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Argonne National Laboratory

FIFTEEN-YEAR CLIMATOLOGICAL SUMMARY

January 1, 1950—December 31, 1964

Argonne National Laboratory, DuPage County, Argonne, Illinois

by

Harry Moses and Mary A. Bogner

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Argonne, Illinois 60439

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January 1, 1950–December 31, 1964

Argonne National Laboratory, DuPage County,
Argonne, Illinois

by

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September 1967

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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

No.	Title	Page

Part I. ANALYSIS BASED ON A SINGLE METEOROLOGICAL VARIABLE

Section 1.1 Wind Speed and Direction

Section 1.2. Air Temperature

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

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INTRODUCTION

The atomic energy industry requires meteorological data for the evaluation of hazards. Theoretical and empirical models of diffusion provide a basis for minimizing potential danger to personnel, for selecting plant locations and for establishing procedures for safe handling and transporting of radioactive material. Meteorological data pertinent to the problems of this industry have been collected at the Argonne National Laboratory meteorology observation site since July 1, 1949.

The data in this report cover the period from January 1, 1950 through December 31, 1964. Data for the first five years were compiled in a previous report[1] in order to present the then available data. The addition of ten years' data should produce increased precision in the estimates of the statistical parameters although 30 years of data are generally necessary to produce a stable statistical pattern and precise estimates of parameters.

The number of combinations of meteorological elements and of estimates of statistical parameters make it impossible to present all studies. Therefore, the studies presented have been restricted to a few formats which presumably answer a large number of questions and present salient facts on the Argonne climatology. Analyses such as the determination of the underlying functional forms of the distributions were relegated to future research. Efforts were made only to present the data in forms which are readily useable for such analyses.

The forms considered most adaptable to further research of the data are frequency distributions, percentage frequency distribution, joint percentage frequency distributions, percentile distributions, persistence studies, extremes, ranges, and averages, or combinations of these forms. Wherever possible the studies are presented in tabular form, again to facilitate useability. When comparison of variates or time trends are important, graphs have also been provided. The tables and graphs have been divided into three parts: analyses involving one variable, analyses of the simultaneous occurrence of two or more variables and analyses of the difference between variables measured at Argonne and those measured at Chicago Midway and O'Hare International Airports.

All data have been reduced to punched cards and transferred to magnetic tape after a considerable amount of screening. Appendix I contains a description of the punched card decks and the methods of data processing. All times are Central Standard Time.

Figure 1, Meteorological Instrumentation, provides a listing of the equipment used for the period of record covered in this report, the location above ground, and the dates on which automatic processing of the data began. A detailed description of the automatic data processing system can be found in Moses and Kulhanek.[2]

A map of the general area and an illustration showing instrument locations are in Appendix II.

Five interim reports based on the Argonne data have been published to date.[1,3-6] These cover the period from July 1949 through June 1954. An additional report, ANL-6470[7] contains a climatological study based on soil temperature and related observations at Argonne.

Inevitably there comes a time when publication of data requires a cessation of processing and an initiation of analysis and discussion. The reader is invited to furnish suggestions for the issuance of supplementary material. Within the limits of financial support and time available these suggestions will receive full attention.

Errors in data brought to the attention of the authors will be corrected in the archives.

Figure 1. Meteorological Instrumentation

Meteorological Element	Type of Instrument	Elevation with Respect to Ground	Period of Record Covered	Period Data Processed Automatically
Wind Speed	Friez Aerovane	a. 150 ft b. 18.75 ft	Jan. 1, 1950–Jan. 5, 1961 Jan. 1, 1950–Dec. 31, 1960	
	Belfort 3-cup Anemometer Model No. 339-A	a. 150 ft b. 75 ft c. 37.5 ft d. 18.75 ft	Jan. 6, 1961–Dec. 31, 1964 Jan. 1, 1961–Dec. 31, 1964 Jan. 1, 1961–Dec. 31, 1964 Dec. 1, 1960–Dec. 31, 1964	Jan. 6, 1961–Dec. 31, 1964 Jan. 1, 1961–Dec. 31, 1964 Jan. 1, 1961–Dec. 31, 1964 Dec. 1, 1960–Dec. 31, 1964
Wind Direction	Friez Aerovane	a. 150 ft b. 18.75 ft	Jan. 1, 1950–Dec. 31, 1964 Jan. 1, 1950–Dec. 31, 1964	Jan. 1, 1961–Dec. 31, 1964 Jan. 1, 1961–Dec. 31, 1964
Temperature	Friez Hygrothermograph Model No. 594	5 ft	Jan. 1, 1950–June 30, 1951	
	5-junction Copper-constantan Thermopile No. 36 wire and Honeywell Electronik Potentiometer	a. 3.5 ft b. 5.5 ft	July 1, 1951–Aug. 5, 1952 Aug. 5, 1952–Jan. 17, 1962	 Aug. 8, 1960–Jan. 17, 1962
	5-junction Copper-constantan Thermopile No. 16 wire and Honeywell Electronik Potentiometer	5.5 ft	Jan. 17, 1962–Dec. 31, 1964	Jan. 18, 1962–Dec. 31, 1964
Dew Point Temperature	Foxboro Dewcel	a. 5.5 ft b. 4.7 ft c. 9.4 ft d. 131 ft	Mar. 12, 1958–Dec. 1, 1960 Dec. 1, 1960–Dec. 31, 1964 Dec. 1, 1960–Dec. 31, 1964 Mar. 16, 1958–Dec. 31, 1964	Aug. 8, 1960–Nov. 30, 1960 Dec. 1, 1960–Dec. 31, 1964 Dec. 1, 1960–Dec. 31, 1964 Dec. 1, 1960–Dec. 31, 1964
Relative Humidity	Friez Hygrothermograph Model No. 594	5 ft	Jan. 1, 1950–Dec. 31, 1961	
Stability	Copper-constantan thermocouple No. 36 wire at all levels and Honeywell Electronik Potentiometer	Temperature difference measured between thermocouples at: a. 3.5 and 144 ft b. 5.5 and 144 ft c. 5.5 and 15.2 ft	 July 1, 1951–Aug. 5, 1952 Aug. 5, 1952–Jan. 18, 1962 Jan. 1, 1961–Jan. 18, 1962	
	Copper-constantan thermocouple No. 16 wire at lower level (5.5 ft) and No. 36 wire at upper levels and Honeywell Electronik Potentiometer	d. 5.5 and 144 ft e. 5.5 and 15.2 ft	Jan. 18, 1962–July 14, 1962 Jan. 18, 1962–July 14, 1962	
	Copper-constantan thermocouple No. 16 wire at lower level (5.5 ft) and No. 28 wire at upper levels and Honeywell Electronik Potentiometer	f. 5.5 and 144 ft g. 5.5 and 15.2 ft	July 14, 1962–Dec. 31, 1964 July 14, 1962–Dec. 31, 1964	Jan. 1, 1964–Dec. 31, 1964 Jan. 1, 1964–Dec. 31, 1964
Precipitation	Friez Weighing-type Rain Gage Model No. 755-B	3 ft	Jan. 1, 1950–Aug. 7, 1960	
	Bendix Friez Tipping Bucket Precipitation Gage	3 ft	Aug. 8, 1960–Dec. 31, 1964	Aug. 8, 1960–Dec. 31, 1964
Direct and Diffuse Solar Radiation	Eppley 50-junction Pyranometer and Leeds and Northrup Micromax Recorder	6 ft	Sept. 1, 1950–Dec. 31, 1964	Sept. 1, 1960–Dec. 31, 1964
Net Radiation	Beckman & Whitley Net Radiometer Model No. N-188	6 ft	June 1, 1956–Dec. 31, 1964	Aug. 8, 1960–Dec. 31, 1964
Pressure	Friez Microbarograph Model No. 790-1	Ivory point of mercurial barometer 746 ft above sea level Microbarograph checked against mercurial barometer	Jan. 1, 1950–Dec. 31, 1964	
Soil Temperature	Leeds and Northrup 100-ohm copper thermohms and Micromax Recorder	1 cm, 10 cm, 20 cm, 50 cm, 100 cm, 10 ft and 20 ft below ground surface	Jan. 1, 1952–Dec. 31, 1964	Oct. 1, 1957–Dec. 31, 1964

