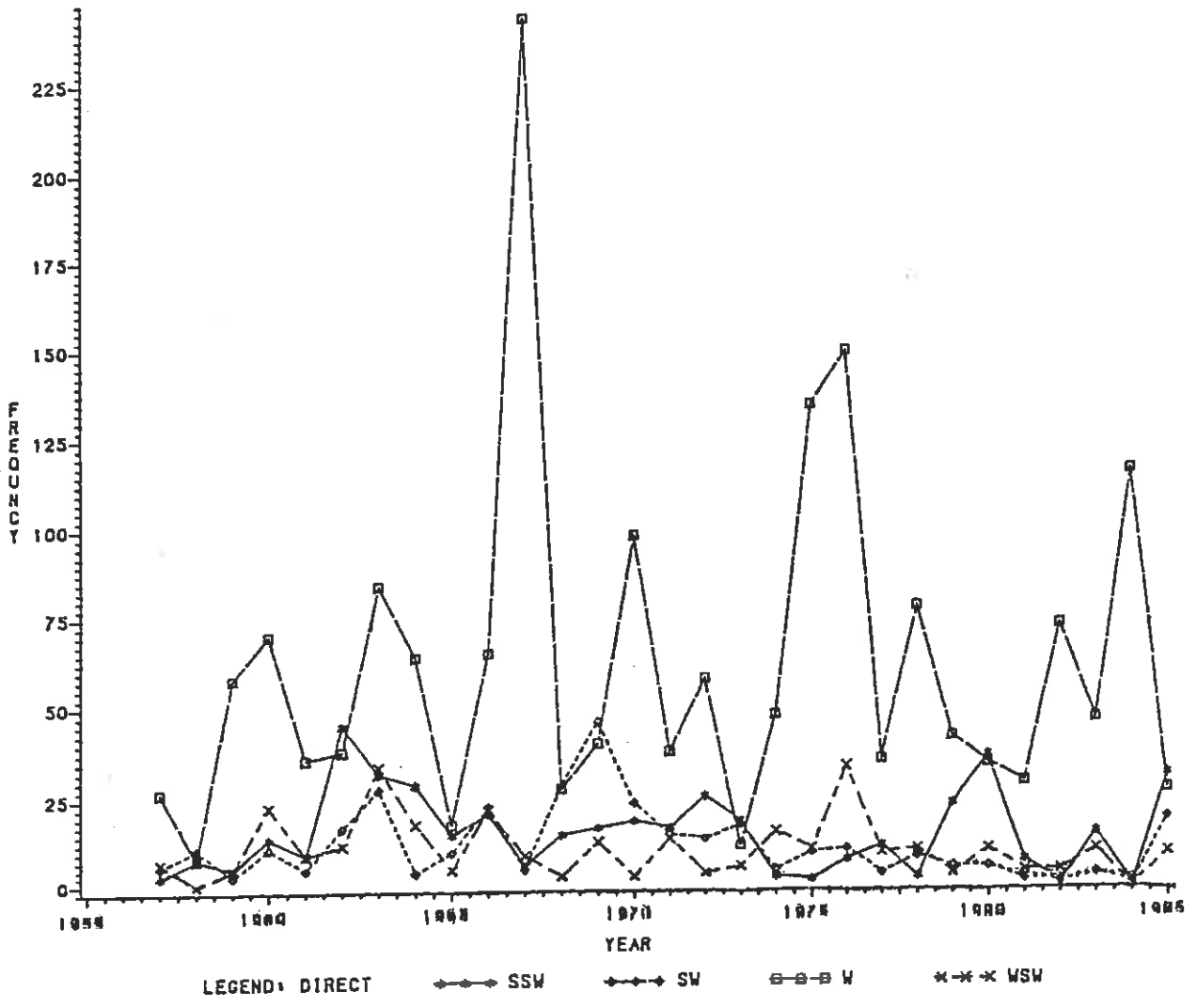
KISR X 20763

Fig. 5a. Frequency distribution of wind directions in the southwest sector during June (1957 - 1985).



KISRX 20764

Fig. 5b. Frequency distribution of wind directions in the southwest sector during July (1957 - 1985).



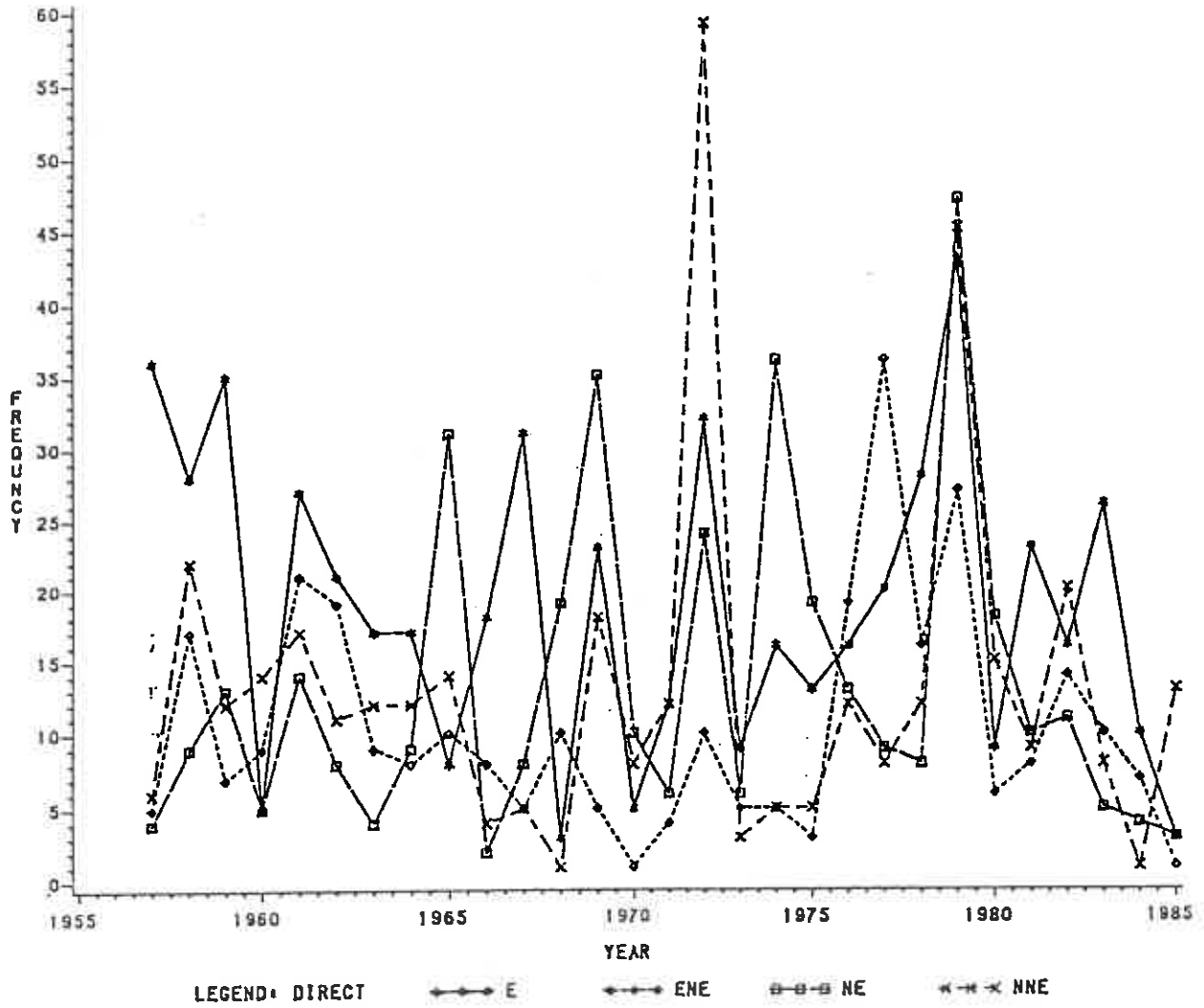
KISRX 20765

Fig. 5c. Frequency distribution of wind directions in the southwest sector during August (1957 - 1985).

Table 9. Correlation Coefficients of SW sector with other Wind Directions, 1957 - 1985

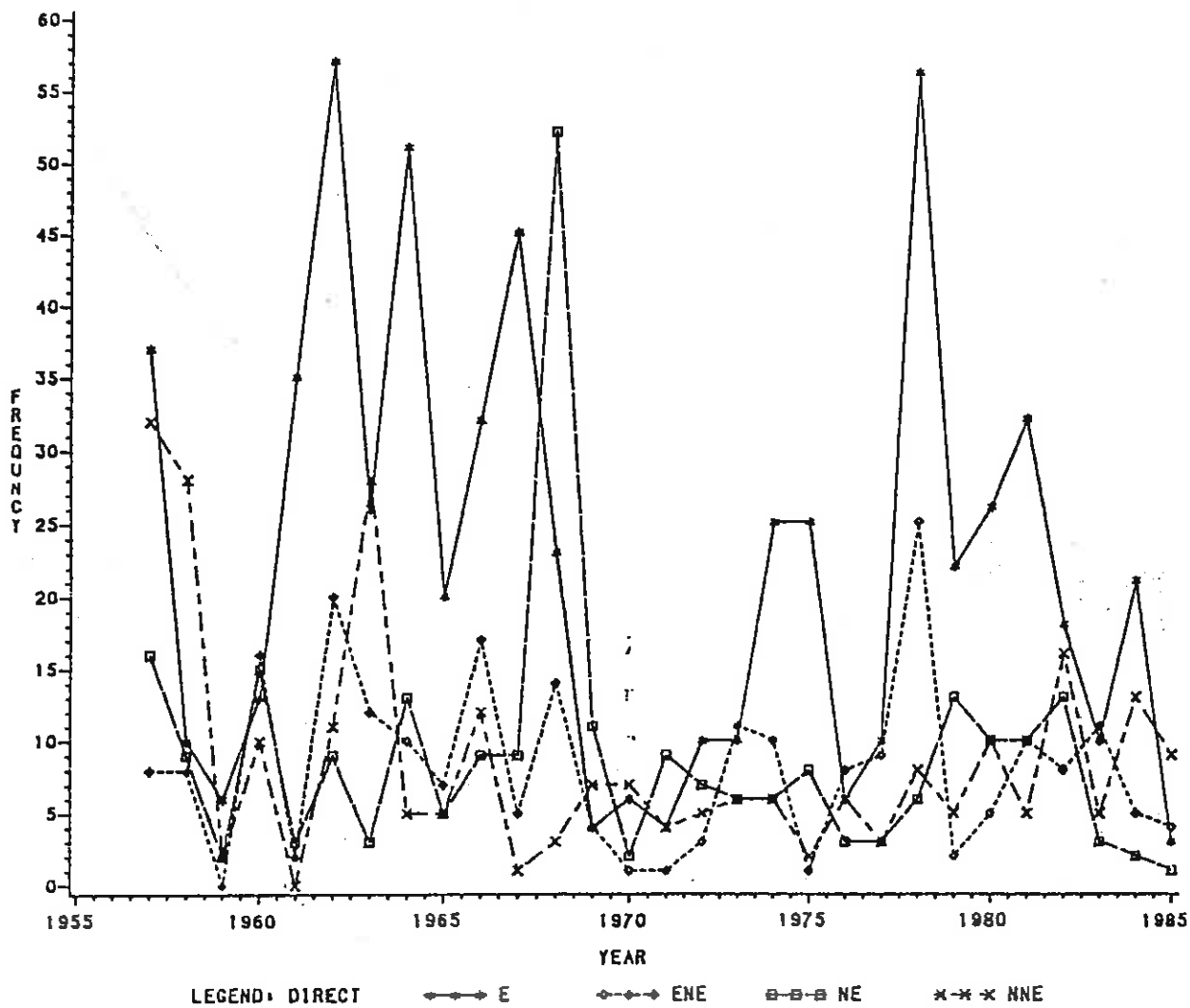
Direction	June				July				August			
	SSW	SW	WSW	W	SSW	SW	WSW	W	SSW	SW	WSW	W
SSW					1							
SW	0.40	1			0.68	1			0.39	1		
WSW	0.39	0.13	1		-	-	1		0.23	0.24	1	
W	0.30	0.31	1	1	-	-	0.71	1	-0.29	-	0.27	1
NNE	-	-	-	-0.32	-	-	-	-0.26	0.26	0.24	-	-0.4
NE	-	-	-0.28	-0.29	0.60	0.79	-	-0.26	-	0.64	-0.22	-0.43
ENE	-	-	-	-	0.35	-	-	-	0.28	-	-	-0.37
E	-	-	-	-	0.37	-	-	-	0.47	-	-	-0.38
ESE	-	-	-	-0.59	0.42	-	-	-	0.37	-	-0.21	-0.39
SE	-	-	-	-	0.43	0.35	-	-	0.32	-0.37	-0.27	-0.39
SSE	0.28	-	-	-	0.21	-	-	-	0.22	-	-	-0.42
S	0.18	0.15	0.39	-	0.38	-	-	-	0.55	0.24	-	-0.30
N	-	-0.32	-	-0.35	-	-0.24	-0.53	-0.27	-	-	0.27	-0.36
NNW	-	-0.54	-0.20	-0.38	0.24	-0.42	-0.44	-0.37	-	-0.30	-0.14	-0.26
NW	-	-0.39	-	-0.29	-	0.33	-0.29	-0.38	-0.33	-	-0.20	0.18
WNW	-	-	0.42	0.50	-	-	0.81	-0.37	-0.33	-	0.41	0.63

Note: Coefficients below #0.12 were not included (no correlation)



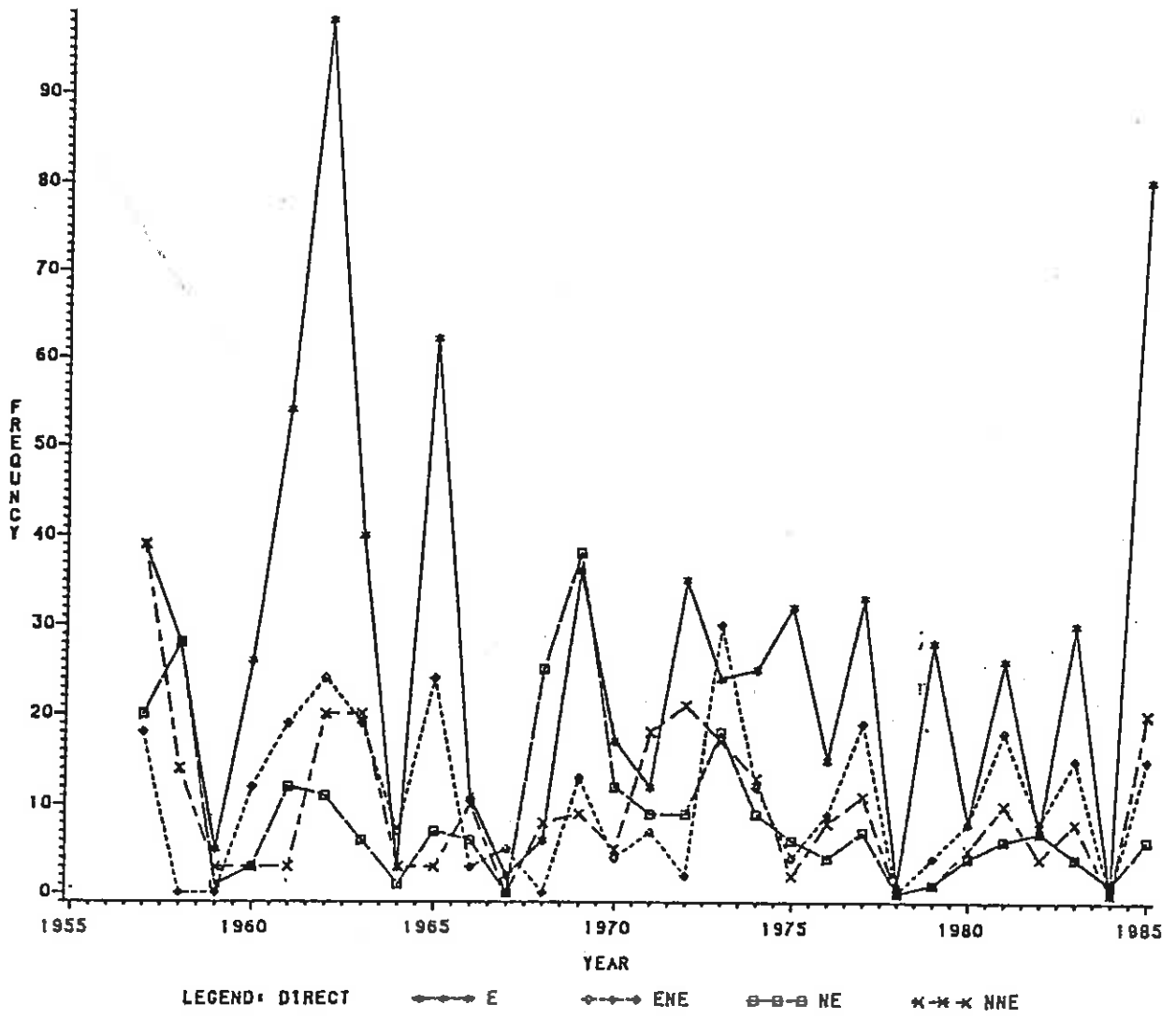
KISRX 20766

Fig. 6a. Frequency distribution of wind directions in the northeast sector during June (1957 - 1985).



KISRX 20767

Fig. 6b. Frequency distribution of wind directions in the northeast sector during July (1957 - 1985).



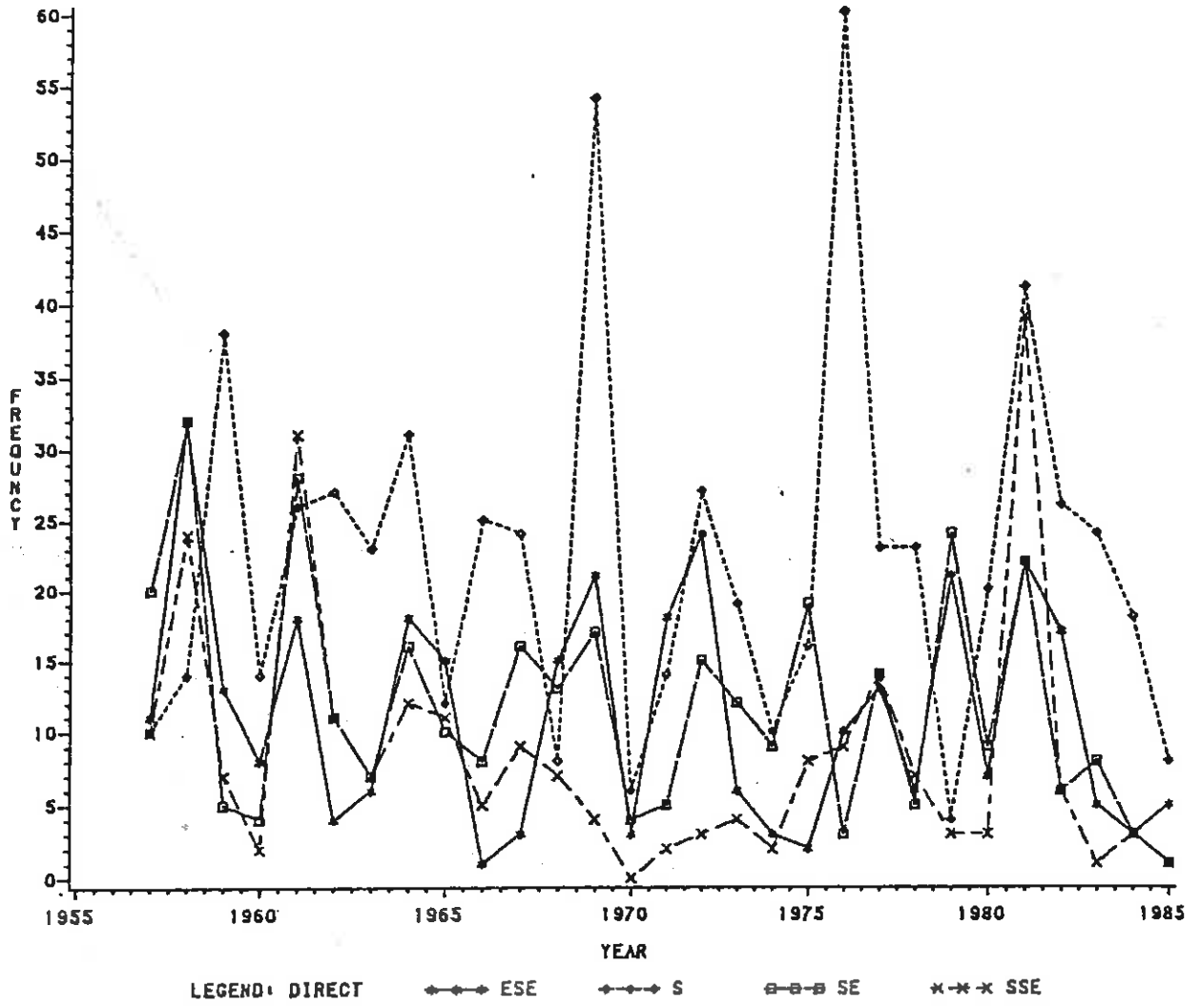
KISRX 20768

Fig. 6c. Frequency distribution of wind directions in the northeast sector during August (1957 - 1985).

Table 10. Correlation Coefficients of NE Sector With Other Wind Directions, 1957-1985

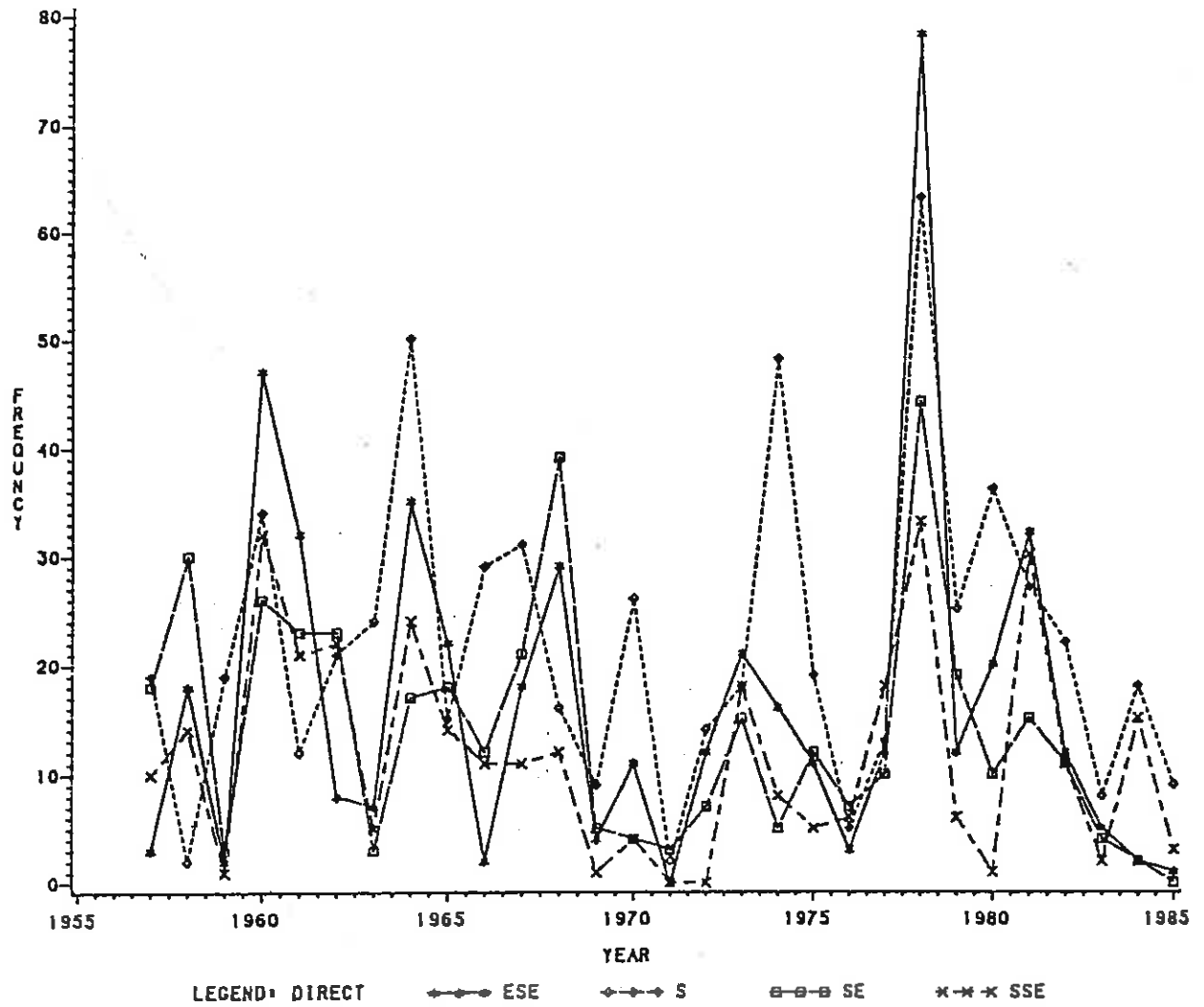
Direction	June					July					August				
	NNE	NE	ENE	E	S.D.	NNE	NE	ENE	E	S.D.	NNE	NE	ENE	E	S.D.
NNE	1				12.1	1				8.8	1				8.8
NE	0.49	1			13.4	-				8.9	0.40	1			9.0
ENE	0.30	0.17	1		10.5	0.23	0.24	1		8.2	0.41	0.15	1		10.3
E	0.47	0.23	0.38	1	19.0	-	-	0.54	1	22.2	0.45	0.21	0.65	1	27.0
ESE	0.60	0.33	0.33	0.38	11.4	-	0.22	0.54	0.49	16.4	-	-	0.38	0.51	14.8
SE	-	0.31	0.32	0.53	11.9	-	0.55	0.57	0.55	14.0	0.50	0.52	0.33	0.61	19.0
SSW	-	-	0.33	0.27	8.4	-	-	0.65	0.57	11.6	0.37	-	0.60	0.83	13.6
S	-	-	-	-	22.2	-	-	0.48	0.65	21.9	0.32	-	0.63	0.91	28.6
N	0.79	0.65	0.19	0.49	69.7	0.65	-	-	-	39.8	0.69	0.31	-	0.24	42.5
NNW	-	-0.39	-	-	119.8	0.29	-0.24	-0.33	-0.43	98.8	-	0.23	-	-0.27	90.4
NW	-0.37	-	-0.20	-0.56	24.7	-0.39	-	-0.28	-0.34	236.5	-0.58	-	-0.37	-0.53	194.4
WNW	-0.38	-0.32	-0.15	-0.24	73.7	-0.34	-0.29	-	-	101.3	-0.46	-0.46	-0.33	-0.51	96.9
SSW	-	-	-	-	9.7	-	0.60	0.35	0.37	9.1	0.26	-	0.28	0.47	15.4
SW	-	-	-	-	10.0	-	0.79	-	-	10.8	0.24	0.64	-	-	12.0
WSW	-	-0.28	-	-	8.2	-	-	-	-	12.0	-	0.22	-	-	10.9
W	-0.32	-0.29	-	-	35.0	-0.26	-0.26	-	-	58.6	-0.4	-0.43	-0.37	-0.38	62.1
															49.0

Note: Coefficients below ± 0.12 were not included (no correlation)



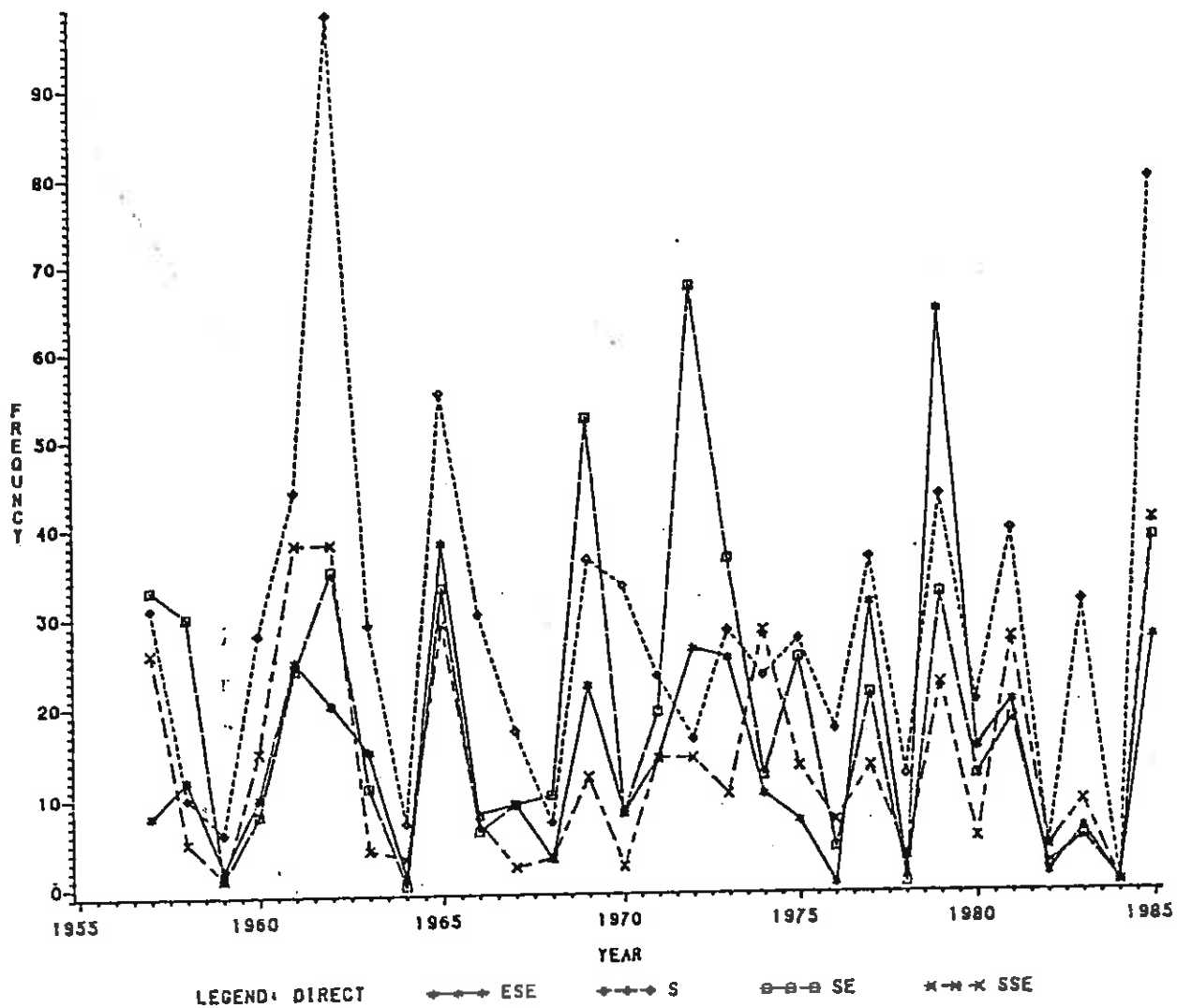
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Fig. 7a. Frequency distribution of wind directions in the southeast sector during June (1957 - 1985).



KISRX 20770

Fig. 7b. Frequency distribution of wind direction in the southeast sector during July (1957 - 1985).



KISRX 20771

Fig. 7c. Frequency distribution of wind directions in the southeast sector during August (1957 - 1985).

Table 11. Correlation Coefficients of Wind Directions in the SE Sector (1957 - 1985)

Direction	June				July				August			
	ESE	SE	SSE	S	ESE	SE	SSE	S	ESE	SE	SSE	S
ESE	1				1				1			
SE	0.6	1			0.76	1			0.63	1		
SSE	0.48	0.66	1		0.76	0.66	1		0.54	0.52	1	
S	0.18		0.28	1	0.65	0.34	0.47	1	0.55	0.47	0.81	1
SSW	-	-	0.28	0.18	0.42	0.43	0.21	0.38	0.37	0.32	0.22	0.55
SW	-	-	-	0.15	-	0.35	-	-	-	0.37	-	0.24
WSW	-	-	-	0.39	-	-	-	-	0.21	-0.27	-	-
W	-0.59	-	-	-	-	-	-	-	-0.39	-0.39	-0.42	-0.30
N	0.40	0.26	-	-	0.29	-	-0.28	-	-	0.48	0.24	-
NNW	-	-0.26	-	-0.18	-0.33	-0.43	-0.33	-0.28	-	-0.18	-0.55	-0.39
NW	-0.45	-0.34	-0.43	-0.18	-0.28	-0.34	-	-0.22	-0.26	-0.42	-0.60	-0.39
WNW	-0.39	-0.23	-	-0.27	-	-	-	-	-0.22	-0.40	-0.48	-0.42
NNE	0.60	0.29	-	-	-	-	-	-	-	0.50	0.37	0.32
NE	0.33	0.31	-	-	0.22	0.55	-	-	-	0.52	-	-
ENE	0.33	0.32	0.33	0.12	0.54	0.57	0.65	0.48	0.38	0.33	0.60	0.63
E	0.38	0.53	0.27	0.22	0.55	0.57	0.65	0.37	0.51	0.61	0.83	0.91

Note: Coefficients below #0.12 were not included (no correlation)

cient was 0.61 between ESE and SE and 0.66 between SE and SSE in June. In July the coefficients between ESE and SE increased to 0.76. These coefficients indicate that the wind directions in this sector are more highly related than in other sectors, and the variations between their monthly frequency means are less pronounced.

Finally, in order to summarize the monthly frequency means for each wind direction during the three months. Table 12 was used to test whether there were significant differences among monthly frequency means. The table showed that the N, W, and SSW winds have the highest fluctuation. The F-values were 4.19, 3.78, and 4.09, and were significant at 0.05 probability level.

Wind Speed

The monthly frequencies of the five wind speed categories (as defined in Table 5) are presented in Tables 13a to 13c. Table 13a shows monthly frequency of wind speed categories for June. It shows that the most frequent category in June was the moderate category (8-18 mph), and the least frequent was moderate gale (\geq 32 mph). It also shows that the highest mean wind speed was in 1970 (\bar{X} = 18.40 mph and SD = 7.43), and the lowest in 1965 (\bar{X} = 5.74 mph and SD = 4.6).

On the other hand, the calm category was the highest frequency in 1965 and the lowest in 1970, but this category was not included in the analysis since calm by definition means no wind speed or direction thus the dust mobility tends to rigidity. The daily average wind speeds for these two years are presented in Figs. 8a to 8b, which show that more variation occurred in 1965 than in 1970. The coefficient of variation for 1965, ranged between 75% in August and 82% in July, and in 1970 it ranged between 41% in June and 56% in August.

Tables 13b and 13c show the similar results for July and August. The moderate category had the highest frequency and the gale category had the lowest.

Figs. 9a to 9c show that the frequency of the moderate wind speed category (8-18 mph) tended to decrease approximately every four to five years (1957, 1961, 1965, 1969, 1974, 1978 and 1981).