Part I

ANALYSIS BASED ON A SINGLE METEOROLOGICAL VARIABLE

The tables in the following sections present an analysis of the meteorological variables measured at the Argonne Meteorology Site. Many statistical methods of presentation were used. These are discussed briefly below.

The frequency distributions, percentage frequency distributions, and joint percentage frequency distributions are essentially of the same form. The percentage in the title indicates that the table entries have been divided by the total number of observations and are expressed in percent. In a number of tables, single variate frequency distributions are, in fact bivariate distributions where the second variable is time, e.g., the hour of the day or a number of consecutive hours, such as in the persistence tables. A table entry in a joint percentage frequency distribution represents the percent of the total number of observations during which the two variables simultaneously attained values within the specified intervals. The row and columns labeled "total" present the distributions of the single variables. These totals represent the number of observations in the row or column divided by the total number of observations and multiplied by 100. Owing to rounding of the table entries, the totals may not be the exact sum of the percents listed in the row or column. The rows and columns labeled "cumulative total" present the cumulative distribution of the variables.

Percentile distributions present the specified percentile values in the cumulative distribution of the variable. A percentile value is a position indicator in the distribution of the variable where all observations have been placed in order from the minimum to the maximum. For instance, the 75 percentile value of the wind speed distribution indicates the position in the cumulative distribution of the wind speed which equals or exceeds 75% of the wind speed values. In some cases, such as the wind speed, where the cumulative distribution is based on two mph intervals, the percentile value shown is an interpolation within an interval of the distribution. These cases are pointed out individually in the explanatory notes accompanying the tables.

Persistence studies are somewhat different for each variable, so individual explanations have been written for these in the text. It may be noted, though, that the counting method indicated in Figure 5 of the wind section may be applied to counting persistences of any variable above or below specified values.

Range and extreme values are derived in two ways. Daily extremes, unless otherwise specified in the table write-up, are values read directly from the chart traces of the recording instrument independently of the hourly observations. The daily ranges are then the difference between these maxima and minima. Other ranges are based on the maximum and minimum of the hourly observations of the variables.

Percentage frequency distributions of ranges based on the maximum and minimum of the hourly values within 2-hour, 11-hour and 23-hour intervals have been presented. For these tables the two-hour range values, representing the difference between the maximum and minimum of three consecutive hourly values of the variable, were calculated for overlapping time intervals beginning with each hour of the day. If one hourly observation was missing, the range was considered missing for all time intervals which included that observation. One hour of missing data would, therefore, result in 3 missing observations of 2-hour range data since each hour is counted three times in the overlapping intervals. The 11-hour and 23-hour ranges were calculated in the same way as the 2-hour ranges. The 11-hour range is based on 12 consecutive hourly observations and the 23-hour range on 24.

A table entry in these percentage frequency distributions represents the percent of the total number of observations during which the ranges as calculated above fell within the specified range intervals when the first hour of the time interval in question was equal to the specified hour of the day. For instance, the first row of the percentage frequency distribution of 2-hour ranges presents the distribution of the maximum change each day in the hourly observations at 0100, 0200 and 0300 CST. The second row presents the distribution of the maximum change each day in the hourly observations at 0200, 0300 and 0400 CST.

Averages and means are summations of nonmissing observations appropriate to the averaging interval divided by the number of items in the summation.

Section 1.1

Wind Speed and Direction

Two types of wind instrument have been used at the Argonne Meteorology Site—Aerovanes and 3-cup anemometers. Figure 1 shows the periods of records for each type of instrument. Wind speed and direction measurements are made at 150-, 75-, 37.5-, 18.75- and 9.4 foot levels. In this report the 37.5- and 18.75-foot levels are referred to as the 37- and 19-foot levels respectively. The 9.4-foot wind speed and direction are recorded but not used in this report. The wind instruments at 150 feet are mounted on a mast extending upward from the top of a 120-foot forest fire lookout tower located at the meteorological observation site. These instruments on the tower top are unobstructed from all directions. Originally, the 19-foot instrument was mounted on a boom extending 8½ feet from the tower. This instrument gave low wind speed measurements when the wind was blowing through the tower; so on November 20, 1951, the instrument was moved to the top of a 19-foot pole about 200 feet northwest of the tower, and on June 2, 1960, it was moved to its present location, the top of a 19-foot pole 180 feet east of the tower, as shown in Figure 2 of Appendix II. This pole also has a 3-cup anemometer mounted 19 feet above ground on a boom extending 6 feet from the top of the pole. Wind instruments at the intermediate levels, 75 and 37 feet, are mounted on top of poles like the present mounting of the 19-foot level. The location of these poles also is shown in Figure 2 of Appendix II.