Table 12. Summary results of wind direction for the three months, 1957 - 1985

Wind Direction	June			July			August			F-value
	\bar{x}	SD	Max. Frequency	\bar{x}	SD	Max. Frequency	\bar{x}	SD	Max. Frequency	
N	69.7	56.0	208.0	39.8	36.7	173.0	42.5	34.5	152.0	4.19
NNW	119.8	61.7	283.0	99.0	88.8	306.0	92.3	70.6	305.0	1.08
NW	221.7	89.8	407.0	236.5	108.5	491.0	194.4	99.2	457.0	1.34
WNW	73.7	47.7	175.0	101.3	64.1	301.0	96.9	67.4	260.0	1.75
W	35.0	19.6	87.0	58.6	46.99	249.0	62.1	48.9	243.0	3.78
WSW	8.2	6.6	27.0	12.03	7.97	40.0	10.9	8.6	34.0	1.82
SW	10.0	7.7	31.0	10.8	11.0	62.0	12.0	10.4	46.0	1.82
SSW	9.7	7.8	31.0	9.1	7.9	33.0	15.4	11.6	45.0	4.09
S	22.2	13.2	60.0	21.9	14.2	63.0	28.6	21.4	98.0	1.49
SSE	8.5	8.0	39.0	11.73	9.7	33.0	13.6	12.1	40.0	1.81
SE	11.9	7.9	32.0	14.0	11.0	44.0	19.0	16.8	67.0	2.46
ESE	11.4	8.0	32.0	16.4	16.7	78.0	14.7	14.0	64.0	1.04
E	18.9	10.6	43.0	22.2	15.8	57.0	27.1	23.3	98.0	1.61
ENE	10.5	7.9	36.0	8.2	6.0	25.0	10.2	8.6	30.0	0.79
NE	13.4	11.2	47.0	8.9	9.3	52.0	9.0	8.6	38.0	2.0
NNE	13.2	12.1	59.0	8.8	8.0	32.0	9.6	8.8	39.0	1.68

Table 13A. Wind Speed Frequency for June

Year	Wind Speed Category					Avg.	SD	C.V.	Max.
	Calm	1-7	8-18	19-31	≥ 32				
1957	59	242	271	72	0	9.57	6.94	0.73	30
1958	89	179	304	123	2	10.98	8.15	0.74	33
1959	33	240	326	98	5	11.09	7.24	0.61	34
1960	71	194	334	112	0	10.38	6.99	0.67	28
1961	80	306	258	76	0	8.32	6.59	0.79	28
1962	18	143	417	109	0	12.17	5.96	0.50	28
1963	17	154	392	149	0	12.84	6.34	0.49	27
1964	12	171	410	124	3	12.07	6.46	0.54	35
1965	143	319	258	0	0	5.74	4.62	0.80	17
1966	59	182	338	135	0	11.62	7.31	0.63	27
1967	33	162	419	105	0	11.83	6.51	5.50	28
1968	16	162	434	107	0	12.41	6.19	0.50	27
1969	76	190	317	136	0	11.16	7.43	0.67	30
1970	12	91	334	248	8	18.40	7.47	0.41	38
1971	44	142	348	173	1	15.12	7.97	0.52	39
1972	47	192	391	89	0	11.00	6.64	0.60	29
1973	42	67	324	258	27	16.13	8.51	0.52	40
1974	168	149	257	137	9	10.58	9.26	0.88	34
1975	31	111	330	237	11	15.33	8.30	0.54	38
1976	46	137	386	151	0	12.69	7.09	0.56	31
1977	67	148	357	145	3	12.20	7.83	0.64	34
1978	82	153	341	144	0	11.60	7.59	0.65	30
1979	22	124	416	152	6	13.77	6.90	0.50	33
1980	16	153	362	153	26	14.36	7.64	0.53	36
1981	66	217	358	74	0	9.75	6.26	0.64	30
1982	23	150	389	158	0	12.88	6.36	0.49	27
1983	21	118	435	146	0	13.10	6.04	0.46	26
1984	16	128	440	129	0	14.66	5.57	0.38	30
1985	44	161	464	42	0	12.51	5.38	0.43	27

Table 13B. Wind Speed Frequency for July

Year	Wind Speed Category					Avg.	SD	C.V.	Max.
	Calm	1-7	8-18	19-31	≥ 32				
1957	45	286	336	57	9	9.74	6.61	0.68	36
1958	127	232	262	109	14	9.90	8.52	0.86	35
1959	12	174	356	181	1	13.43	7.58	0.56	33
1960	71	281	336	56	0	8.42	6.33	0.75	27
1961	96	255	321	72	0	8.71	6.56	0.75	25
1962	27	142	412	73	2	11.34	6.07	0.54	32
1963	30	174	409	126	0	11.97	6.97	0.58	28
1964	33	153	432	97	0	11.82	6.28	0.53	30
1965	111	380	252	1	0	5.63	4.59	0.82	20
1966	134	188	373	38	0	8.64	6.28	0.73	26
1967	15	187	440	102	0	11.28	5.92	0.52	26
1968	32	234	389	88	0	10.72	6.14	0.57	30
1969	54	158	325	207	0	13.65	8.19	0.60	31
1970	13	161	383	187	0	15.78	7.18	0.46	31
1971	33	197	355	159	0	13.60	7.58	0.56	29
1972	40	161	353	183	3	12.98	7.55	0.58	33
1973	51	142	337	203	11	13.70	8.36	0.61	34
1974	120	207	333	84	0	9.12	7.21	0.79	30
1975	46	176	344	169	9	12.74	7.87	0.62	33
1976	47	114	375	208	0	13.70	7.52	0.55	30
1977	64	137	333	208	2	13.36	8.15	0.61	32
1978	53	240	374	76	1	9.87	6.42	0.65	32
1979	43	213	292	190	5	13.07	8.34	0.64	33
1980	49	212	310	171	2	12.56	7.58	0.60	36
1981	82	257	301	104	0	9.62	7.20	0.75	26
1982	38	206	401	99	0	10.90	6.21	0.57	27
1983	20	149	496	79	0	11.90	5.45	0.46	25
1984	41	300	378	21	1	10.18	5.05	0.50	38
1985	46	167	392	138	1	14.66	6.49	0.44	37

Table 13C. Wind Speed Frequency for August

Year	Wind Speed Category					Avg.	SD	C.V.	Max.
	Calm	1-7	8-18	19-31	≥ 32				
1957	71	382	244	37	3	7.30	5.64	0.77	36
1958	288	289	151	16	0	4.25	5.23	1.23	28
1959	46	165	368	139	4	12.20	7.43	0.61	33
1960	37	358	277	72	0	8.29	6.71	0.81	26
1961	112	350	239	35	0	6.79	5.72	0.84	22
1962	65	238	356	39	0	9.19	5.70	0.62	25
1963	37	276	342	52	0	9.85	5.80	0.59	30
1964	40	174	469	53	0	11.27	5.46	0.48	25
1965	201	278	265	0	0	5.75	4.33	0.75	18
1966	74	278	347	33	0	8.53	5.69	0.67	25
1967	12	201	467	64	0	10.83	5.28	0.49	24
1968	16	124	395	185	2	13.99	6.95	0.50	32
1969	53	215	369	100	0	10.35	6.93	0.67	31
1970	39	213	348	135	5	13.34	7.53	0.56	38
1971	41	217	321	129	5	12.44	7.57	0.61	38
1972	63	185	451	43	0	9.95	5.82	0.58	24
1973	104	273	315	45	0	7.87	6.01	0.76	26
1974	87	164	366	127	0	11.04	7.59	0.69	31
1975	45	170	347	167	15	12.99	8.17	0.63	36
1976	89	196	365	94	0	10.26	6.97	0.68	29
1977	88	254	346	56	0	8.57	6.21	0.72	25
1978	19	193	395	137	0	12.37	6.65	0.54	28
1979	29	246	392	77	0	10.74	6.01	0.56	30
1980	72	147	388	135	0	11.63	7.28	0.63	31
1981	109	258	301	76	0	8.65	6.83	0.79	26
1982	40	106	440	158	0	13.22	6.22	0.47	27
1983	27	193	408	110	0	11.75	6.54	0.56	28
1984	33	172	473	62	0	12.85	5.40	0.42	26
1985	123	388	231	1	0	7.02	4.20	0.60	23

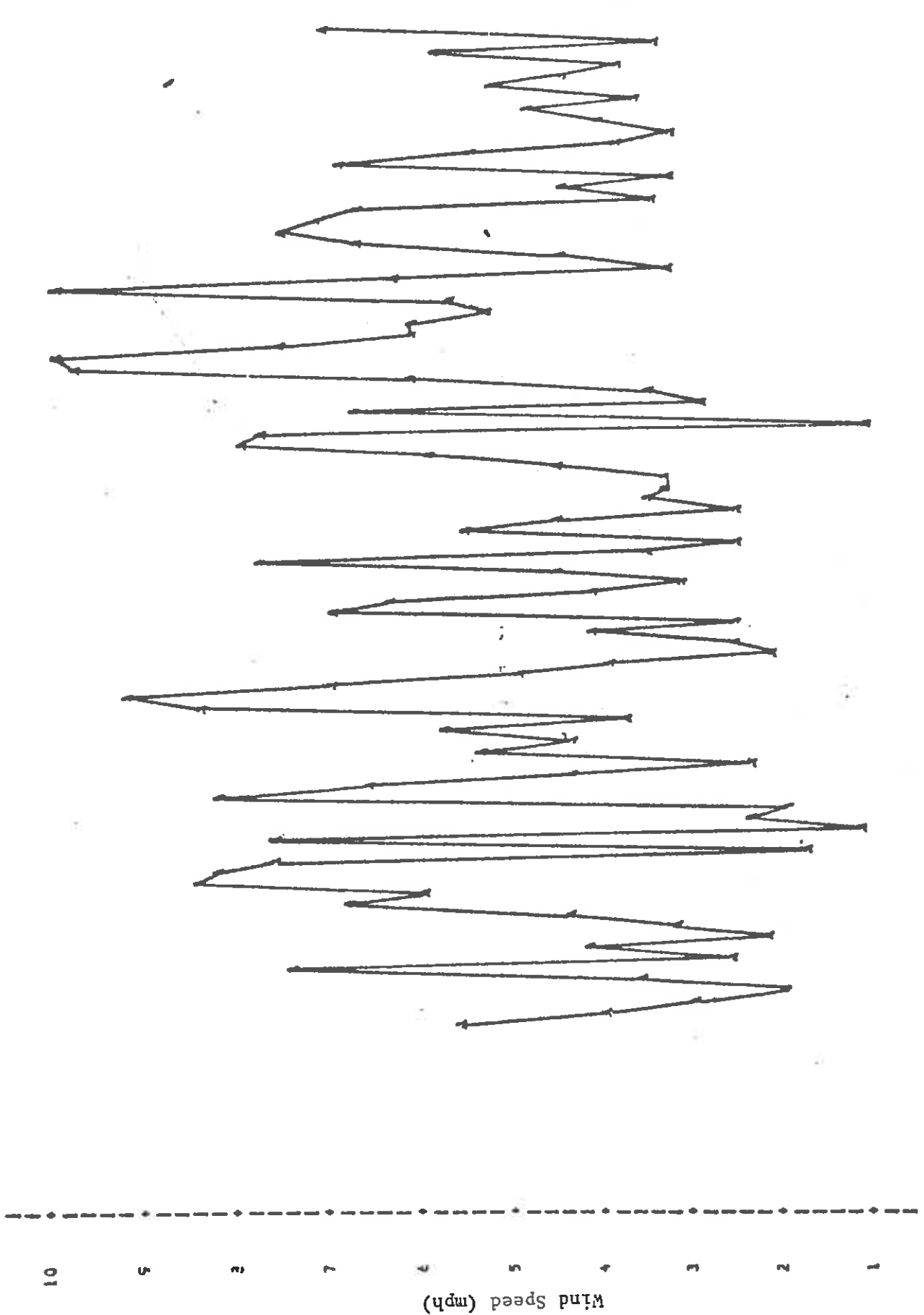
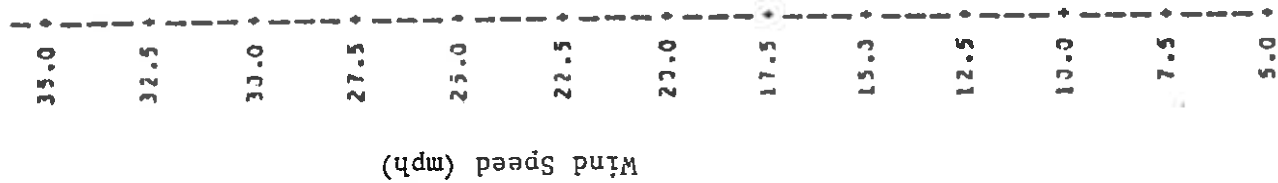


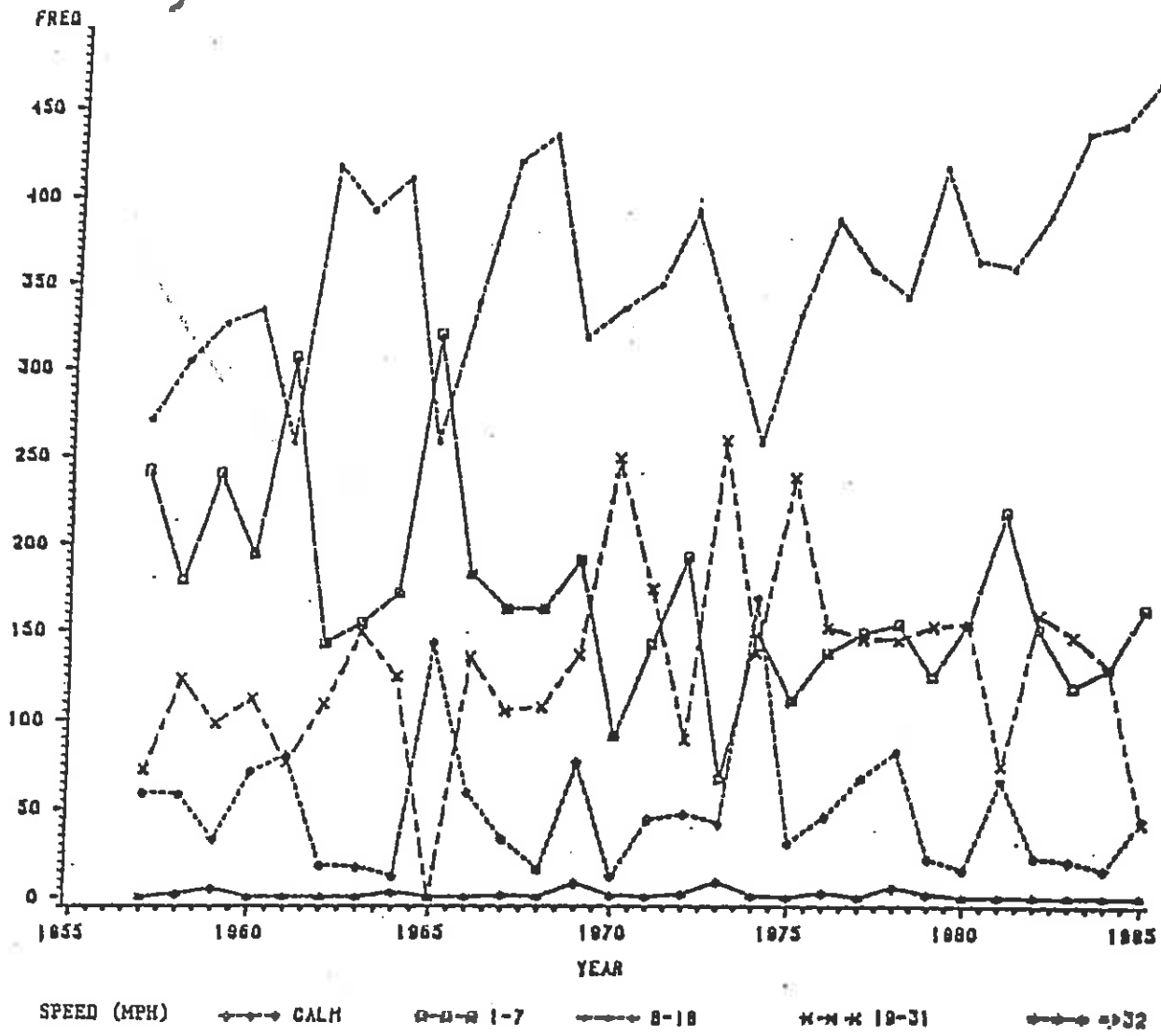
Fig. 8a. Daily average wind speed for June, July, and August of 1965.

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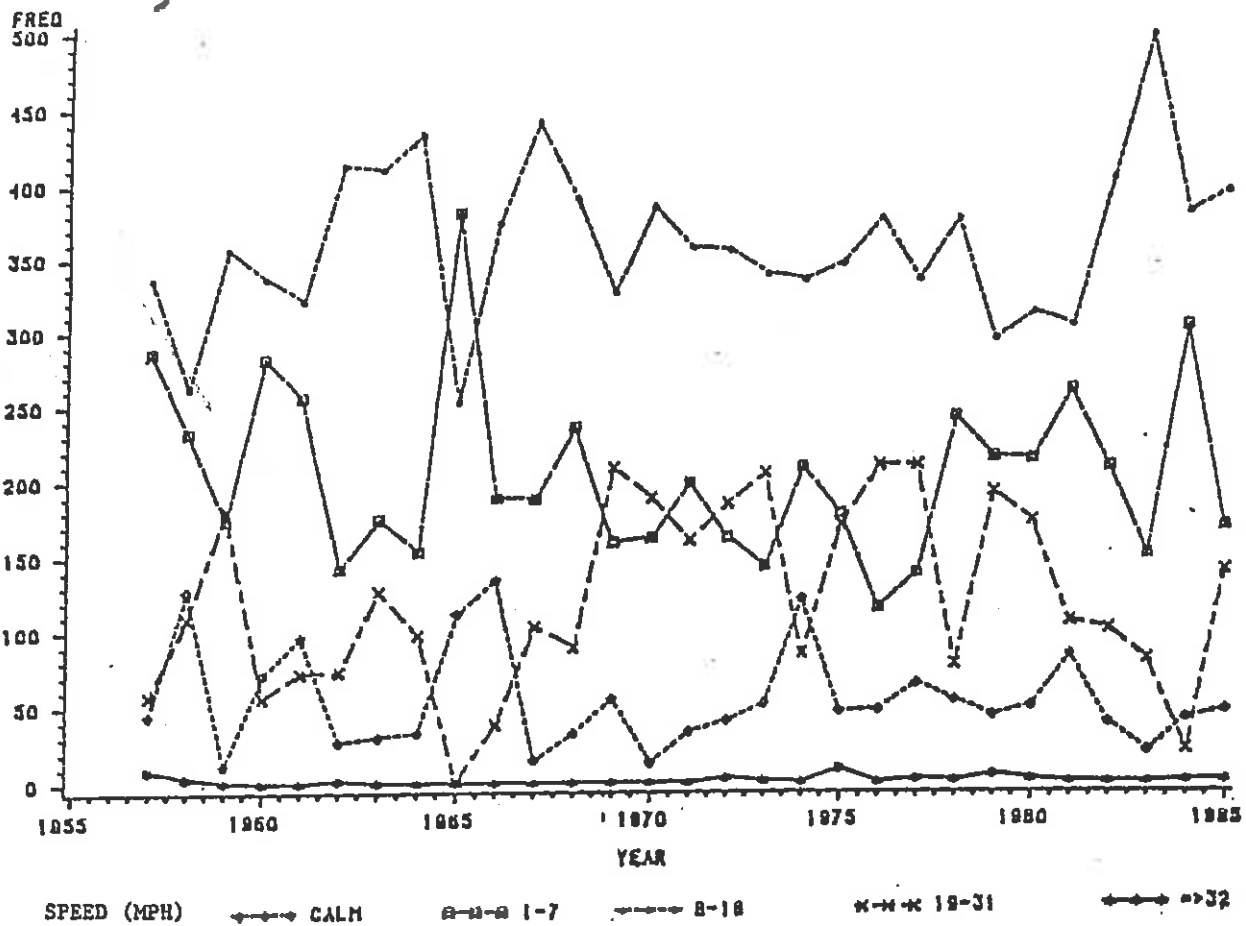
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Fig. 8b. Daily average wind speed for June, July, and August of 1970.



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Fig. 9a. Frequency distribution of wind speed during June (1957 - 1985).



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Fig. 9b. Frequency distribution of wind speed during July (1957 - 1985).