Wind speeds measured by Aerovanes were recorded on Esterline-Angus recorder traces. Prior to the installation of the automatic data processing system, hourly values representing ten-minute averages centered on the hour were read to the nearest mph. After the installation of the automatic data processing system 3-cup anemometers were used. The ten-minute averaging was done automatically, and the data were recorded to the nearest tenth of a mph. The wind speeds were rounded to the nearest whole mile per hour. For example, 3.5 mph is rounded to 3 mph and 3.6 mph is rounded to 4 mph. The automatic data processing system began recording wind speeds at 150 feet on January 6, 1961, at 75 and 37 feet on January 1, 1961, and at 19 feet on December 1, 1960. The Aerovanes, providing pen and ink traces of wind speed records, were continued in operation after the installation of the automatic data processing system.

A wind speed recorded as calm by the Aerovane may represent actual wind speeds from 0.0 to 3.0 mph. Generally a calm wind speed is defined as 0.0 through 0.5 mph; however, for some analyses calm was defined differently. Such cases are indicated in the individual write-up of the figures or tables.

The daily peak wind gusts represent the maximum wind recorded on the Esterline-Angus recorder each day without regard to the wind speed duration. This peak gust is somewhat less than the true speed since its value depends in part upon the response time of the Esterline-Angus recorder (99% in less than 1 second) and the distance constant of the Aerovane (about 15 feet).*

Wind direction data from the 19- and 150-foot levels only are used in this report since these are the levels incorporated in the automatic data processing system. Prior to the installation of the automatic data processing system, wind direction data to the nearest ten degrees were obtained from the Esterline-Angus recording charts and represented 10-minute averages centered on the hour. After the installation of the automatic data processing system on January 1, 1961, the 10-minute integration was done automatically and recorded on paper punch tape to the nearest ten degrees. Wind direction data have been provided by the Aerovane throughout the entire 15 years.

When the records were obtained from the Esterline-Angus pen-and-ink traces, indeterminate directions occurring over 10-minute averaging intervals were coded as variable. The automatic data processing system, however, integrated these directions. The readings coded as variable before use of the automatic data processing system were grouped as missing in this report. This procedure introduced a small error, but variable wind direction for the most part occurs with wind speeds of one to three miles per hour, when Aerovane readings are unreliable. The wind direction data read from the Esterline-Angus recorder traces are biased also to directions which are multiples of 30. This occurs because the Esterline-Angus charts are scaled to every 15 degrees but read to 10 degrees. Therefore, there is a tendency to read directions being from the 30-, 60-, 90-degree, etc. directions marked by heavy lines on the charts rather than the intermediate 10-degree intervals which are not explicitly marked. The unbiased data from the automatic data processing system partially smooth the wind direction distribution; however, since the biased data cover a ten-year period and the unbiased cover a five year period the bias is still evident.

For some studies, wind direction to 8 or 16 points of the compass is desirable. Therefore, direction initially recorded to 36 points was converted to the 8- or 16-point scale by the scheme shown in Figure 2. This technique introduces a bias toward the cardinal directions which may be corrected by any one of various methods.[9-10] Such a correction is not made here.

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* Information received from Professor Gerald C. Gill, The University of Michigan, and discussed in greater detail in Reference 8.

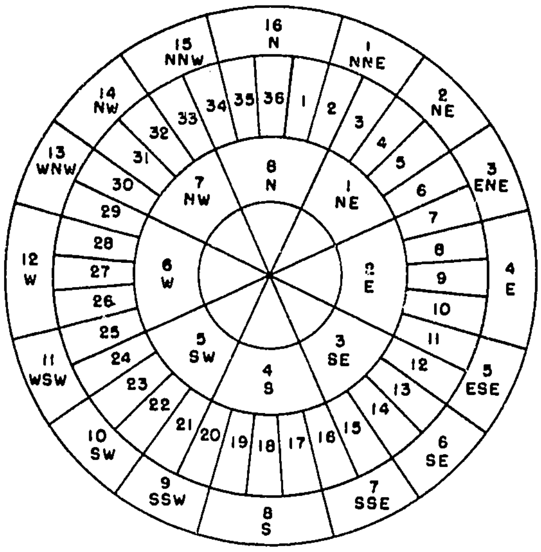


Figure 2

Wind Direction
Conversion Diagram

1.1.1 Wind Roses

Figures 8 through 13: 19- and 150-foot Wind Roses. Monthly and Total Period. January 1950–December 1964.

The wind rose is a graphical illustration of the joint percentage frequency distribution of wind speed and wind direction. Roses for the 19- and 150-foot wind distributions during all hours, during the hours 0700–1800 CST, and during the hours 1900–0600 CST are presented in Figures 8 and 9, 10 and 11, and 12 and 13 respectively. Tabular presentation of these distributions is given in Tables 1-39 and discussed later. The wind roses are essentially polar coordinate plots where the length of the radii represents percentage frequency of wind speeds in classes of 4 to 12 mph, 4 to 24 mph, and greater than 4 mph. The direction of the radii represents the direction from which the wind blows. Data for every ten degrees of the compass were plotted, and corresponding points of the wind-speed groupings on adjacent radii were connected. Connecting the points in this manner for each given wind speed grouping will form three concentric closed patterns, one for each wind-speed grouping, showing the relative percentage of wind observations in the given speed intervals to 36 points of the compass. For example, on the 15-year summary rose for January in Figure 8 the three points plotted on the spoke extending horizontally to the left represent the wind speed distribution when the wind is blowing from the ten-degree sector, 266 to 275 degrees. These points indicate that about 3.8 percent of the wind observations in January were from the west in the speed interval 4 to 12 mph, about 5.1 percent in the speed interval 4 to 24 mph and about 5.2 percent in the speed interval greater than 4 mph. The number 12.67 in the center of the rose represents the percent of observations of wind speed less than 4 mph. The wind rose does not indicate explicitly the amount of missing data; however, the percentages graphed are percent of total number of hours in the 15-year period. The frequency of winds greater than 24 mph is often so small that the curves representing the frequency of all measurements greater than 4 mph and the one representing the data from 4 to 24 mph are indistinguishable.

1.1.2 Distribution of Wind Speed and Direction

Figures 14 through 26. Percentile Distribution of 19- and 150-foot Wind Speed (mph). Monthly and Total Period. January 1950–December 1964.

These figures give the 25-, 50-, 75-, 90-, 95- and 99-percentile values of hourly wind speed for each month and year. The percentile values were calculated from frequency distributions based on the wind speed observations grouped into 2-mph speed intervals. Figure 3 indicates schematically the percentile values assigned to the bars of the histogram.

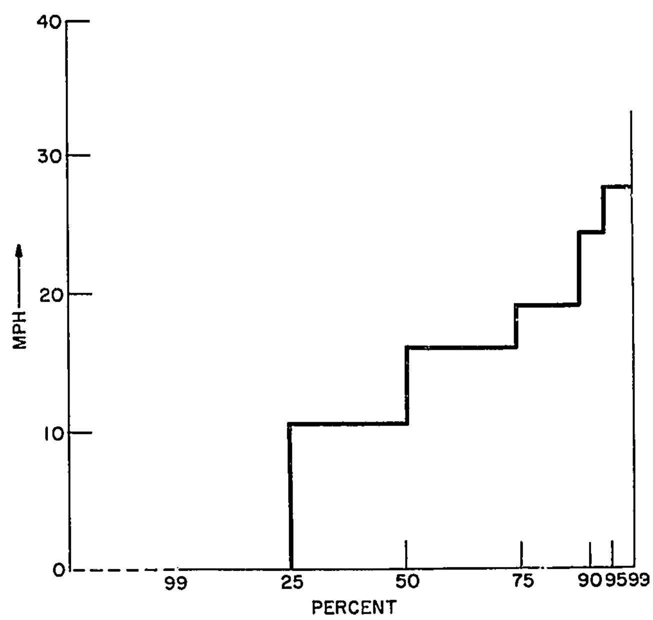


Figure 3

Percentile Values Assigned to the Bars on the Histogram

Tables 1 through 39. Percentage Frequency and Mean of 19- and 150-foot Wind Speed (mph) for Indicated Wind Direction. Monthly and Total Period. January 1950–December 1964.

These tables present the monthly and annual joint percentage frequency distribution of wind speed and direction during all hours of the day, during the hours 0700-1800 CST, and during the hours 1900-2400 CST at the 19- and 150-foot levels. There are three series: Tables 1-13, Tables 14-27, and Tables 28-39 for each grouping of hours as given above.

The tabular presentations above have been combined and presented in graphical form in Figures 8-13. Figures 8 and 9 are based on data from Tables 1-13; Figures 10 and 11 on the data from Tables 14-27; and Figures 12 and 13 on the data from Tables 28-39.

The tabular column "mean speed" contains the average of all wind speeds from the indicated direction. These averages are based on the values of the individual wind speed measurements and not on the mean value of the speed intervals.

The category "calm" appears both under speed and direction and in a few cases a direction is sometimes given where the speed was indicated calm and the speed recorded with a calm direction. This apparent discrepancy arises from the use of the automatic data processing system since this equipment records a 10-minute integrated Aerovane wind direction position whether wind is present or not. Before the installation of the automatic data processing system wind directions were forced to read calm if the wind speed was less than 1 mph.

Tables 40 through 44. Percentage Frequency, Mean and Percentile Distribution of 19-foot Wind Speed (mph) for Each Hour of the Day. Monthly and Total Period. January 1950–December 1964.

This set of tables presents the wind speed distribution for each hour of the day at the 19-foot level. In addition, for each hour the mean, 25-, 50- (median), 75- and 90-percentile values and extreme of hourly wind speed are shown. The mean wind speed for each hour and for each of the months represents the sum of the hourly wind speed values divided by the total number of hourly observations other than missing. The percentile values were calculated from frequency distributions based on 2-mph wind speed groupings.

The diurnal variation of the wind speeds is shown clearly in these tables. An examination of the mean or median column shows the highest values occurring in the midafternoon between 1300 or 1400 CST, with the lowest values occurring in the early morning just before sunrise. The extreme speeds, of course, depend upon the large-scale synoptic conditions and may occur during any part of the day. Also of interest is the appreciably greater frequency of calms during the night and the corresponding lower frequency during the middle of the day.

Tables 45 through 47. Mean and Percentile Distribution of 150-foot Wind Speed (mph) for Each Hour of the Day. Monthly and Total Period. January 1950–December 1964.

These tables present the mean, 25-, 50-, 75-, and 90-percentile values and the extreme value of 150-foot wind speed for each hour of the day. These values were determined as in Tables 40 through 44. At the 150-foot level, the diurnal variation of wind speed has a lower amplitude than at the 19-foot level. Nevertheless, the midday maximum and early morning minimum are still evident. As may be expected, the extreme speed values at the 150-foot level are higher than those at the 19-foot level.

Tables 48 through 51. Percentage Frequency Distribution of 19-foot Wind Direction for Each Hour of the Day. Monthly and Total Period. January 1950–December 1964.

This group of tables presents the percentage frequency distribution of wind direction to eight points of the compass. The 36-point hourly readings were converted to the eight-point scale shown in Figure 2. These tables show the effect of the lake breeze on Argonne observations. This effect is most pronounced during the afternoon hours of the spring and summer months when the percentage frequencies show an increase in winds from an easterly direction and a corresponding decrease in directions from the southwest.

1.1.3. Wind Direction and Speed Persistence

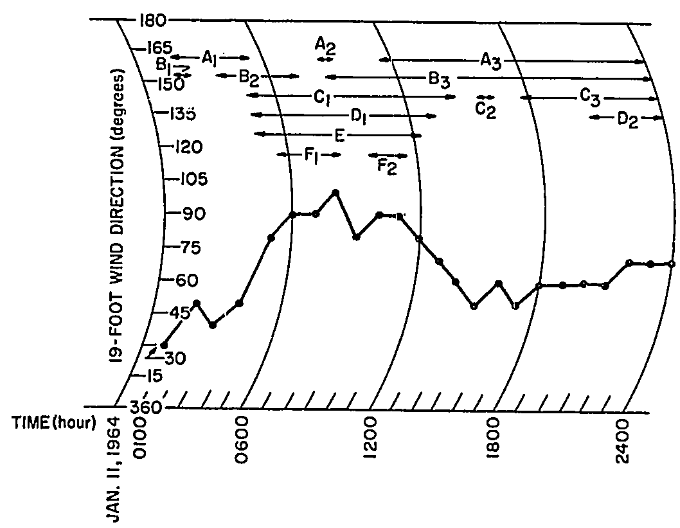
Tables 52 through 64. Frequency Distribution of the Number of Consecutive Hours of 19- and 150-foot Wind Direction Persistence from Indicated Directions. Monthly and Total Period. January 1950–December 1964.