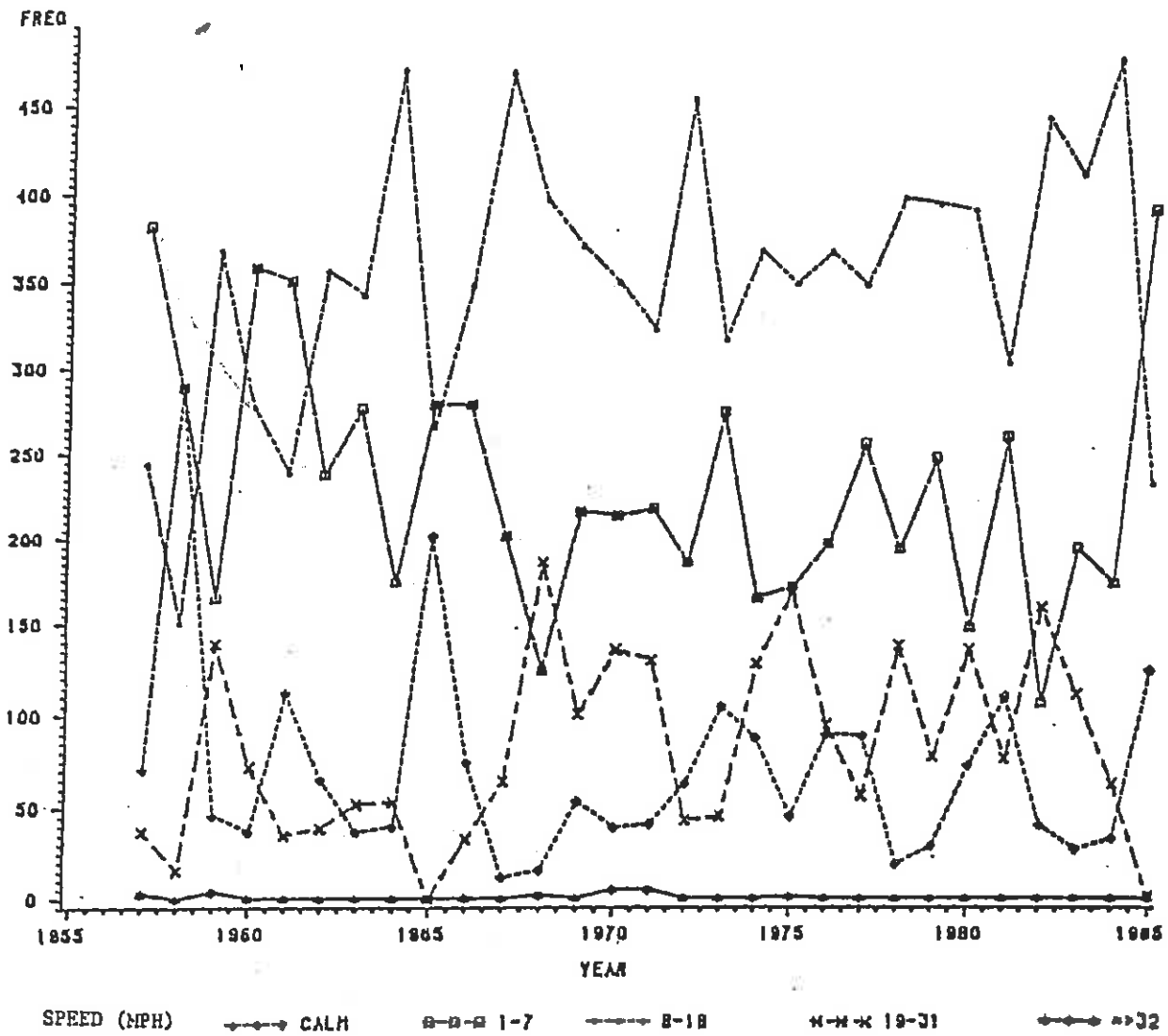


Fig. 9c. Frequency distribution of wind speed during August (1957 - 1985).

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Wind Direction and Wind Speed

It can be concluded from the previous sections on wind direction and wind speed that there was no clear linear trend in the behavior of wind. However, the most frequent feature during June, July and August is NW and NNW winds with moderate wind speeds.

In June, the wind direction changed to N and NNW and the monthly mean wind speed increased to 15 mph; in July NW became the prevailing direction and the wind speed ranged between 8 to 15 mph; and in August the wind direction usually turned to NW and WNW with a decrease in wind speed (7 to 13 mph).

It can also be concluded that the NNW and NW winds were prevailing during the last 29 years, with some variations such as the S wind prevailing during 1962 and 1969, and the E during 1962 and 1965.

To study the effect of wind speed on wind direction for the last 29 years, wind roses were constructed for every five-year periods, such as 1957-1961, 1962-1966, 1967-1971, 1972-1976, 1977-1981, and for one four-year period, 1982-1985. The five-year interval was selected because of the similarity of wind directions and wind speeds. For example, the interval of 1957 to 1961 has similar yearly wind speed means and the prevailing directions were N and WNW. The interval of 1962 to 1966 has a greater monthly wind speed mean frequency and the prevailing wind directions were NW and WNW. Similar findings were used to group the years (Table 14).

A wind rose is a polar plot of the frequency of wind flow as a function of direction (Graedel, 1977).

For example, Tables 15 to 20 show the frequency percentage of wind speed and direction for each five year period. Figs. 10a to 15c show the wind roses of the data for the same period. The tables show that during the three months, the highest frequency of wind speed was within the moderate range (8-18 mph) except for 1965, and the gale category (wind speed \geq 32 mph) had the lowest frequency. The tables also show that the light wind speed category (1-7 mph) had the second highest frequency percentage in August except for the first five years (1957-1961), when it had the highest frequency. During June and July the light and

Table 14. Prevailing Wind Directions and Monthly Mean Wind Speed for the Three Months (1957-1985)

Year	June				July				August			
	Direction		Mean	Speed	Direction		Mean	Speed	Direction		Mean	Speed
	1st	2nd	\bar{X}	SD	1st	2nd	\bar{X}	SD	1st	2nd	\bar{X}	SD
1957	N	NNW	9.57	6.94	N	NNW	9.74	6.61	N	NNW	7.30	5.64
1958	N	NNW	10.98	8.15	NNW	N	9.90	8.52	NNW	N	4.25	5.23
1959	N	NNW	11.09	7.24	NNW	WNW	13.43	7.58	NNW	NW	12.20	7.43
1960	NNW	NW	10.38	6.99	NW	WNW	8.42	6.33	NNW	NW	8.29	6.71
1961	NW	NNW	8.32	6.59	NW	WNW	8.71	6.56	NW	NNW	6.79	5.72
1962	NW	WNW	12.17	5.96	WNW	NN	11.34	6.07	S	E	9.19	5.70
1963	NW	NNW	12.84	6.34	NW	WNW	11.97	6.97	NW	WNW	9.85	5.80
1964	NW	NNW	12.07	6.46	WNW	NW	11.82	6.28	WNW	NW	11.27	5.46
1965	NW	NNW	5.74	4.62	NW	WNW	5.63	4.59	NW	NNW	5.75	4.33
1966	NW	WNW	11.62	7.31	NW	WNW	8.64	6.28	N	NW	8.53	5.69
1967	NW	WNW	11.83	6.51	WNW	NW	11.28	5.92	NW	W	10.83	5.28
1968	NW	WNW	12.41	6.19	NW	SW	10.72	6.14	NW	WNW	13.99	6.95
1969	NW	S	11.16	7.43	NW	WNW	13.65	8.19	NW	WNW	10.35	6.93
1970	NW	NNW	18.40	7.47	NW	NNW	15.78	7.18	NW	NNW	13.34	7.53
1971	NW	NNW	15.12	7.97	NW	WNW	13.60	7.58	NW	NW	12.44	7.57
1972	N	NW	11.00	6.64	NNW	NW	12.98	7.55	N	NW	9.95	5.82
1973	NW	NNW	16.13	8.51	NW	NNW	13.70	8.36	NW	NNW	7.87	6.01
1974	NW	N	10.58	9.26	NW	WNW	9.12	7.21	NW	WNW	11.04	7.59
1975	NW	WNW	15.33	8.30	NW	WNW	12.74	7.87	NW	WNW	12.99	8.17
1976	NW	WNW	12.69	7.09	WNW	W	13.70	7.52	WNW	W	10.26	6.97
1977	NW	WNW	12.20	7.83	NW	WNW	13.36	8.15	NW	WNW	8.57	6.21
1978	NW	WNW	11.60	7.59	NW	WNW	9.87	6.42	NW	WNW	12.37	6.65
1979	NW	NNW	13.77	6.90	NW	NNW	13.07	8.34	NW	NNW	10.74	6.01
1980	NW	NNW	14.36	7.64	NW	NNW	12.56	7.58	WNW	NW	11.63	7.28
1981	NNW	NW	9.75	6.26	NW	WNW	9.62	7.20	NW	NNW	8.65	6.83
1982	NW	NNW	12.88	6.36	NW	NNW	10.90	6.21	NW	WNW	13.22	6.22
1983	NW	NNW	13.10	6.04	NW	NNW	11.90	5.45	NW	NNW	11.75	6.54
1984	NW	NNW	14.66	5.57	NNW	NW	10.18	5.05	NW	WNW	12.85	5.40
1985	NW	NNW	12.51	5.38	NW	WNW	14.66	6.49	NW	E	7.02	4.20

1st = First prevailing wind direction
 2nd = Second prevailing wind direction
 \bar{X} = Mean wind speed
 SD = Standard deviation

Table 15. Frequency Percentage of Wind Speed and Wind Direction for 1957-1961

MONTH	SPEED(KPH)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	MNW	TOTAL	
JUNE	CALM																	9.2	
	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	3.5	1.1	0.9	0.9	1.5	1.0	1.2	1.8	2.3	0.9	0.7	0.4	1.6	3.6	3.9	3.2	28.4	
	8-16	8.1	0.9	0.4	0.7	2.1	1.9	1.1	0.3	0.5	0.1	0.2	0.1	0.7	3.3	7.9	13.9	42.2	
	17-31	4.2	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.2	6.4	13.4	
	>32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	
	MISS																	5.9	
	VARIABLE																		0.7
	TOTAL	15.8	2.0	1.2	1.6	3.6	3.1	2.5	2.0	2.8	1.0	0.9	0.5	2.4	7.0	14.0	23.6	100.0	
	CALM																		5.4
JULY	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	2.0	0.7	0.8	0.5	1.0	0.9	1.5	1.5	1.7	0.6	0.4	1.1	3.3	5.1	4.7	3.5	29.3	
	8-16	5.3	1.1	0.4	0.4	1.7	1.9	1.2	0.6	0.5	0.0	0.0	0.1	1.1	4.2	12.0	12.8	43.3	
	17-31	1.7	0.1	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.2	7.2	12.8	
	>32	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	
	MISS																	4.0	
	VARIABLE																	0.6	
	TOTAL	9.2	2.0	1.2	0.9	2.7	3.1	2.7	2.1	2.2	0.7	0.5	1.2	4.4	9.5	19.8	23.9	100.0	
	CALM																		14.9
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		2.7	1.1	1.5	0.8	2.3	1.0	1.3	1.9	3.0	1.0	1.0	1.1	4.9	4.5	4.9	3.9	37.4	
8-16		5.5	0.5	0.2	0.5	1.8	0.7	0.8	0.4	0.2	0.0	0.0	0.0	0.3	2.1	8.8	12.3	34.2	
17-31		1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	4.6	8.0	
>32		0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	
MISS																		4.4	
VARIABLE																		0.9	
TOTAL		10.0	1.7	1.7	1.3	4.1	1.7	2.6	2.3	3.2	1.0	1.0	1.2	5.3	6.7	15.2	20.8	100.0	

Table 16. Frequency Percentage of Wind Speed and Wind Direction for 1962-1966

MONTH	SPEED (KPH)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	
JUNE	CALM																	6.9	
	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	1.4	0.6	1.3	0.5	0.7	0.5	0.6	0.6	1.8	1.7	1.3	1.3	2.7	4.8	3.9	2.3	25.6	
	8-16	3.8	0.9	0.5	0.9	1.5	1.5	0.9	0.7	1.5	0.9	0.3	0.6	2.5	8.3	15.9	9.7	50.8	
	17-31	0.8	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	7.7	4.3	14.4	
	>32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	
	MISS																	6.8	
	VARIABLE																		1.4
	TOTAL		6.0	1.4	1.5	1.4	2.2	2.1	1.4	1.3	3.3	2.6	1.6	1.9	5.7	14.6	27.6	16.3	100.0
	CALM																		9.0
JULY	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	1.0	0.4	0.4	0.5	0.9	0.7	0.9	1.0	2.1	1.9	1.6	1.5	4.4	4.2	3.8	0.5	26.4	
	8-16	1.8	1.2	0.6	1.2	3.9	2.2	1.1	1.0	1.6	0.2	0.2	0.6	3.3	10.3	16.4	5.3	51.0	
	17-31	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.3	4.7	1.4	9.0	
	>32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	
	MISS																	3.1	
	VARIABLE																	1.3	
	TOTAL		2.8	1.6	1.0	1.8	5.0	3.0	2.0	2.0	3.7	2.2	1.9	2.1	8.1	16.8	24.9	7.6	100.0
	CALM																		11.2
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		1.2	0.8	0.4	0.8	1.2	0.8	0.9	1.3	3.2	2.8	2.0	2.3	5.0	5.3	2.7	1.8	32.5	
8-16		1.4	0.7	0.4	1.2	4.1	3.0	1.4	0.9	2.7	0.8	0.2	0.2	2.2	9.5	13.4	6.2	48.3	
17-31		0.1	0.0	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.5	1.4	5.2	
>32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MISS																		1.3	
VARIABLE																		1.5	
TOTAL			2.6	1.5	0.8	2.0	5.8	4.5	2.3	2.2	5.9	3.8	2.2	2.4	7.2	15.7	17.6	9.4	100.0

Table 17. Frequency Percentage of Wind Speed and Wind Direction for 1967-1971

MONTH	SPEED(MPH)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	
JUNE	CALM																	5.1	
	CALM	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.3	0.3	0.5	0.2	0.6	0.2	0.7	0.4	2.5	1.1	2.4	0.6	3.1	2.4	3.4	0.4	19.1	
	8-18	2.3	0.8	1.7	0.5	1.5	1.4	0.8	0.3	0.5	0.1	0.3	0.1	2.0	6.4	25.5	4.5	48.5	
	19-31	2.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.0	13.1	6.7	23.4	
	>=32	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	1.9	
	MISS																	1.2	
	VARIABLE																		0.9
	TOTAL	4.8	1.2	2.2	0.7	2.1	1.6	1.6	0.7	3.0	1.2	2.8	0.7	5.2	9.8	42.4	12.9	100.0	
	CALM																		4.0
JULY	CALM	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.6	0.2	0.9	0.2	0.5	0.2	0.8	0.4	1.6	1.4	2.8	1.0	4.2	3.7	4.4	0.3	23.3	
	8-18	2.3	0.4	1.3	0.4	1.7	1.3	1.1	0.4	0.6	0.3	0.5	0.4	4.1	7.3	22.3	3.0	47.5	
	19-31	1.5	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	13.5	6.7	24.1	
	>=32	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.6	
	MISS																		0.0
	VARIABLE																		0.5
	TOTAL	4.4	0.6	2.2	0.7	2.2	1.6	1.9	0.8	2.3	1.7	3.3	1.4	8.4	13.0	40.4	10.6	100.0	
	CALM																		4.3
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		0.8	0.3	0.7	0.2	0.2	0.1	0.9	0.5	2.2	1.7	2.8	0.9	6.8	2.6	3.1	0.3	24.1	
8-16		2.7	0.5	1.5	0.5	1.8	1.2	1.7	0.4	1.0	0.3	0.3	0.2	5.2	8.4	20.3	3.9	49.9	
19-31		1.1	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.7	10.7	5.2	18.2	
>=32		0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	
MISS																			1.8
VARIABLE																			0.6
TOTAL		4.8	1.1	2.3	0.6	2.0	1.3	2.6	0.9	3.1	2.0	3.2	1.1	12.0	11.7	34.4	10.1	100.0	

Table 18. Frequency Percentage of Wind Speed and Wind Direction for 1972-1976

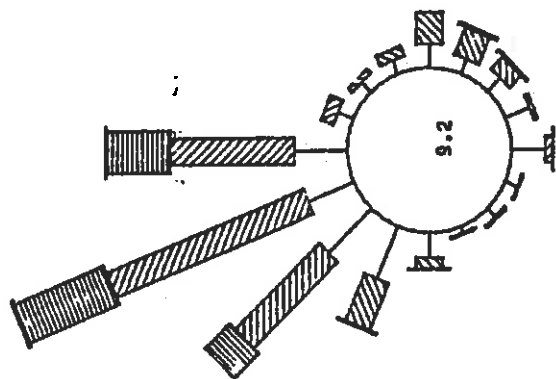
MONTH	SPEED(MPH)	N	NNE	NE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NNW	TOTAL		
JUNE	CALM															9.3		
	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	1.6	0.4	0.9	0.4	0.3	0.7	0.4	2.6	0.6	0.7	0.6	2.3	1.9	3.3	1.1	18.0	
	8-18	7.5	1.4	1.9	0.8	0.9	0.9	0.3	1.1	0.1	0.1	0.2	2.2	7.4	13.5	6.5	46.7	
	19-31	3.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	2.6	12.8	4.6	24.2	
	>=32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.3	
	MISS																0.1	
	VARIABLE																0.4	
	TOTAL	12.5	2.4	2.7	1.2	2.4	1.2	1.6	0.7	3.7	0.7	0.7	0.8	4.7	11.9	30.5	12.6	100.0
	CALM																8.2	
JULY	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.5	0.1	0.3	0.2	0.5	0.6	0.6	2.5	0.6	0.8	1.3	4.9	3.5	0.5	21.0		
	8-18	2.0	0.6	0.4	0.6	1.2	0.6	0.3	0.3	0.1	0.0	0.8	6.5	10.0	15.6	5.9	46.5	
	19-31	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	5.0	11.3	4.7	22.8	
	>=32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.6	
	MISS																0.1	
	VARIABLE																0.8	
	TOTAL	2.9	0.7	0.8	0.9	2.0	1.7	1.2	1.0	2.8	0.6	0.8	2.2	12.8	18.5	30.9	11.1	100.0
	CALM																10.4	
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		0.8	0.6	0.6	0.5	1.2	0.5	1.1	2.9	0.9	1.3	1.0	4.7	3.7	3.5	1.0	25.7	
8-18		3.6	0.9	0.6	1.0	2.3	1.2	2.4	0.7	1.9	0.6	0.3	0.9	5.6	12.4	4.8	49.2	
19-31		0.3	0.1	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.5	4.0	6.6	0.9	12.8	
>=32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.4	
MISS																	0.3	
VARIABLE																	1.2	
TOTAL		4.7	1.6	1.2	1.5	3.5	3.9	1.8	1.9	4.8	1.6	1.6	1.9	10.8	17.8	22.7	6.7	100.0