These tables present frequency distributions of the number of consecutive hours during which the hourly value of wind direction was recorded within 50-degree intervals centered on each of the 36 points of the compass. For example, within the 50-degree interval centered on the 080-degree direction, winds recorded as 060, 070, 080, 090 and 100 degrees would be considered. Readings from any of these directions would initiate counting of the number of hours of persistence. The number of hours of persistence were determined from an item count of the number of consecutive hourly observations of wind direction within the 50-degree sector. Each hourly observation, therefore, was used five times in the tables, because 50-degree intervals centered at each of thirty-six points must overlap. Fluctuations which occurred between hourly readings were not considered. The number of hours of persistence ended if one hourly observation was calm, missing, or outside the defined interval. A period of persistence which began in one month and ended in the following month was counted with the data of the month in which it began. The last line of these tables labeled "maximum persistence" gives the maximum number of hours during which the wind persisted within the indicated direction sector. Figure 4 presents a sample plot of hourly wind direction and illustrates persistences which would be counted for the direction sectors 6 through 11.

Tables 65 through 71. Frequency Distribution of the Number of Consecutive Hourly 19- and 150-foot Wind Speeds (mph) above Indicated Values. Monthly and Total Period. January 1950–December 1964.

These tables present the frequency distribution of the number of consecutive hourly values of wind speed above specified values. Figure 5 indicates the method of counting the number of hours of wind speed persistence. The number of hours of persistence ended if the data were missing or the hourly reading reached or fell below the specified value. Hourly wind speeds recorded to tenths were not rounded for these tables; therefore, persistence above calm was ended only if missing data or wind speed of 0.0 mph was recorded. As in the direction persistence tables, a period which began in one month and continued into the next month was counted with the month during which it began. The last line of these tables labeled "maximum persistence" presents the maximum number of consecutive hours the hourly wind speeds exceeded each value. Note the change in the class intervals of the number of hours of persistence which produces pseudomodal values in the distribution.

Figure 4. Method for Counting Wind Direction Persistence from the Indicated Directions



Label	Direction	Time of Persistence	No. of Hours
A_1	6	0200-0500	4
A_2	6	0900	1
A_3	6	1200-2400	13
B_1	7	0200	1
B_2	7	0400-0700	4
B_3	7	0900-2400	16
C_1	8	0500-1400	10
C_2	8	1600	1
C_3	8	1800-2400	7
D_1	9	0500-1300	9
D_2	9	2100-2400	4
E_1	10	0500-1200	8
F_1	11	0600-0800	3
F_2	11	1000-1100	2

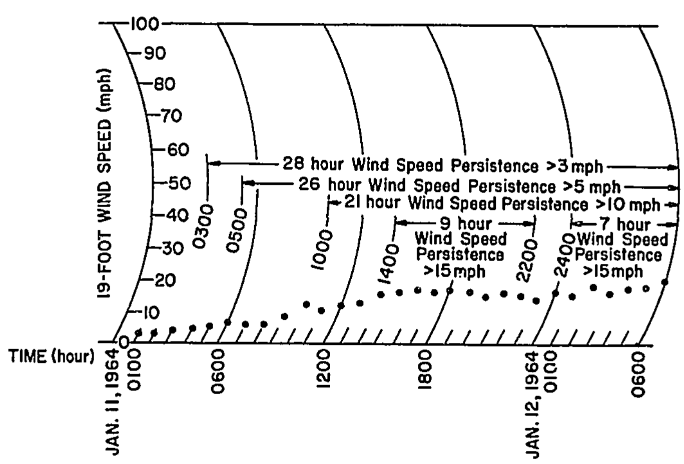


Figure 5
Method for Counting Wind Speed Persistence above Indicated Values

These tables bring out the relative infrequency of long periods of high winds. For example, during the 15-year period there was no 24-hour period during which the wind speed remained above 20 mph and no 48-hour period when the wind remained above 15 mph at the 19-foot level.

Tables 72 through 84. Frequency Distribution of the Number of Consecutive Hourly 19-foot Wind Speeds (mph) above Indicated Values When the Wind Direction Is within Specified Quadrants. Monthly and Total Period. January 1950–December 1964.

These tables are constructed similarly to Tables 65 through 71 except for the additional restriction of wind direction from a specified quadrant. The period of persistence, therefore, was terminated not only for missing data and wind speeds below the threshold level but also for directions outside the specified quadrant. The northeast, southeast, southwest and northwest quadrants defined as 6 to 95^c, 96 to 185°, 186 to 275° and 276 to 5° respectively were used. The explanatory comments made concerning the previous set of tables also apply here.

1.1.4 Peak Gust Speed and Wind Speed Range

Table 85. Percentage Frequency Distribution of Time of Daily Peak Wind Gust. January 1950–December 1964.

This table presents the percentage frequency of the occurrence of the daily peak gust within specified time intervals. The daily peak wind gust represents the highest instantaneous value for the day as read from the Esterline-Angus recorder chart trace. It is interesting to note that the daily peak gust occurs more frequently during the day in the summer months.

Of significance, especially for air pollution problems, are the minima in the distribution shortly after sunrise and sunset. This phenomenon may well be related to reduced vertical mixing since infrared photographs indicate that temperature fluctuations and surface temperature gradients also have minima at these times.

Table 86. Percentage Frequency Distribution of Daily Peak Gust Magnitude (mph). January 1950–December 1964.

Little variation is evident in the distribution of the magnitude of daily peak gusts from month to month. Of interest is the fact that there was no day during which the wind remained below 5 mph and only 1.61 percent of the days during which the wind remained less than 10 mph for the entire day at the 19-foot level.

Table 87. Maximum Daily Peak Wind Gust (mph) for Each Month and Year. January 1950–December 1964.

Strong wind gusts may occur in any month; however, the highest recordedgusts at 19 and 150 feet were associated with thunderstorms in July 1957 and June 1964, respectively.

Figure 27: Annual Peak Gusts (mph). January 1950–December 1964.

This figure presents the annual peak gust speeds at 19- and 150-foot levels plotted on an arithmetic normal probability scale. The lines fitted to the data were drawn through values of the mean and standard deviation computed from the data samples. Peak gusts are bounded on the low size at zero; therefore, the Fisher-Tippett Type II distribution perhaps provides a better fit. The straight lines on Figure 27, however, indicate that for this sample the normal probability distribution will serve to describe the sample and the underlying distribution. No tests of the null hypothesis have been made for the skew and kurtosis.

Tables 88 through 90. Percentage Frequency Distribution of 2-hour, 11-hour and 23-hour Range of 19- and 150-foot Wind Speed (mph) Beginning with Indicated Hour. Total Period. January 1950–December 1964.

These tables present percentage frequency distributions of the 2-hour, 11-hour and 23-hour range of the wind speed for periods beginning with the indicated hours. The ranges were calculated before the wind speeds were rounded.

The 2-hour ranges indicate that in over 90 percent of the cases change in wind speed in two hours was less than 6 mph at 19 feet and 7 mph at 150 feet.

The 11-hour range distribution shows appreciable variations in wind speed in 11 hours with the maximum percent of the ranges being between 6.0 and 6.9 mph at 19 feet and between 8.0 and 8.9 mph at 150 feet.

The 23-hour range distribution at 19 feet indicates that 85 percent of the ranges are less than 14.9 mph with 42 percent being between 10.0 and 14.9 mph. The wind speed has varied at least 2 mph in any 23-hour period. The 150-foot range distribution shows 32 percent of the ranges greater than 15 mph while there were no cases of wind speed varying less than 3.0 mph in the 23-hour period.

1.1.5 Interlevel Wind Speed Relationships

There are a variety of ways to express the variation of wind speed with height. Among these are the logarithmic law, the log plus linear law, Deacons' law and the power law. In this report, the power law is adopted for study since it is used very frequently for engineering problems.

The power law may be expressed as

$$U/U_1 = (Z/Z_1)^P, \qquad (1)$$

where

U is the wind speed at height Z

U_1 is the wind speed at height Z_1

p is the exponential parameter.

According to Sutton,[11] $p = n/(2 - n)$, where n is a parameter of diffusion. He assumes that this same n appears in his equation describing diffusion from a point source at ground level:

$$\chi = \frac{2Q}{\pi C_y C_z U X^{2-n}} \exp\left(-\frac{Y^2}{C_y^2 X^{2-n}} - \frac{Z^2}{C_z^2 X^{2-n}}\right), \qquad (2)$$

where

χ = concentration of contaminant at distance X from the source

U = wind speed

n, C_y, C_z = diffusion parameters

X, Y, Z = coordinates with the origin at the source

Q = source strength

Figure 6 gives the relation between suggested values of n and p for various stability categories.[11]

Figure 6. Values of n, p and Stability

n	p	Stability
0.20	0.11	Unstable
0.25	0.14	Neutral
0.33	0.20	Moderately Stable
0.50	0.33	Very Stable

Tables 91 through 97. Percentage Frequency Distribution of p-values Based on 19- and 75-foot Wind Speeds (mph) for Each Hour of the Day. Monthly and Total Period. January 1961–December 1964.

Hourly values of p were calculated from hourly wind speed observations at the 19- and 75-foot levels according to Equation 1. If the 19-foot wind speed was 0.0 mph the p-value was considered missing. Figure 7 shows the p-value intervals which are represented by the modal values. As indicated in this figure, p-value intervals are centered about the values of n frequently used in diffusion work.

Figure 7. Group Intervals Represented by p-value Headings

p-value	Group Interval Represented	p-value	Group Interval Represented
0.035	≤0.035	0.20	0.186-0.215
0.05	0.036-0.065	0.25	0.216-0.285
0.08	0.066-0.095	0.33	0.286-0.375
0.11	0.096-0.125	0.45	0.376-0.525
0.14	0.126-0.155	0.60	0.526-0.675
0.17	0.156-0.185	0.676	≥0.676

These tables show that relatively lower p-values occur during the day and higher values at night. Low values of p indicate that there is considerable turbulent mixing. Under this condition air with greater momentum in the upper layers is mixed with air in the lower layers resulting in relatively small variation of wind speed with height. At night under stable conditions the atmosphere is stratified, mixing is reduced and the wind speed increases more rapidly with height.

In the January distribution, the most frequent values of p during the daytime and nighttime hours are 0.11 or 0.14, corresponding to n-values of 0.20 or 0.25. In July the most frequent values are 0.33 or 0.45, corresponding to n-values of 0.50 or 0.62.

Tables 98 through 99. Joint Percentage Frequency Distribution of p-values Based on 19- and 75-foot Wind Speeds (mph) and 19-foot Wind Speed (mph). Monthly and Total Period. January 1961–December 1964.

The relationship between p-values and wind speed at 19 feet is shown in this set of tables. For these tables, wind speeds of 0.0 to 0.5 mph were considered missing.

When the winds are less than 8 mph the tables show that p-values of 0.25, 0.33 or 0.45 are most frequent, but for speeds exceeding 8 mph p-values of 0.11 or 0.14 are most frequent. The light winds and high p-values are associated with nocturnal inversions. Many of the monthly tables show two maxima–one for daytime and one for nighttime conditions.

Table 100. Percentage Frequency Distribution of the Difference between p-values Based on 19- and 75-foot Wind Speeds (mph) and p-values Based on 19- and 150-foot Wind Speeds (mph) for Each Hour of the Day. Total Period. January 1961–December 1964.

If the p-values were representative of all levels on the tower, all of the data would be found in the 0.0 column. However, we see that an appreciable percentage of the observations falls outside of this column, that is, the p-values based on the 19- and 150-foot levels differ from those based on the 19- and 75-foot levels. More values were found to the left of the 0.0 column indicating that the wind speed at the 150-foot level was usually greater than expected from the power law calculations based on the 19- and 75-foot levels. There are two reasons for this: one, the tower acts as an obstruction providing higher wind speeds at the top than the true wind speed because of the Bernoulli effect;[12] and second, especially during the night, the wind speeds at the higher levels increase more rapidly than indicated by a power law based on speeds measured at lower levels. A plot of ln z versus ln u with u as the abscissa and z as the ordinate is therefore nonlinear and concave downward. This table does show that during the daylight hours most of the observations appear to follow the power law fairly well, but during the nighttime hours considerable deviation occurs.

Table 101. Joint Percentage Frequency Distribution of the 19-foot Wind Speed (mph) and the Difference between the 150-foot Wind Speed Calculated from p-values Based on 19- and 75-foot Wind Speeds (mph) and the Observed 150-foot Wind Speed (mph). Total Period. January 1961–December 1964.

The 150-foot wind speed was calculated from the p-values based on 19- and 75-foot wind speeds, i.e., p-values were calculated from observed 19- and 75-foot wind speeds using Equation 1 and these values of p and the 19-foot wind speed were then used in Equation 1 to calculate a wind speed value at 150 feet. About 68% of the calculated wind speeds are within 1 mph of the observed wind speed and 86% are within 2 mph of the observed speed.