Table 19. Frequency Percentage of Wind Speed and Wind Direction for 1977-1981

MONTH	SPEED(KPH)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	MNW	TOTAL	
JUNE	CALM																	7.0	
	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	1.2	0.6	0.4	0.6	0.8	0.6	0.6	1.0	2.4	1.1	1.2	1.2	3.6	2.4	2.6	1.3	21.4	
	8-16	5.2	1.8	2.1	1.8	2.6	1.0	1.2	0.8	0.7	0.3	0.4	0.2	2.0	6.3	16.2	7.9	50.4	
	19-31	0.8	0.1	0.1	0.1	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.3	1.6	11.5	3.4	18.6	
	=>32	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	1.0	
	MISS																	0.7	
	VARIABLE																		0.9
	TOTAL	7.2	2.5	2.6	2.6	3.4	1.9	2.1	1.8	3.1	1.4	1.6	1.3	1.4	5.8	10.3	30.6	13.1	100.0
	CALM																		7.8
JULY	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.6	0.3	0.6	0.6	0.6	0.9	1.0	1.5	3.7	1.3	1.1	1.4	4.1	3.4	4.4	0.9	27.0	
	8-16	1.5	0.5	0.4	0.7	2.8	3.1	1.6	0.9	0.8	0.1	0.1	0.2	2.0	7.1	16.5	4.6	42.8	
	19-31	0.2	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	15.4	2.0	20.1	
	=>32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	
	MISS																		0.5
	VARIABLE																		1.4
	TOTAL	2.4	0.9	1.1	1.4	3.9	4.1	2.6	2.4	4.4	1.4	1.4	1.1	1.5	6.2	12.7	36.6	7.5	100.0
	CALM																		8.5
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		0.6	0.5	0.3	0.5	0.8	0.9	0.9	1.4	3.1	1.6	0.7	1.0	5.0	5.0	4.5	1.4	28.3	
8-16		1.5	0.3	0.2	0.8	1.6	2.5	1.3	0.5	1.0	0.6	0.1	0.1	1.0	6.0	21.8	9.8	48.8	
19-31		0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	7.8	4.0	12.9	
=>32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MISS																			0.1
VARIABLE																			1.3
TOTAL		2.2	0.7	0.5	1.3	2.6	3.5	2.2	1.9	4.0	2.3	0.7	1.1	5.9	11.8	34.1	15.1	100.0	

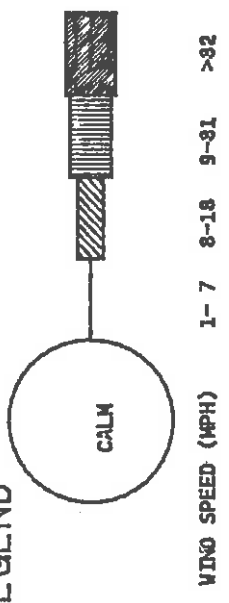
Table 20. Frequency Percentage of Wind Speed and Wind Direction for 1982-1985

MONTH	SPEED(MPH)	N	MNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL	
JUNE	CALM																	3.6	
	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.6	0.3	0.2	0.5	0.5	0.4	0.3	0.3	2.4	0.7	0.5	1.2	3.5	1.6	1.5	1.1	15.7	
	8-16	4.8	1.2	0.6	1.4	0.7	0.3	0.1	0.2	0.0	0.1	0.1	0.1	1.9	5.0	25.8	14.9	57.7	
	19-31	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	14.3	6.2	21.6	
	>=32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	MISS																	0.8	
	VARIABLE																		0.6
	TOTAL	6.2	1.5	0.8	1.1	1.9	1.1	0.6	0.4	2.6	0.7	0.7	1.3	1.3	5.4	6.9	41.6	22.1	100.0
	CALM																		4.9
JULY	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	1-7	0.8	0.6	0.3	0.9	0.3	0.4	0.3	0.9	1.8	0.5	1.0	1.1	4.9	3.3	3.5	2.2	22.8	
	8-16	2.7	0.8	0.4	0.6	0.9	0.4	0.1	0.2	0.1	0.0	0.1	0.0	2.2	6.2	25.9	14.5	55.1	
	19-31	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	10.2	3.7	15.1	
	>=32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	
	MISS																	0.2	
	VARIABLE																	1.8	
	TOTAL	3.6	1.4	0.6	0.9	1.7	0.7	0.6	1.0	1.9	0.5	1.0	1.1	1.1	7.2	10.5	39.7	20.4	100.0
	CALM																		7.5
	AUGUST	CALM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-7		0.7	0.4	0.3	0.5	1.2	0.9	0.9	1.3	3.4	1.5	0.6	0.6	6.0	2.6	2.3	0.9	24.1	
8-16		1.8	0.7	0.3	0.7	2.8	0.5	0.6	0.5	0.4	0.2	0.2	0.2	2.8	10.7	22.0	8.9	53.3	
19-31		0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	9.8	2.4	13.6	
>=32		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MISS																		0.4	
VARIABLE																		1.0	
TOTAL		2.9	1.1	0.6	1.3	3.9	1.3	1.5	1.8	3.8	1.7	0.8	0.9	0.9	8.9	14.3	34.1	12.2	100.0



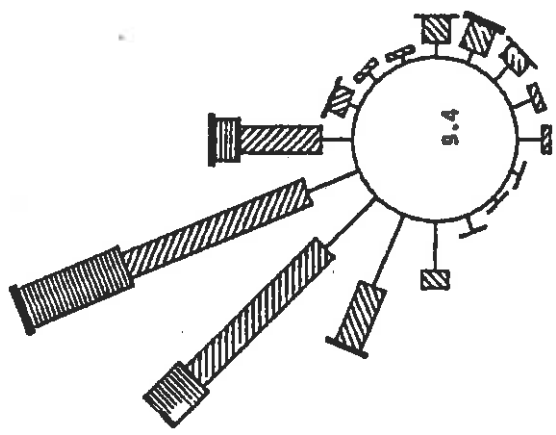
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LEGEND

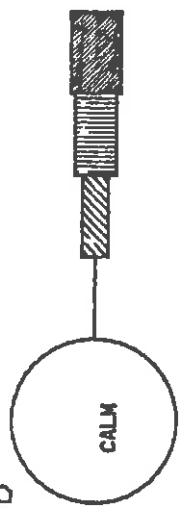


KISRX 20777

Fig. 10a. Wind rose for June (1957-1961).



LEGEND

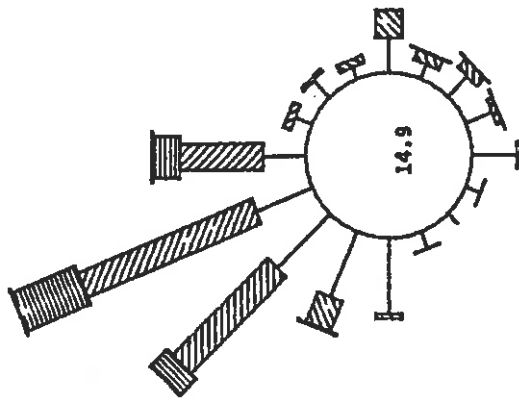


WIND SPEED (MPH) 1-7 8-16 9-31 >32

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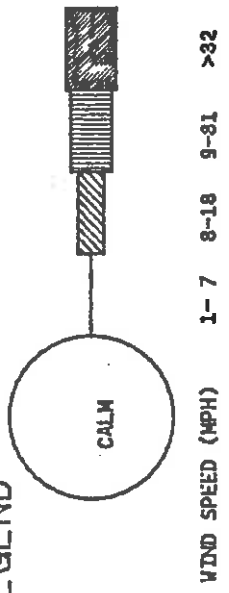
KISRX 20778

Fig. 10b. Wind rose for July (1957-1961).



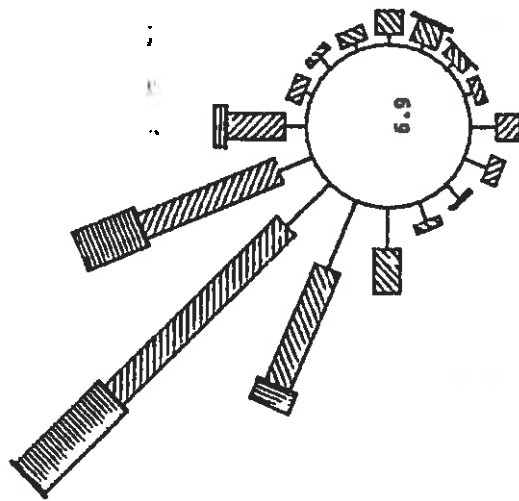
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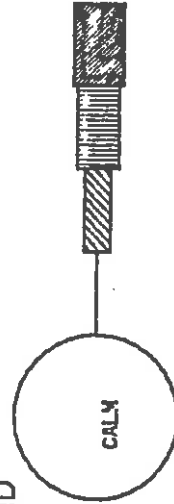


KISRX 20779

Fig. 10c. Wind rose for August (1957-1961).



LEGEND

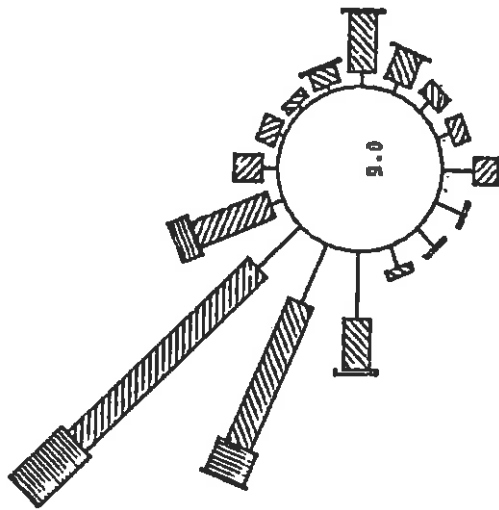


SCALE
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WIND SPEED (MPH) 1-7 8-18 9-31 >32

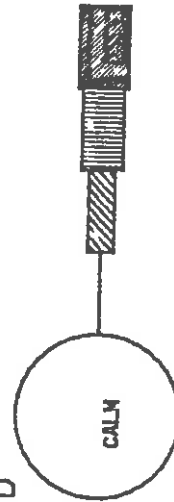
KISRX 20780

Fig. 11a. Wind rose for June (1962-1966).



SCALE
5.0%

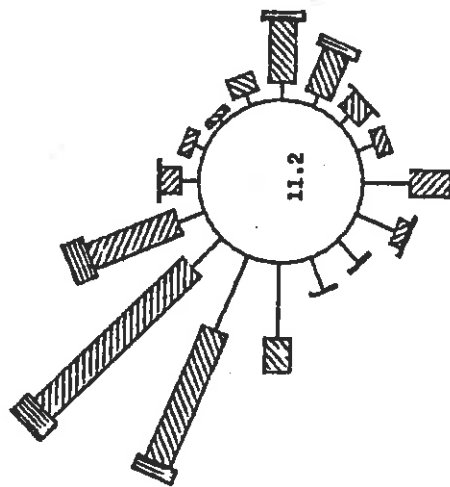
LEGEND



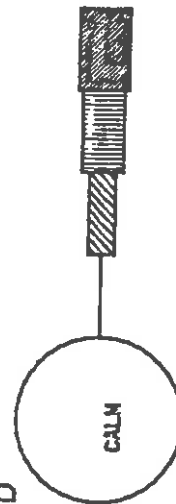
WIND SPEED (MPH) 1-7 8-10 9-31 >32

KISRX 20781

Fig. 11b. Wind rose for July (1962-1966).



LEGEND



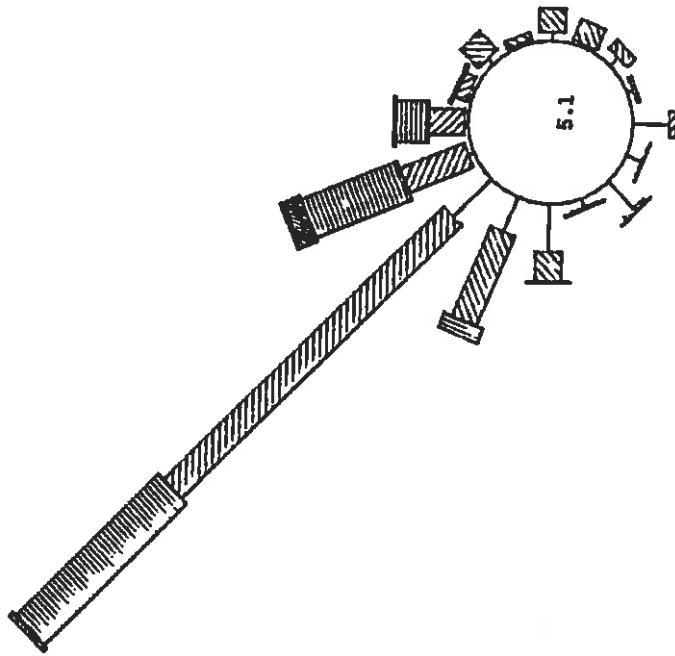
WIND SPEED (MPH) 1-7 8-16 9-31 >32

SCALE



KISRX 20782

Fig. 11c. Wind rose for August (1962-1966).



SCALE
5.0%

LEGEND

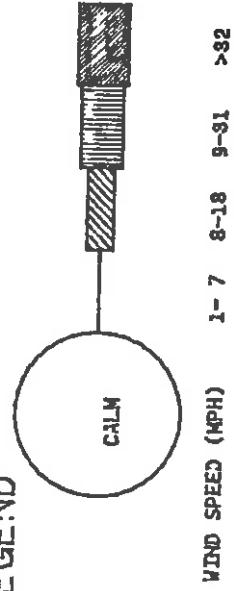
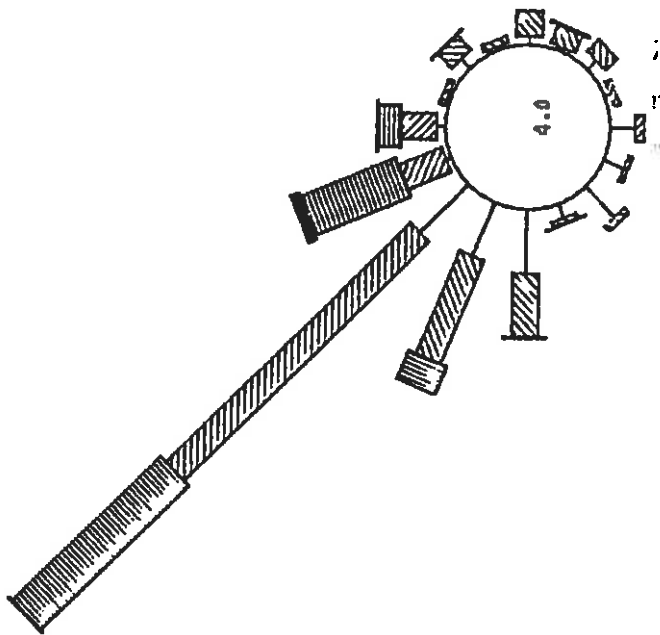
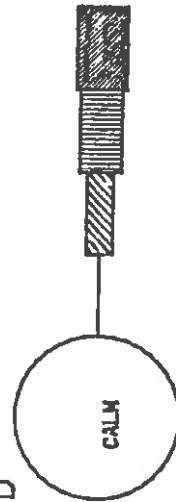


Fig. 12a. Wind rose for June (1967-1971).

KISRX 20783



LEGEND

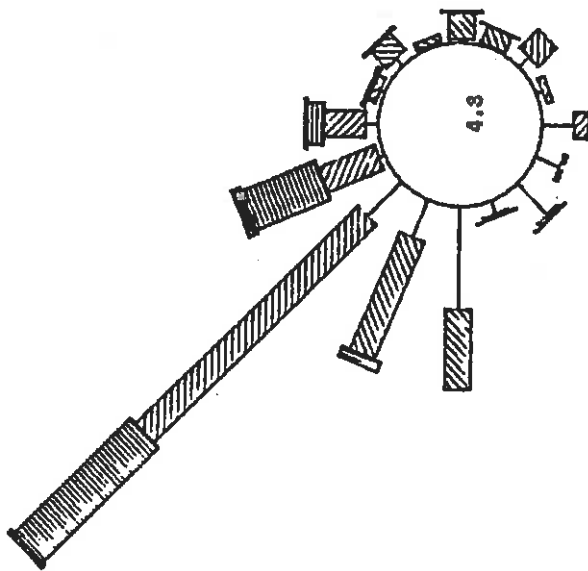


WIND SPEED (MPH) 1-7 8-18 9-31 >32

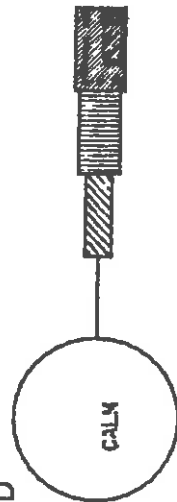
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Fig. 12b. Wind rose for July (1967-1971).

KISRX 20784



LEGEND



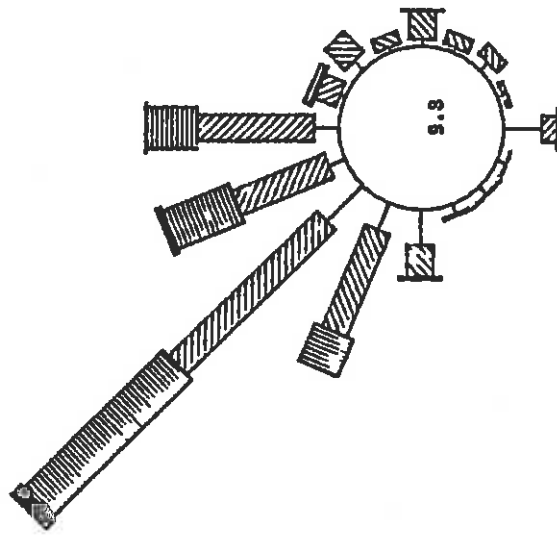
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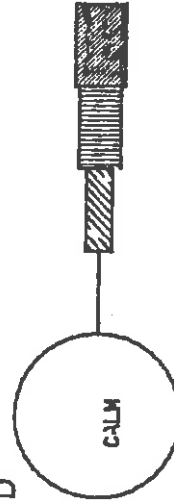


KISRX 20785

Fig. 12c. Wind rose for August (1967-1971).



LEGEND



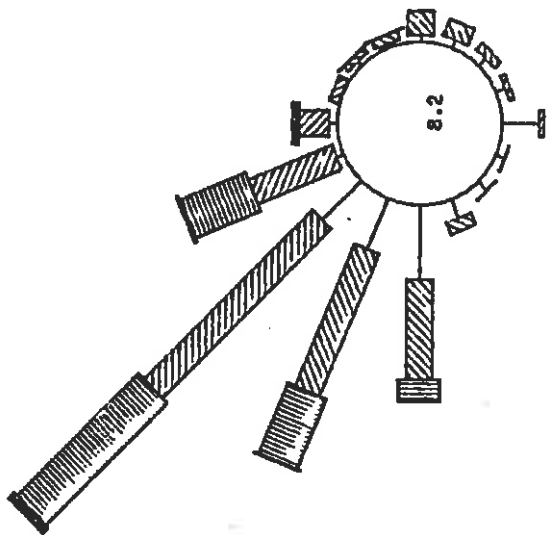
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SCALE

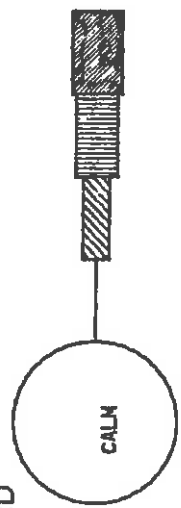


KISRX 20786

Fig. 13a. Wind rose for June (1972-1976).