Table 102. Joint Percentage Frequency Distribution of the 19-foot Wind Speed (mph) and the Difference between the 37-foot Wind Speed Calculated from p-values Based on 19- and 75-foot Wind Speeds (mph) and the Observed 37-foot Wind Speed (mph). Total Period. January 1961–December 1964.

The 37-foot wind speeds were calculated as the computed 150-foot wind speeds in the previous table. The 37-foot calculated wind speeds represent interpolation between the 19- and 75-foot levels, while the 150-foot calculated wind speeds are extrapolated from the 19- and 75-foot levels. Therefore, it would be expected that the 37-foot calculated wind speeds would be more accurate.

About 81 percent of the calculated speeds are equivalent to the observed values and over 93 percent are within 1 mph of the observed values.

Figure 8. Wind Roses Based on All Hourly Observations.
January 1950–December 1964. 19-foot Level

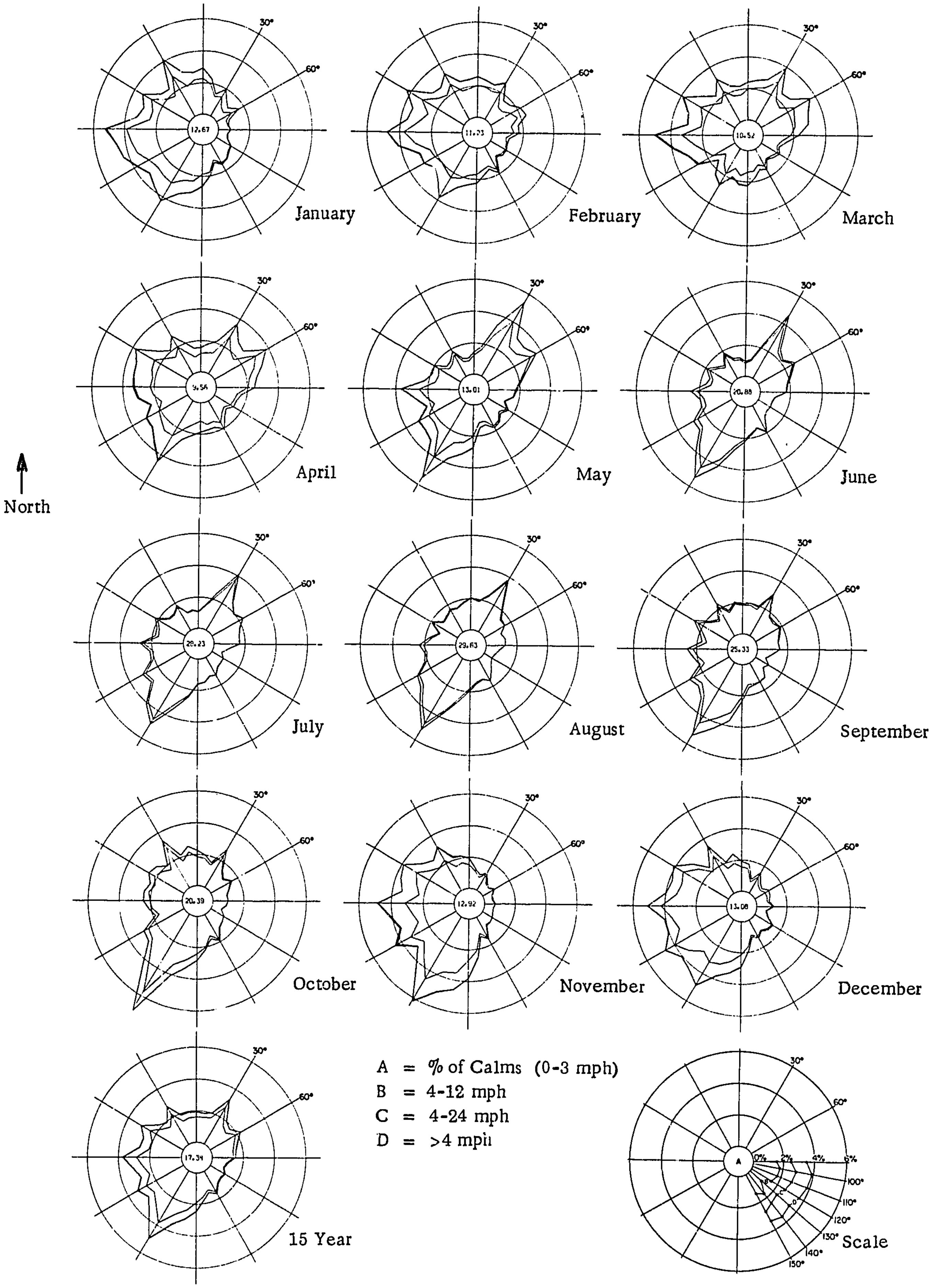


Figure 9. Wind Roses Based on All Hourly Observations. January 1950–December 1964. 150-foot Level