LEGEND

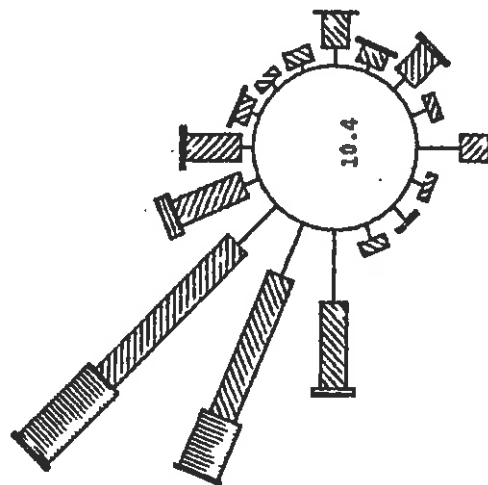


WIND SPEED (MPH) 1-7 8-18 9-31 >32

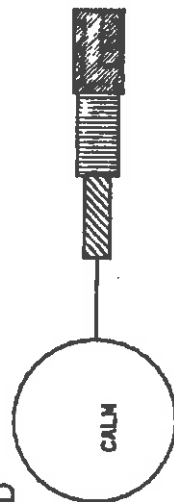
SCALE
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 5.0%

KISRX 20787

Fig. 13b. Wind rose for July (1972-1976).



LEGEND

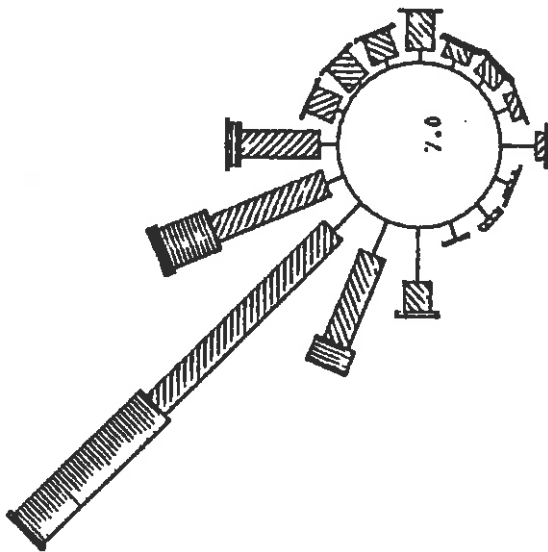


WIND SPEED (MPH) 1-7 8-18 9-31 >32

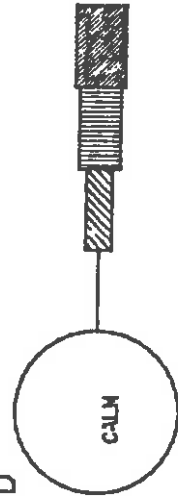
SCALE
5.0%

KISR 20788

Fig. 13c. Wind rose for August (1972-1976).



LEGEND

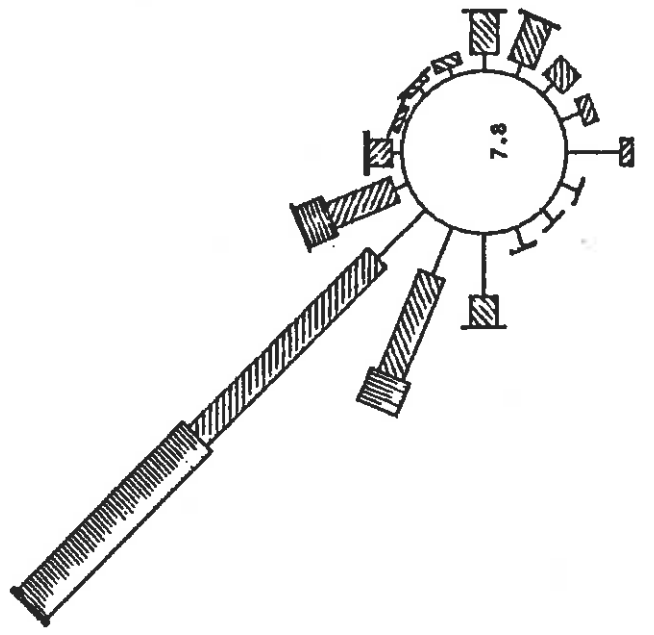


WIND SPEED (MPH) 1-7 8-18 9-31 >32

SCALE
5.0%

KISRX 20789

Fig. 14a. Wind rose for June (1977-1981).



LEGEND

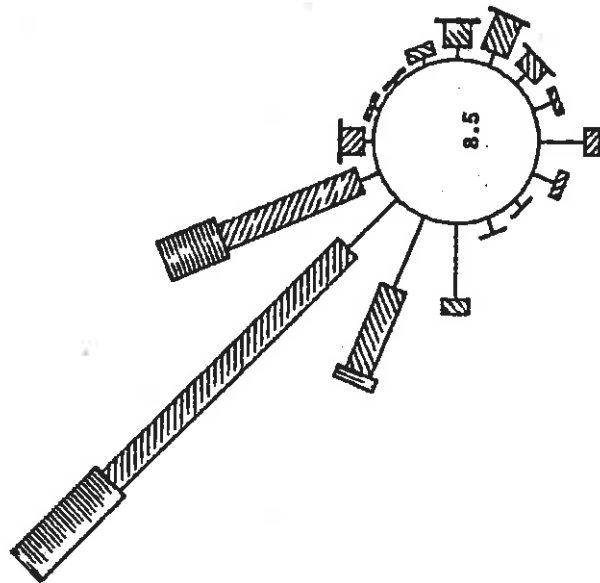


WIND SPEED (MPH) 1-7 8-18 9-31 >82

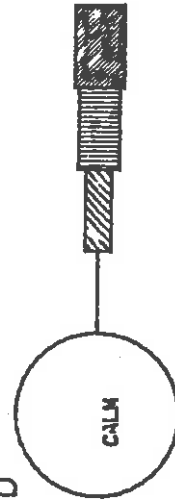
SCALE  5.0%

KISRX 20790

Fig. 14b. Wind rose for July (1977-1981).



LEGEND



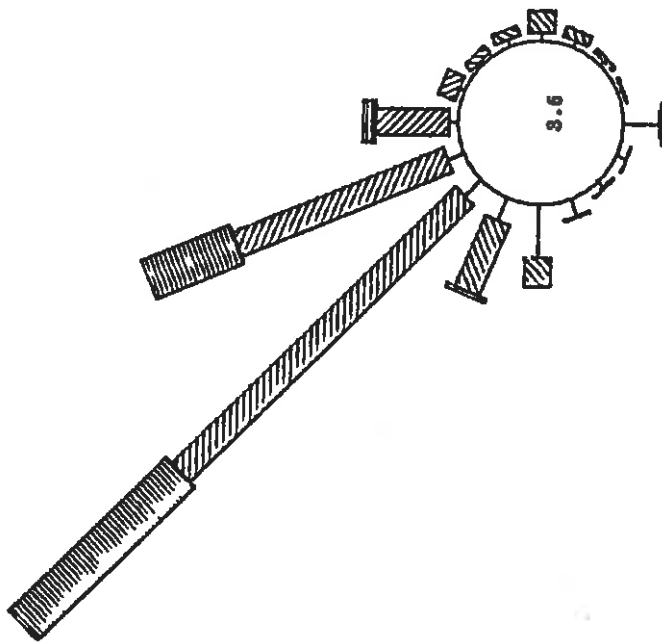
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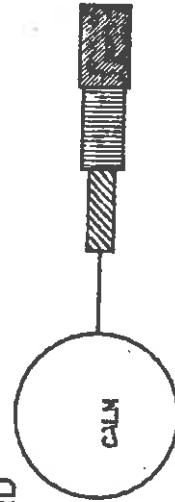
WIND SPEED (MPH) 1-7 8-18 9-81 >82

KISRX 20791

Fig. 14c. Wind rose for August (1977-1981).



LEGEND



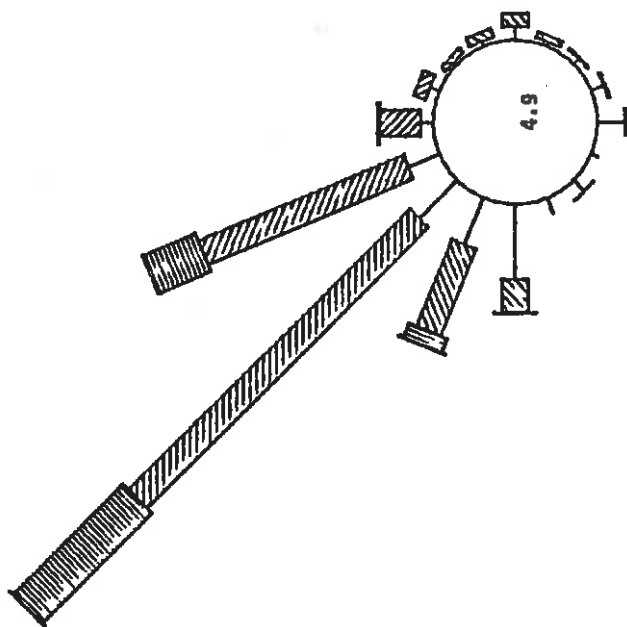
SCALE



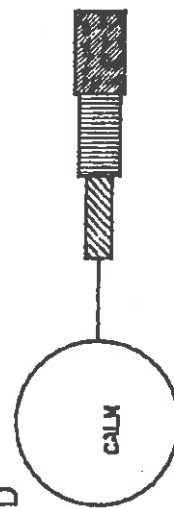
WIND SPEED (MPH) 1-7 8-18 9-31 >32

KISRX 20792

Fig. 15a. Wind rose for June (1982-1985).



LEGEND

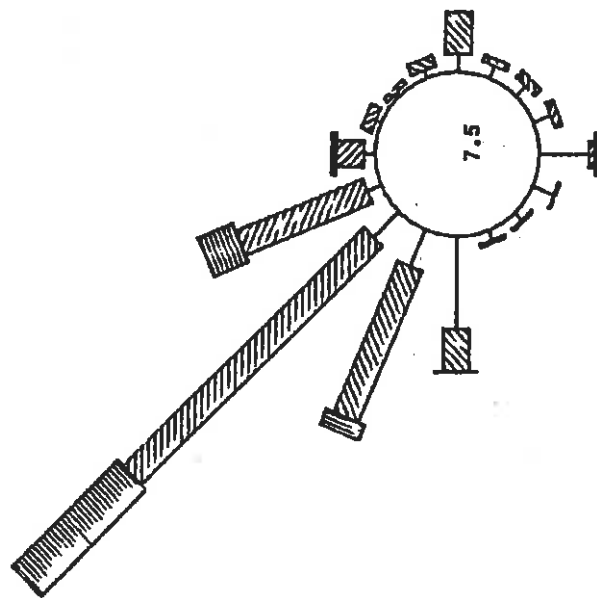


WIND SPEED (MPH) 1-7 8-18 9-31 >32

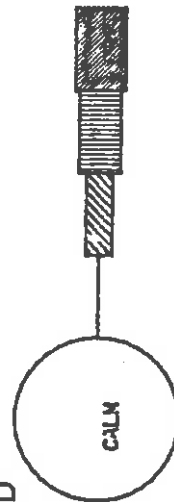
SCALE
5.0%

KISRX 20793

Fig. 15b. Wind rose for July (1982-1985).



LEGEND



WIND SPEED (MPH) 1-7 8-18 9-81 >82

SCALE
 ┌───┐
 5.0%

KISRX 20794

Fig. 15c. Wind rose for August (1982-1985).

strong wind categories had variable frequencies, but for the period 1967-1976 strong wind speeds (19-31 mph) were more frequent than light wind speeds.

Tables 21-26 present the frequency percentage of wind speed and wind direction for each month in each five-year period. The tables show that the Northwest sector (sector 4) is the dominant direction, especially for moderate wind speeds.

Figs. 16a, 16b and 16c present the overall 1957-1985 wind roses for June, July and August, respectively. These figures show that NW was the dominant wind direction for the 29 years.

Summary and Conclusion

In this study we have presented some preliminary data analyses, and some diagnostic tools for wind direction and speed. These analyses were used to describe the trends during the dust storm season, i.e., June, July and August, for 1957-1985.

There was undoubtedly much information available which the study does not exploit. In particular, the valuable information that contained in the records of wind direction, and adequately into a model was another major challenge. This is because little work appears to have been done on time series of angular observations. Therefore, most of the preliminary analysis of this study were presented on the previous sections and could be summarized as follows:

The Northwest and North Northwest winds were the prevailing winds, but there was no linear trend in the behavior of either wind direction or wind speed from 1957 to 1985. There were, however, some indications that the NW wind followed smooth trends during June from 1957 to 1968, when the correlation coefficient between the monthly mean frequency and years was 0.65. The highest mean frequency of NW winds was in June ($\bar{X} = 477.7$), with a relative variation of -0.14, and the lowest mean frequency was in August with $\bar{X} = 416.9$, and $CV = 0.28$.

The mean frequency of SE winds appeared to have a peak cycle approximately every three to four years during August, with the highest

Table 21. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1957-1961).

MONTH	SPEED (M.P.H.)	SECTOR 1 (NNE, NE, ENE, E)	SECTOR 2 (ESE, SE, SSE, S)	SECTOR 3 (SSW, SW, WSW, W)	SECTOR 4 (WNW, NW, NNW, N)	TOTAL
	1-7	4.4	6.2	3.6	14.2	28.4
JUNE	8-13	4.1	3.8	1.2	33.1	42.2
	15-31	0.0	0.4	0.1	12.9	13.4
	>=2	0.0	0.0	0.0	0.2	0.2
GRAND TOTAL		8.5	10.4	4.8	60.5	84.1
	1-7	3.0	5.6	5.4	15.3	29.3
JULY	8-13	3.6	4.1	1.2	34.3	43.3
	15-31	0.1	0.4	0.0	12.3	12.8
	>=2	0.0	0.0	0.0	0.6	0.6
GRAND TOTAL		6.8	10.1	6.7	62.5	86.0
	1-7	5.7	7.6	8.1	16.0	37.4
AUGUST	8-13	3.1	2.1	0.4	28.7	34.2
	15-31	0.0	0.1	0.0	8.0	8.0
	>=2	0.0	0.0	0.0	0.1	0.1
GRAND TOTAL		8.8	9.8	8.4	52.8	79.8

Table 22. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1962-1966).

MONTH	SPEED (MPH)	SECTOR 1 (NNE, NE, ENE, E)	SECTOR 2 (ESE, SE, SSE, S)	SECTOR 3 (SSW, SW, WSW, W)	SECTOR 4 (WNW, NW, NNW, N)	TOTAL
JUNE	1-7	2.8	3.4	7.0	12.4	25.6
	6-13	3.8	4.5	4.8	37.8	50.8
	15-31	0.0	0.2	0.0	14.3	14.4
	>=2	0.0	0.0	0.0	0.1	0.1
JULY	GRAND TOTAL	6.5	8.1	11.8	64.5	90.9
	1-7	2.3	4.7	9.5	9.9	26.4
	6-13	6.9	5.9	4.4	33.8	51.0
	15-31	0.3	0.1	0.3	8.4	9.0
AUGUST	>=2	0.0	0.0	0.0	0.1	0.1
	GRAND TOTAL	9.5	10.7	14.2	52.1	86.5
	1-7	3.2	6.2	12.2	11.0	32.5
	6-13	6.4	8.0	3.4	30.5	48.3
TOTAL	15-31	0.5	0.7	0.2	3.8	5.2
	>=2	0.0	0.0	0.0	0.0	0.0
	GRAND TOTAL	10.1	14.9	15.7	45.3	86.0

Table 23. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1967-1971).

MONTH	SPEED (M.P.H.)	SECTOR 1 (NNE, NE, ENE, E)	SECTOR 2 (ESE, SE, SSE, S)	SECTOR 3 (SSW, SW, MSW, W)	SECTOR 4 (WNW, NW, NNW, N)	TOTAL
JUNE	1-7	1.5	3.8	7.3	6.5	19.1
	6-13	4.4	3.0	2.5	38.6	48.5
	15-31	0.2	0.0	0.2	23.0	23.4
	>32	0.0	0.0	0.0	1.9	1.9
GRAND TOTAL		6.2	6.8	9.9	69.9	92.9
JULY	1-7	1.9	3.1	9.4	9.0	23.3
	6-13	3.8	3.4	5.3	34.9	47.5
	15-31	0.1	0.1	0.1	23.8	24.1
	>32	0.0	0.0	0.0	0.6	0.6
GRAND TOTAL		5.7	6.6	14.8	68.4	95.5
AUGUST	1-7	1.4	3.6	12.2	6.9	24.1
	6-13	4.3	4.3	6.0	35.3	49.9
	15-31	0.3	0.0	0.1	17.7	18.2
	>32	0.0	0.0	0.0	1.0	1.0
GRAND TOTAL		6.0	8.0	18.3	61.0	93.3

Table 24. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1972-1976).

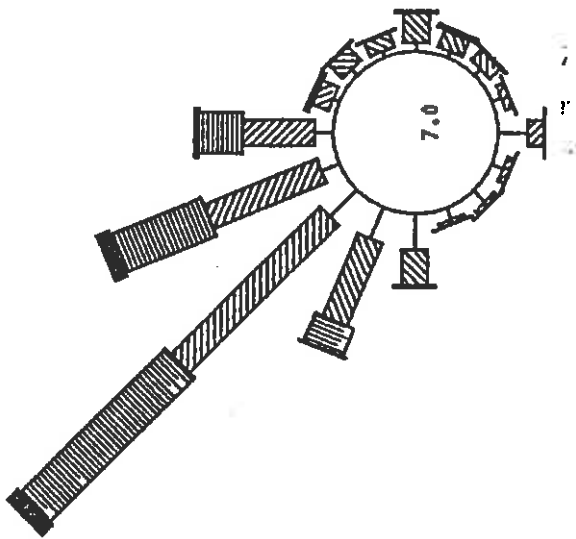
MONTH	SPEED (M.P.H.)	NORTHEAST SECTOR		SOUTHWEST SECTOR		NORTHEAST SECTOR		TOTAL
		(NNE, NE, ENE, E)	(ESE, SE, SSE, S)	(SSW, Sd, WSW, W)	(WNW, NW, NNW, N)			
	1-7	2.0	4.0	4.2	7.8		18.0	
JUNE	8-13	6.0	3.2	2.5	34.9		46.7	
	19-31	3.6	0.0	0.2	23.4		24.2	
	>32	0.0	0.0	0.0	1.3		1.3	
GRAND TOTAL		3.6	7.3	6.9	67.4		90.2	
	1-7	1.0	4.3	7.6	8.1		21.0	
JULY	8-13	3.3	2.4	7.4	33.4		46.5	
	19-31	0.1	0.0	1.4	21.3		22.8	
	>32	0.0	0.0	0.0	0.6		0.6	
GRAND TOTAL		4.4	6.7	16.4	63.4		90.9	
	1-7	2.9	5.7	8.0	9.1		25.7	
AUGUST	8-13	4.9	6.2	7.4	30.8		49.2	
	19-31	0.1	0.5	0.5	11.7		12.8	
	>32	0.0	0.0	0.0	0.4		0.4	
GRAND TOTAL		7.9	12.4	15.8	52.0		88.1	

Table 25. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1977-1981).

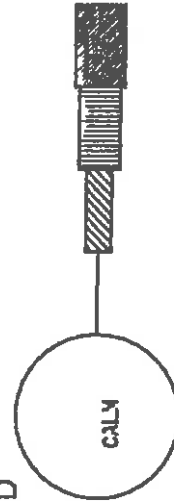
MONTH	SPEED (MPH)	SECTOR 1 (NNE, NE, ENE, E)	SECTOR 2 (ESE, SE, SSE, S)	SECTOR 3 (SSH, SH, WSW, W)	SECTOR 4 (WNW, NW, NNW, N)	TOTAL
	1-7	2.4	4.6	7.0	7.4	21.4
JUNE	8-13	8.3	3.6	2.9	35.6	50.4
	19-31	0.3	0.6	0.3	17.3	18.6
	>32	0.0	0.0	0.0	1.0	1.0
	GRAND TOTAL	11.0	8.9	10.2	61.3	91.4
JULY	1-7	2.7	7.0	7.9	9.4	27.0
	8-13	4.4	6.4	2.3	29.8	42.8
	19-31	0.1	0.1	0.0	19.9	20.1
	>32	0.0	0.0	0.0	0.3	0.3
	GRAND TOTAL	7.3	13.5	10.2	59.2	90.2
AUGUST	1-7	2.1	6.3	8.3	11.5	28.3
	8-13	2.9	5.2	1.7	39.0	48.8
	19-31	0.1	0.1	0.0	12.7	12.9
	>32	0.0	0.0	0.0	0.0	0.0
	GRAND TOTAL	5.1	11.7	10.0	63.3	90.1

Table 26. Frequency Percentage of Wind Speed in the Four Wind Direction Sectors (1982-1985).

MONTH	SPEED (MPH)	SECTOR 1 (NNE, NE, ENE, E)	SECTOR 2 (ESE, SE, SSE, S)	SECTOR 3 (SSW, SW, WSW, W)	SECTOR 4 (WNW, NW, NNW, N)	TOTAL
	1-7	1.6	3.5	5.9	4.7	15.7
JUNE	6-13	3.8	1.2	2.2	50.5	57.7
	19-31	0.0	0.0	0.0	21.6	21.6
	>32	0.0	0.0	0.0	0.0	0.0
GRAND TOTAL		5.4	4.8	8.1	76.8	95.0
	1-7	2.1	3.4	7.6	9.7	22.8
JULY	6-13	2.7	0.8	2.3	49.4	55.1
	19-31	0.0	0.0	0.1	15.1	15.1
	>32	0.0	0.0	0.0	0.1	0.1
GRAND TOTAL		4.8	4.2	9.9	74.2	93.1
	1-7	2.4	6.4	8.8	6.5	24.1
AUGUST	6-13	4.5	2.0	3.4	43.4	53.3
	19-31	0.0	0.0	0.0	13.6	13.6
	>32	0.0	0.0	0.0	0.0	0.0
GRAND TOTAL		6.9	8.5	12.3	63.5	91.1



LEGEND



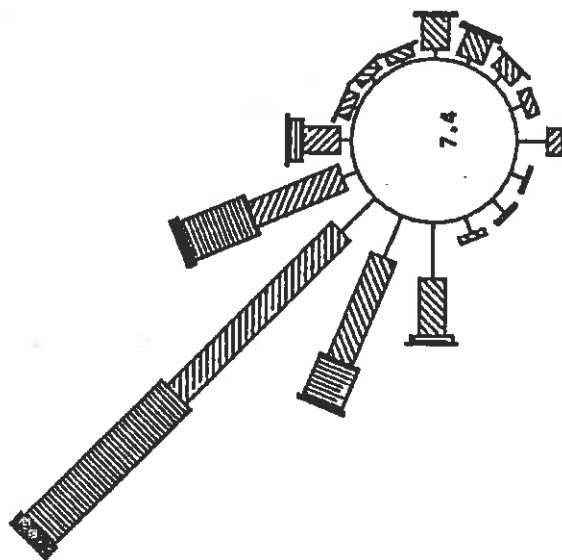
SCALE



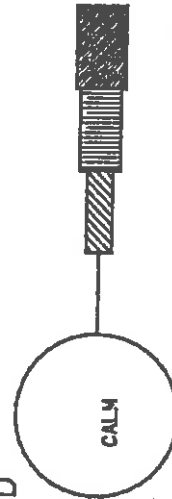
WIND SPEED (MPH) 1-7 8-16 9-31 >32

KISRX 20795

Fig. 16a. Wind rose for June (1957-1985).



LEGEND



WIND SPEED (MPH) 1-7 8-18 19-31 >32

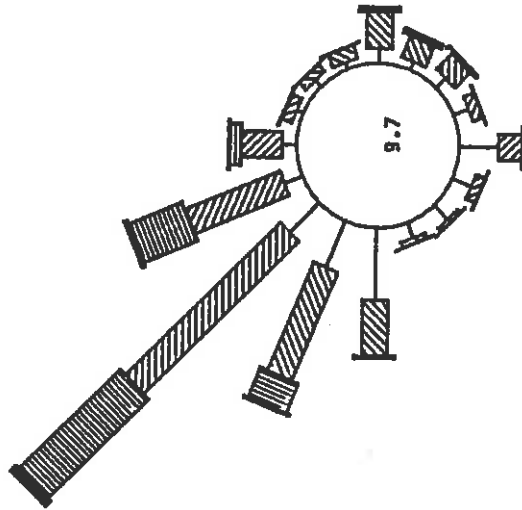
KISRX 20796

SCALE

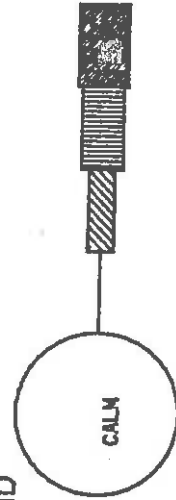


Fig. 16b. Wind rose for July (1957-1985).

MONTH : AUGUST



LEGEND



WIND SPEED (MPH) 1-7 8-18 9-31 >32

SCALE
5.0%

Fig. 16c. Wind rose for August (1957-1985). KISR X 20797

mean frequency and coefficient of variation in August ($\bar{X} = 81.4$ and $C.V=0.60$), and the lowest in June ($\bar{X}=56.2$ and $C.V=0.26$).

Most correlation coefficients between NW and NNW and other wind directions were low or negative, especially in June and August.

During June, July and August the N, W, and SSW winds had the highest fluctuation with coefficients of variation of 92.2%, 80% and 87% respectively.

Wind speed was seen to vary with both daily and monthly, but these effects are neither strong nor stable. However, in the long term these effects do have important implications on the dust storms and mobility of sand.

The monthly frequency means and variation of wind speed were shown to peak approximately every four to five years. It seems that the variability is small but there are definite peaks between 1957 and 1961, between 1962 and 1967, and so on.

Wind speed reached its lowest in August of every year. The daily mean frequencies were very similar in most years, but 1965 and 1970 were exceptional years.

The wind roses charts showed that NW and NNW winds had the highest frequency. These wind directions were mainly associated with moderate wind speeds (8-18 mph), and the frequency of light wind speed (1-7 mph) increased in August except for the period from 1957 to 1965.

On the basis of the finding and conclusions of this study, the following suggestions are made.

1. A comparison study should be conducted between more than two weather stations to study the changes of the wind speed and direction at different areas.
2. A study of the effect of south and west winds on the movement of dust storms should be undertaken. These two winds have shown to behave differently behavior than other winds through the period of this study.

References

- Graedel, T. 1977. The wind boxplot. An improved wind rose. Journal of Applied Meteorology 16:448-450.
- Safar, M. I. 1985. Dust and Dust storms in Kuwait. State of Kuwait, Directorate General of Civil Aviation, Meteorological Department. p. 59-84.
- Melarango, M. 1982. Wind In Architectural and Environmental Design. New York: Van Nostrand Reinhold.
- Hays, W. 1981. Statistics. New York: Holt, Rinchart and Winston.

Appendix A

**Frequency of Wind Direction for
June, July and August (1957-1985)**

Table A1. The Percentage of Frequency of wind direction for June (1957-1985)

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
57	R	21.8	0.8	0.6	0.7	5.0	3.6	2.8	1.2	1.3	0.3	1.0	0.0	2.2	5.1	7.6	12.4
	C	8.4	1.6	1.0	1.6	6.5	3.3	5.8	4.1	1.6	3.7	0.7	3.3	1.8	1.8	0.9	2.7
58	R	23.2	3.1	1.2	2.4	3.9	4.4	4.4	3.3	1.9	1.2	0.1	0.6	1.2	5.8	6.2	21.2
	C	8.3	5.7	2.3	5.6	5.1	9.7	9.2	9.8	2.2	3.3	0.3	1.7	0.9	2.0	0.7	4.4
59	R	26.1	1.7	1.8	1.0	4.9	2.6	0.7	1.0	5.1	1.5	1.0	0.3	3.3	6.9	7.6	25.6
	C	10.0	3.1	3.3	2.3	6.4	3.9	1.4	2.9	6.0	4.4	2.4	0.8	2.4	2.4	0.9	5.4
60	R	3.2	1.9	0.7	1.2	0.7	2.4	0.6	0.3	1.9	0.7	0.7	1.0	2.8	11.2	21.2	39.3
	C	1.1	3.6	1.3	2.9	0.9	2.4	1.2	0.8	2.2	1.8	1.7	2.9	2.0	3.8	2.4	8.1
61	R	4.6	2.4	1.9	2.9	3.7	2.5	3.9	4.3	3.6	1.3	1.7	0.8	2.2	6.0	27.4	19.7
	C	1.6	4.4	3.6	6.9	4.9	5.4	8.1	12.7	4.1	3.3	4.2	2.5	1.6	2.0	3.1	4.1
62	R	2.5	1.4	1.0	2.2	2.6	3.1	1.5	1.5	3.7	3.9	2.8	3.7	11.2	16.5	26.2	8.2
	C	2.0	2.9	2.1	6.2	3.8	1.2	3.2	4.5	4.3	10.3	7.3	11.3	8.0	5.6	2.9	1.7
63	R	6.9	1.7	0.6	1.2	2.4	1.9	1.0	1.0	3.2	4.3	1.0	1.5	4.9	11.9	28.9	23.1
	C	3.2	3.1	2.3	2.9	3.1	1.8	2.0	2.9	3.6	11.4	2.4	4.6	3.4	4.0	3.2	4.8
64	R	9.2	1.7	1.2	1.1	2.4	2.5	2.2	1.7	4.3	3.1	1.8	2.8	3.3	15.4	26.4	19.3
	C	3.3	3.1	7.9	2.6	3.1	5.4	4.6	4.9	4.9	8.1	4.5	8.4	2.4	5.2	3.0	4.0
65	R	7.9	1.9	4.3	1.4	1.1	2.1	1.4	1.5	1.7	0.3	1.4	0.4	1.8	9.0	26.5	16.5
	C	3.1	3.6	0.5	3.3	1.5	4.5	2.9	4.5	1.9	0.7	3.5	1.3	1.3	3.0	3.0	3.4
66	R	3.5	0.6	0.3	1.1	2.5	1.0	1.1	0.7	3.5	1.5	1.0	1.1	7.1	20.0	30.0	14.4
	C	1.8	1.0	2.1	2.6	3.3	0.3	2.3	2.0	3.9	4.0	2.4	3.3	5.0	6.7	3.4	3.0
67	R	1.0	0.1	1.1	0.7	4.3	0.4	2.2	1.4	3.3	0.3	3.6	1.3	12.1	20.0	38.2	3.1
	C	1.2	0.3	4.9	1.6	5.6	0.9	4.6	3.7	3.8	0.7	9.0	3.8	8.6	6.7	4.3	0.6
68	R	1.4	0.7	2.6	1.4	0.4	2.1	1.8	1.0	1.1	3.1	4.3	0.4	3.1	12.4	56.5	5.4
	C	0.5	1.3	9.0	3.3	0.5	4.5	4.9	2.8	1.3	8.0	10.7	1.3	2.2	4.2	6.3	1.1

Table A1 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
69	R	4.3	2.5	4.9	0.7	3.2	2.9	2.4	0.6	7.5	1.8	3.6	1.4	2.4	3.3	42.6	5.3
	C	1.6	4.7	2.6	1.6	4.2	6.3	1.2	1.6	8.5	4.8	9.0	4.2	1.7	1.1	4.8	1.1
70	R	14.6	1.1	1.4	0.1	0.7	0.4	0.6	0.0	0.8	0.4	1.2	0.1	5.8	3.2	25.1	28.9
	C	5.2	2.1	1.5	0.3	0.9	0.9	1.2	0.0	0.9	1.1	3.1	0.4	4.1	1.1	3.9	6.0
71	R	2.9	1.7	0.8	0.6	1.7	2.5	0.7	0.3	1.9	1.0	1.0	0.7	3.3	10.6	39.2	21.8
	C	1.6	3.1	1.5	1.3	2.2	5.4	1.4	0.8	2.2	2.6	2.4	2.1	2.4	3.6	4.9	4.5
72	R	28.8	8.2	3.3	1.4	4.4	3.3	2.1	0.4	3.7	1.7	1.5	0.7	3.3	4.6	13.7	11.9
	C	10.3	15.4	6.2	3.3	5.8	7.3	4.3	1.2	4.3	4.4	3.8	2.1	2.4	1.5	1.5	2.5
73	R	9.3	0.4	0.8	0.7	1.1	0.8	1.7	0.6	2.6	0.6	0.4	0.4	3.3	8.6	36.1	26.0
	C	3.4	0.8	1.5	1.6	1.6	1.8	3.5	1.6	3.0	1.5	1.0	1.3	2.4	2.9	4.0	5.4
74	R	14.6	0.7	5.0	0.7	2.2	0.4	1.2	0.3	1.4	0.0	0.7	1.0	3.5	3.6	31.0	9.9
	C	5.4	1.3	9.2	1.6	2.9	0.9	2.6	0.8	1.6	0.0	1.7	2.9	2.5	1.2	3.5	2.1
75	R	6.8	0.7	2.6	0.4	1.8	0.3	2.6	1.1	2.2	0.4	1.0	0.3	9.3	18.2	43.7	4.2
	C	2.4	1.3	4.9	1.0	2.4	0.6	5.5	3.3	2.5	1.1	2.4	0.8	6.6	6.1	4.9	0.9
76	R	3.3	1.8	1.8	2.6	2.2	1.4	0.4	1.2	8.3	0.8	0.1	1.8	3.9	24.3	27.9	11.0
	C	1.4	3.1	3.3	6.2	2.9	3.0	0.9	3.7	9.4	2.2	0.3	5.4	2.8	8.2	3.1	2.3
77	R	1.2	1.1	1.2	5.0	2.8	1.8	1.9	1.9	3.2	1.9	1.8	1.5	5.6	15.8	34.4	9.0
	C	0.5	2.1	2.3	11.8	3.6	3.9	4.0	5.7	3.6	5.1	4.5	4.6	3.9	5.3	3.9	1.9
78	R	3.3	1.7	1.1	2.2	3.9	0.8	0.7	1.0	3.2	0.4	1.2	2.6	6.4	23.7	30.1	6.1
	C	1.2	3.1	2.1	5.2	5.1	1.8	1.4	2.9	3.6	1.1	3.1	19.2	4.5	8.0	3.4	1.3
79	R	12.2	6.2	6.5	3.7	6.0	2.9	3.3	0.4	0.6	1.4	1.1	0.1	3.3	1.8	29.2	16.8
	C	4.6	11.7	12.1	8.8	7.8	6.3	6.9	1.2	0.6	3.7	2.8	10.0	2.4	0.6	3.3	3.5

Table A1 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
80	R	9.4	2.1	2.5	0.8	1.2	1.0	1.2	0.4	2.8	2.1	2.4	0.4	6.5	2.8	43.1	15.0
	C	4.3	3.9	4.6	2.0	1.6	2.1	2.6	1.2	3.1	5.5	5.9	19.7	4.6	1.0	4.8	3.1
81	R	10.0	1.2	1.4	1.1	3.2	3.1	3.1	5.4	5.7	1.1	1.7	1.9	7.4	7.5	16.1	18.6
	C	3.9	2.3	2.6	2.6	4.2	6.6	6.4	15.9	6.5	2.9	4.2	22.2	5.2	2.6	1.8	3.9
82	R	11.8	3.1	1.5	1.9	2.4	2.4	0.8	0.8	3.6	1.4	0.6	2.6	3.7	3.3	27.5	27.1
	C	4.9	5.3	2.8	4.6	2.9	5.1	1.7	2.4	4.1	3.7	1.4	11.3	2.6	1.1	3.1	5.6
83	R	8.1	1.1	0.7	1.4	3.6	0.7	1.1	0.1	3.3	0.4	1.1	0.3	4.3	3.1	45.6	21.5
	C	2.9	2.1	1.3	3.3	4.7	1.5	2.3	0.4	3.8	1.1	2.8	13.0	3.1	1.0	5.1	4.5
84	R	1.5	0.1	0.6	1.0	1.4	0.7	0.4	0.4	2.5	0.8	0.6	0.6	8.1	12.5	43.7	21.8
	C	0.7	0.3	1.0	2.3	1.8	0.9	0.9	1.2	2.8	2.2	1.4	24.3	5.7	4.2	4.9	4.5
85	R	3.3	1.8	0.4	0.1	0.4	0.7	0.1	0.1	1.1	0.3	0.4	1.7	5.4	8.7	49.6	18.1
	C	1.3	3.4	0.8	0.3	0.5	1.5	0.3	0.4	1.3	0.7	1.0	16.3	3.8	2.9	5.6	3.7

Note:

R = The percentage frequency of a wind direction during each year.

C = Percentage duration of wind direction in that year to total duration in the same direction during 29 years.

Table A2. The Percentage of Frequency of Wind Direction for July (1957-1985)

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
57	R	21.9	4.3	2.2	1.1	5.0	1.9	2.4	1.3	2.6	0.3	0.3	0.4	3.2	5.1	5.5	17.9
	C	15.0	12.5	6.2	3.4	8.0	0.6	4.4	3.0	3.0	0.8	0.6	1.0	1.4	1.3	0.6	4.6
58	R	14.4	3.8	1.2	1.1	1.3	2.4	4.0	1.9	0.3	1.1	0.1	0.4	0.1	0.4	11.0	39.4
	C	9.3	11.0	3.5	3.4	1.6	3.8	7.4	4.1	0.3	3.0	0.3	1.0	0.1	0.1	1.2	10.2
59	R	7.0	0.4	0.3	0.0	0.7	0.4	0.4	0.1	2.0	0.4	0.3	1.6	7.1	17.2	15.3	41.0
	C	5.6	0.8	0.8	0.0	0.9	0.4	0.6	0.3	3.0	1.9	1.1	5.8	3.3	4.4	1.7	10.6
60	R	1.6	1.3	2.0	2.2	1.7	6.3	3.5	4.3	4.6	1.2	0.9	1.9	4.3	13.3	27.4	13.7
	C	1.0	3.9	5.8	6.8	2.0	9.9	5.5	9.5	5.4	3.4	2.0	4.5	1.9	3.4	3.0	3.6
61	R	1.3	0.0	0.4	0.3	4.7	4.3	3.1	2.8	1.6	0.4	0.7	1.5	7.1	11.3	39.9	7.7
	C	0.9	0.0	1.2	0.8	5.4	6.7	4.8	6.2	1.9	1.1	1.4	3.5	3.1	2.9	4.3	2.0
62	R	2.7	1.5	1.2	2.7	7.7	3.8	3.1	3.0	2.8	1.2	1.5	2.3	12.6	16.5	13.7	9.7
	C	2.6	4.3	3.5	8.4	8.9	1.7	4.8	6.5	3.4	3.4	3.2	5.4	5.5	4.2	1.5	2.5
63	R	5.8	3.8	0.4	1.6	3.5	1.6	0.4	0.7	3.2	3.4	2.6	2.3	6.9	14.2	29.8	13.2
	C	3.8	11.0	1.2	5.1	4.0	1.5	0.7	1.5	3.8	9.5	5.4	5.4	3.0	3.6	3.2	3.4
64	R	1.7	0.7	1.7	1.3	6.9	4.7	2.3	3.2	6.7	3.6	2.3	1.7	8.9	21.9	20.8	3.1
	C	2.0	2.0	5.0	4.2	7.9	7.4	4.2	7.1	8.0	10.3	4.9	4.2	3.9	5.5	2.2	0.8
65	R	1.9	0.7	0.7	0.9	2.7	3.0	2.4	1.9	2.0	2.0	1.7	2.2	6.3	14.8	36.4	3.0
	C	2.9	2.0	1.9	3.0	3.1	4.6	4.4	4.1	2.4	5.7	3.7	5.1	2.8	3.7	4.0	0.8
66	R	2.0	1.6	1.2	2.3	4.3	1.7	1.6	1.5	3.9	0.7	1.3	2.0	5.8	16.5	23.9	8.9
	C	2.9	4.7	3.5	7.2	5.0	0.4	3.0	3.3	4.6	1.9	2.9	4.8	2.6	4.2	2.6	2.3
67	R	2.3	0.1	1.2	0.7	6.0	2.4	2.8	1.5	4.2	1.2	1.9	2.3	19.2	25.4	24.3	1.1
	C	2.3	0.4	3.5	2.1	7.0	3.8	5.2	3.3	5.0	3.4	4.0	5.4	8.4	6.4	2.6	0.3
68	R	2.2	0.4	7.0	1.9	3.1	3.9	5.2	1.6	2.2	4.4	8.3	1.5	3.8	5.2	43.3	1.6
	C	1.4	1.2	20.2	5.9	3.6	6.1	9.6	3.6	2.6	12.5	17.8	3.5	1.6	1.3	4.7	0.4

Table A2 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
69	R	1.6	0.9	1.5	0.5	0.5	0.5	0.7	0.1	1.2	1.3	3.2	1.3	2.4	8.3	66.0	2.0
	C	1.2	2.8	4.3	1.7	0.6	0.8	1.2	0.3	1.4	3.8	6.9	3.2	1.1	2.1	7.2	0.5
70	R	12.5	0.9	0.3	0.1	0.8	1.3	0.5	0.7	3.5	0.4	2.2	0.0	11.0	8.7	37.0	17.5
	C	8.6	2.8	0.8	0.4	0.9	2.3	1.0	1.2	4.2	1.4	4.6	0.0	4.8	2.2	4.0	4.5
71	R	3.4	0.5	1.2	0.1	0.5	0.0	0.4	0.0	0.3	1.2	0.5	1.7	5.5	17.3	3.3	31.0
	C	2.4	1.6	3.5	0.4	0.6	0.0	0.7	0.0	0.3	3.4	1.1	4.2	2.4	4.4	3.4	8.1
72	R	7.8	0.7	0.9	0.4	1.3	1.6	0.9	0.0	1.9	1.1	0.5	0.0	2.2	8.2	29.8	35.9
	C	5.6	2.0	2.7	1.3	1.6	2.3	1.7	0.0	2.2	3.0	1.1	0.0	0.9	2.1	3.2	9.3
73	R	0.9	0.8	0.8	1.5	1.3	2.8	2.0	2.4	2.4	0.8	0.4	1.6	5.5	11.3	44.9	13.6
	C	0.6	2.4	2.3	4.6	1.6	4.4	3.7	5.3	2.9	2.3	0.9	3.8	2.4	2.9	4.9	3.5
74	R	2.8	0.8	0.8	1.3	3.2	2.2	0.7	1.1	6.5	0.9	0.4	2.4	9.5	11.6	32.5	4.2
	C	3.6	2.4	2.3	4.2	3.9	3.4	1.2	2.4	7.7	2.7	0.9	5.6	4.2	2.9	3.5	1.0
75	R	2.3	0.3	1.1	0.1	3.4	1.5	1.6	0.7	2.6	0.3	2.0	1.3	13.2	21.2	40.7	1.6
	C	1.5	0.8	3.1	0.4	3.9	2.3	3.0	1.5	3.0	0.8	4.3	3.2	5.8	5.4	4.4	0.4
76	R	0.7	0.8	0.4	1.1	0.8	0.4	0.9	0.8	0.7	0.1	0.8	5.4	33.5	40.5	6.30	0.3
	C	0.6	2.4	1.2	3.4	0.9	0.6	1.7	1.8	0.8	0.4	1.7	12.8	14.7	10.2	0.7	0.1
77	R	0.8	0.4	0.4	1.2	1.3	1.6	1.3	2.4	1.7	0.4	0.9	3.1	9.4	30.0	32.8	3.5
	C	0.5	1.2	1.2	3.8	1.6	2.5	2.5	5.3	2.1	1.1	2.0	7.3	4.1	7.6	3.6	0.9
78	R	1.3	1.1	0.8	3.4	7.5	10.5	5.8	4.4	8.5	2.3	1.5	1.3	6.0	14.2	17.3	5.2
	C	1.6	3.1	2.3	10.5	8.7	16.4	10.8	9.8	10.1	6.5	3.2	3.2	2.6	3.6	1.9	1.4
79	R	5.2	0.7	1.7	0.3	3.0	1.6	2.6	0.8	3.4	1.2	0.9	0.5	3.2	4.0	47.8	13.6
	C	4.2	2.0	5.0	0.8	3.4	2.5	4.7	1.8	4.0	3.4	2.0	1.3	1.4	1.0	5.2	3.5

Table A2 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
80	R	4.0	1.3	1.3	0.7	3.5	2.7	1.3	0.1	4.8	2.0	1.2	0.5	5.1	4.0	48.0	9.3
	C	4.8	3.9	3.9	2.1	4.0	4.2	2.5	0.3	5.8	5.7	2.6	1.3	2.2	1.0	5.2	2.4
81	R	0.4	0.1	1.3	1.3	4.3	4.3	2.0	4.0	3.6	1.1	1.1	2.2	7.0	11.4	37.2	5.9
	C	1.0	2.0	3.9	4.2	5.0	6.7	3.7	8.9	4.3	3.0	2.3	5.1	3.1	2.9	4.0	1.5
82	R	1.9	2.2	1.7	1.1	2.4	1.6	1.5	1.5	3.0	0.7	1.6	1.9	5.4	10.1	42.9	12.6
	C	2.8	6.3	5.0	3.4	2.8	2.5	2.7	3.3	3.5	1.9	3.4	4.5	2.4	2.6	4.7	3.3
83	R	5.9	0.7	0.4	1.5	1.3	0.7	0.5	0.3	1.1	0.1	1.6	0.9	3.8	2.6	54.6	20.8
	C	4.2	2.0	1.2	4.6	1.6	1.1	1.0	0.6	1.3	0.4	3.4	2.2	1.6	0.6	5.9	5.4
84	R	5.1	1.7	0.3	0.7	2.8	0.3	0.3	2.0	2.4	1.1	0.4	0.8	12.0	10.3	19.5	30.1
	C	6.1	5.1	0.8	2.1	3.3	0.4	0.5	4.4	2.9	3.0	0.9	1.9	5.2	2.6	2.1	7.8
85	R	1.6	1.2	0.1	0.5	0.4	0.1	0.0	0.4	1.2	0.1	0.5	0.9	7.8	19.1	41.7	18.0
	C	1.0	3.5	0.4	1.7	0.5	0.2	0.0	0.9	1.4	0.4	1.1	2.2	3.4	4.8	4.5	4.7

Note:

- R = The percentage frequency of a wind direction during each year.
- C = Percentage duration of wind direction in that year to total duration in the same direction during 29 years.

Table A3. The Percentage of Frequency of Wind Direction for August (1957-1985)

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
57	R	16.8	5.2	2.7	2.4	5.2	2.0	4.4	3.5	4.2	0.4	0.8	0.9	3.6	3.2	3.6	10.3
	C	12.3	11.5	7.7	6.1	5.0	1.9	6.0	6.6	3.7	0.8	1.7	2.2	1.5	0.9	0.5	2.9
58	R	11.8	1.9	3.8	0.0	3.8	1.6	4.0	0.7	1.3	1.1	1.5	0.0	1.1	1.3	9.4	18.0
	C	7.1	4.1	10.7	0.0	3.6	2.8	5.4	1.3	1.2	1.8	3.2	0.0	0.4	0.4	1.2	5.0
59	R	9.1	0.4	0.1	0.0	0.7	0.3	0.1	0.1	0.8	0.7	0.4	0.7	7.4	13.0	15.5	40.7
	C	5.7	0.9	0.4	0.0	0.6	0.5	0.2	0.3	0.7	1.1	0.9	1.6	3.2	3.8	2.1	11.4
60	R	5.2	0.4	0.4	1.6	3.5	1.3	1.1	2.0	3.8	1.9	1.5	3.0	9.4	11.2	23.8	25.0
	C	3.2	0.9	1.1	4.1	3.3	2.4	1.5	3.8	3.4	3.1	3.2	7.3	3.9	3.0	3.1	7.0
61	R	7.1	0.4	1.6	2.6	7.3	3.4	3.2	5.1	5.9	1.2	0.7	1.2	4.8	5.0	23.8	9.9
	C	4.7	0.9	4.6	6.5	6.9	5.9	4.4	9.6	5.3	2.0	1.4	2.9	2.0	1.3	3.1	2.8
62	R	2.3	2.7	1.5	3.2	13.2	8.9	4.7	5.1	13.2	6.0	2.3	1.6	5.1	7.9	6.2	3.6
	C	3.3	5.9	4.2	9.2	12.5	4.7	6.4	9.6	11.8	10.0	4.9	3.8	2.1	2.1	0.8	1.0
63	R	1.6	2.7	0.8	2.4	5.4	5.8	1.5	0.5	3.9	4.3	3.8	4.6	11.3	12.4	18.4	11.4
	C	2.8	5.9	2.3	6.5	5.1	3.5	2.0	1.0	3.5	7.2	8.1	10.8	4.7	3.3	2.4	3.2
64	R	1.3	0.4	0.1	0.9	0.4	0.1	0.0	0.4	0.9	3.9	0.5	2.4	8.6	34.9	22.0	12.8
	C	0.8	0.9	0.4	2.4	0.4	0.2	0.0	0.8	0.8	6.5	1.2	5.7	3.6	9.2	2.9	3.6
65	R	3.8	0.4	0.9	3.2	8.3	5.1	4.4	3.9	7.4	2.0	1.3	0.7	2.4	7.5	13.6	7.9
	C	2.3	0.9	2.7	8.2	7.9	9.0	6.0	7.4	6.6	3.4	2.9	1.6	1.0	2.0	1.8	2.2
66	R	3.9	1.3	0.8	0.4	1.5	2.7	0.8	0.9	4.0	2.8	3.1	3.0	8.7	15.9	28.0	11.0
	C	3.1	3.0	2.3	1.0	1.4	1.9	1.1	1.8	3.6	4.7	6.6	7.0	3.6	4.2	3.7	3.1
67	R	1.1	0.0	0.0	0.0	0.7	0.3	1.2	0.3	2.3	0.8	0.7	1.2	32.7	22.0	33.2	1.2
	C	1.1	0.0	0.0	0.0	0.6	0.5	1.6	0.5	2.1	1.3	1.4	2.9	13.5	5.9	4.4	0.3
68	R	0.9	1.1	3.4	0.0	0.8	0.4	1.3	0.4	0.9	2.0	3.9	0.4	3.8	11.2	61.4	3.0
	C	0.6	2.4	9.6	0.0	0.8	0.7	1.8	3.2	0.8	3.4	8.4	1.0	1.6	3.0	8.1	0.8

Table A3 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
69	R	3.5	1.2	5.1	1.7	4.8	3.0	7.0	1.6	4.8	2.3	6.2	1.7	5.4	8.2	34.0	1.3
	C	2.1	2.7	14.6	4.4	4.6	5.2	9.4	3.0	4.3	3.8	13.3	4.1	2.2	2.2	4.5	0.4
70	R	9.8	0.7	1.6	0.5	2.3	1.1	1.1	0.3	4.4	2.6	3.2	0.4	13.2	7.4	26.9	17.3
	C	6.8	1.5	4.6	1.4	2.2	1.9	1.5	0.5	4.0	4.3	6.9	1.0	5.4	2.0	3.5	4.8
71	R	8.5	2.4	1.2	0.9	1.6	1.9	2.6	1.9	3.1	2.3	2.0	1.9	5.1	9.8	16.5	27.4
	C	5.6	5.3	3.4	2.4	1.5	3.3	3.4	3.6	2.8	3.8	4.3	4.4	2.1	2.6	2.2	7.6
72	R	13.4	2.8	1.2	0.3	4.7	3.5	9.0	1.9	11.2	3.5	1.9	0.5	7.8	7.0	11.8	8.3
	C	9.6	6.2	3.4	0.7	4.5	6.1	12.2	3.6	1.9	5.8	4.0	1.3	3.2	1.8	1.6	2.3
73	R	5.4	2.3	2.4	4.0	3.2	3.4	4.8	1.3	3.8	2.6	2.4	0.8	1.6	7.0	24.6	14.2
	C	4.5	5.0	6.9	10.2	3.1	5.9	6.5	2.5	3.4	4.3	5.2	1.9	0.7	1.8	3.2	4.0
74	R	3.2	1.7	1.2	1.6	3.4	1.3	1.6	3.8	3.1	0.4	0.7	2.2	6.5	16.0	32.0	7.8
	C	3.1	3.8	3.4	4.1	3.2	2.4	1.2	7.1	2.8	0.7	1.4	5.1	2.7	4.2	4.2	2.2
75	R	0.7	0.3	0.8	0.5	4.3	0.9	3.4	1.7	3.6	0.3	1.3	1.5	18.0	24.2	31.7	0.7
	C	0.4	0.6	2.3	1.4	4.1	1.7	4.5	3.3	3.3	0.4	2.9	3.5	7.4	6.4	4.2	0.2
76	R	0.8	1.1	0.5	1.2	2.0	0.0	0.5	0.9	2.3	1.1	1.5	4.6	20.0	34.7	13.6	2.7
	C	0.7	2.7	1.5	3.1	1.9	0.0	0.7	1.8	2.1	1.8	3.2	10.8	8.3	9.2	1.8	0.7
77	R	2.3	1.5	0.9	2.6	4.4	4.2	2.8	1.7	4.8	1.6	0.5	1.3	4.8	14.1	28.6	11.2
	C	1.8	3.3	2.7	6.5	4.2	7.3	3.8	3.3	4.3	2.7	1.2	3.2	2.0	3.7	3.8	3.1
78	R	0.9	0.0	0.0	0.0	0.1	0.1	0.0	0.4	1.6	0.4	1.2	1.5	10.5	26.3	47.0	7.3
	C	0.6	0.0	0.0	0.0	0.1	0.2	0.0	0.8	1.4	0.7	2.6	3.5	4.3	7.0	6.2	2.0
79	R	1.5	0.1	0.1	0.5	3.8	8.6	4.3	3.0	5.8	3.2	0.8	0.5	5.6	6.0	37.6	10.6
	C	3.2	0.3	0.4	1.4	3.6	15.1	5.8	5.6	5.2	5.4	1.7	1.3	2.3	1.6	5.0	3.0

Table A3 continued

YR	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
80	R	3.8	0.7	0.5	1.1	1.1	2.0	1.6	0.7	2.7	5.0	0.8	1.5	4.7	4.3	28.0	31.2
	C	2.4	1.5	1.5	2.7	1.0	3.5	2.2	1.3	2.4	8.3	1.7	3.5	1.9	1.1	3.7	8.7
81	R	2.6	1.3	0.8	2.4	3.5	2.7	2.4	3.6	5.2	1.1	0.3	0.7	4.0	8.3	29.3	15.3
	C	2.6	3.0	2.2	6.1	3.3	4.7	3.3	6.9	4.7	1.8	0.6	1.6	1.7	2.2	3.9	4.3
82	R	0.9	0.5	0.9	1.1	0.9	0.1	0.3	0.5	0.5	0.1	0.0	0.7	9.8	23.4	50.3	4.0
	C	0.8	1.2	2.7	2.7	0.9	0.2	0.4	1.0	0.5	0.2	0.0	1.6	4.1	6.2	6.6	1.1
83	R	5.6	1.1	0.5	2.0	4.0	1.6	0.7	1.2	4.2	2.2	0.5	1.5	6.3	12.1	35.1	17.5
	C	3.5	2.4	1.5	5.1	3.8	1.4	0.9	2.3	3.7	3.6	1.2	3.5	2.6	3.2	4.6	4.9
84	R	0.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	15.6	20.3	38.0	18.8
	C	1.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.0	6.4	5.4	5.0	5.2
85	R	4.3	2.7	0.8	2.0	10.8	3.6	5.1	5.4	10.6	4.3	2.7	1.3	3.8	1.5	12.9	8.6
	C	4.0	1.8	2.3	5.1	10.2	6.4	6.9	10.2	9.5	7.2	5.8	3.2	1.6	0.4	1.7	2.4

Note:

R = The percentage frequency of a wind direction during each year.

C = Percentage duration of wind direction in that year to total duration in the same direction during 29 years.