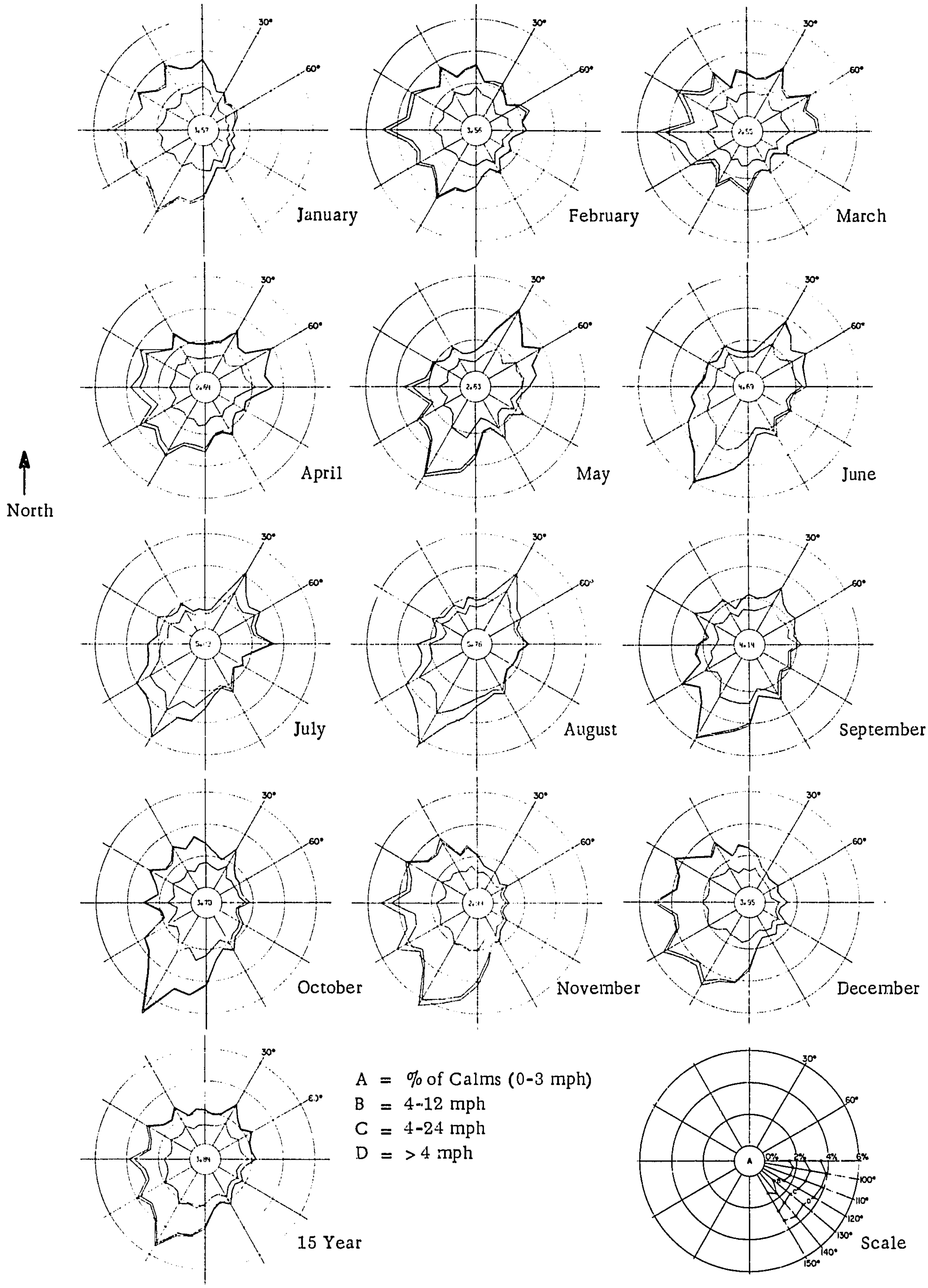


Figure 8. Wind Roses Based on All Hourly Observations. January 1950–December 1964. 19-foot Level

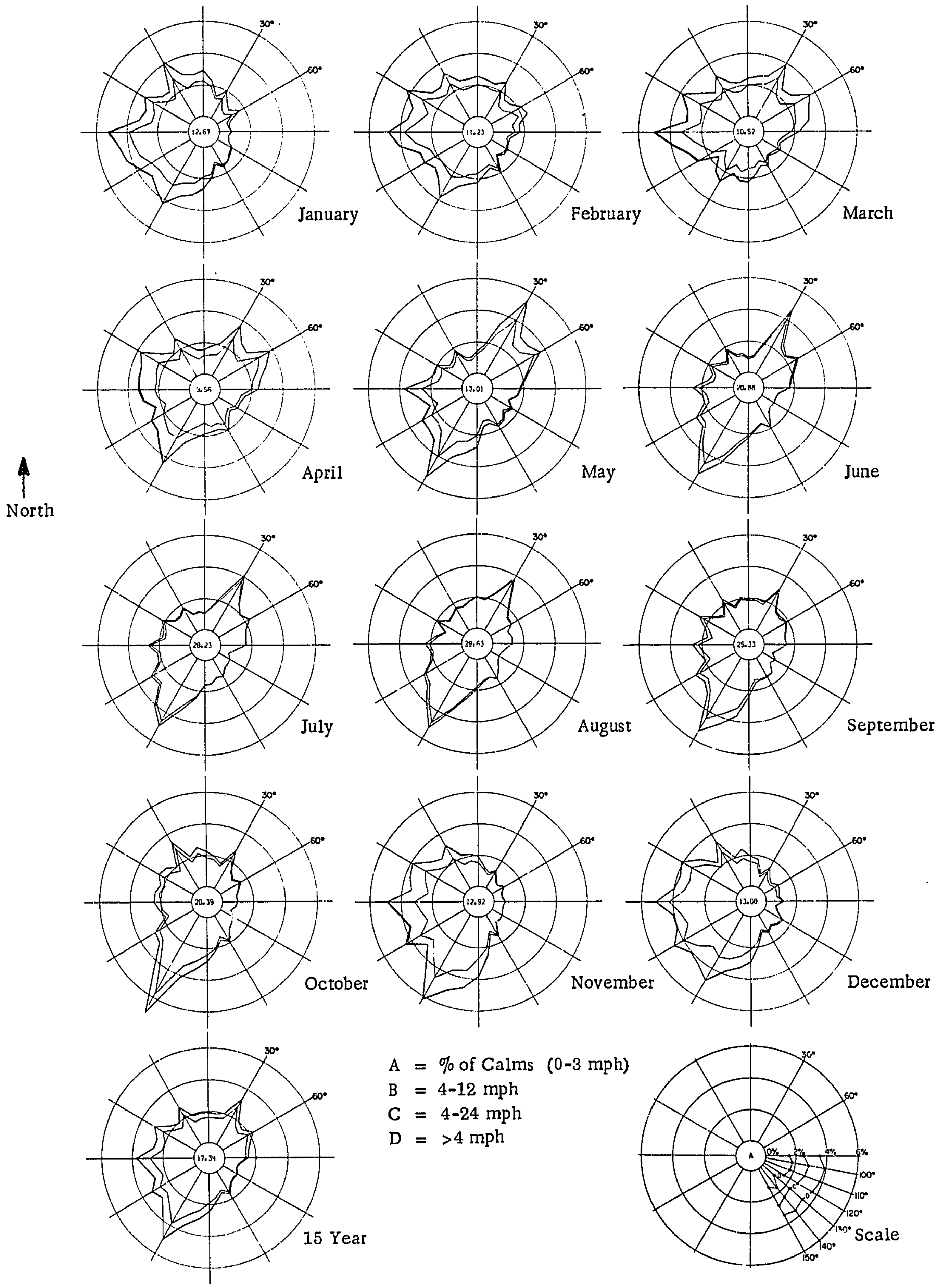


Figure 9. Wind Roses Based on All Hourly Observations. January 1950–December 1964. 150-foot Level

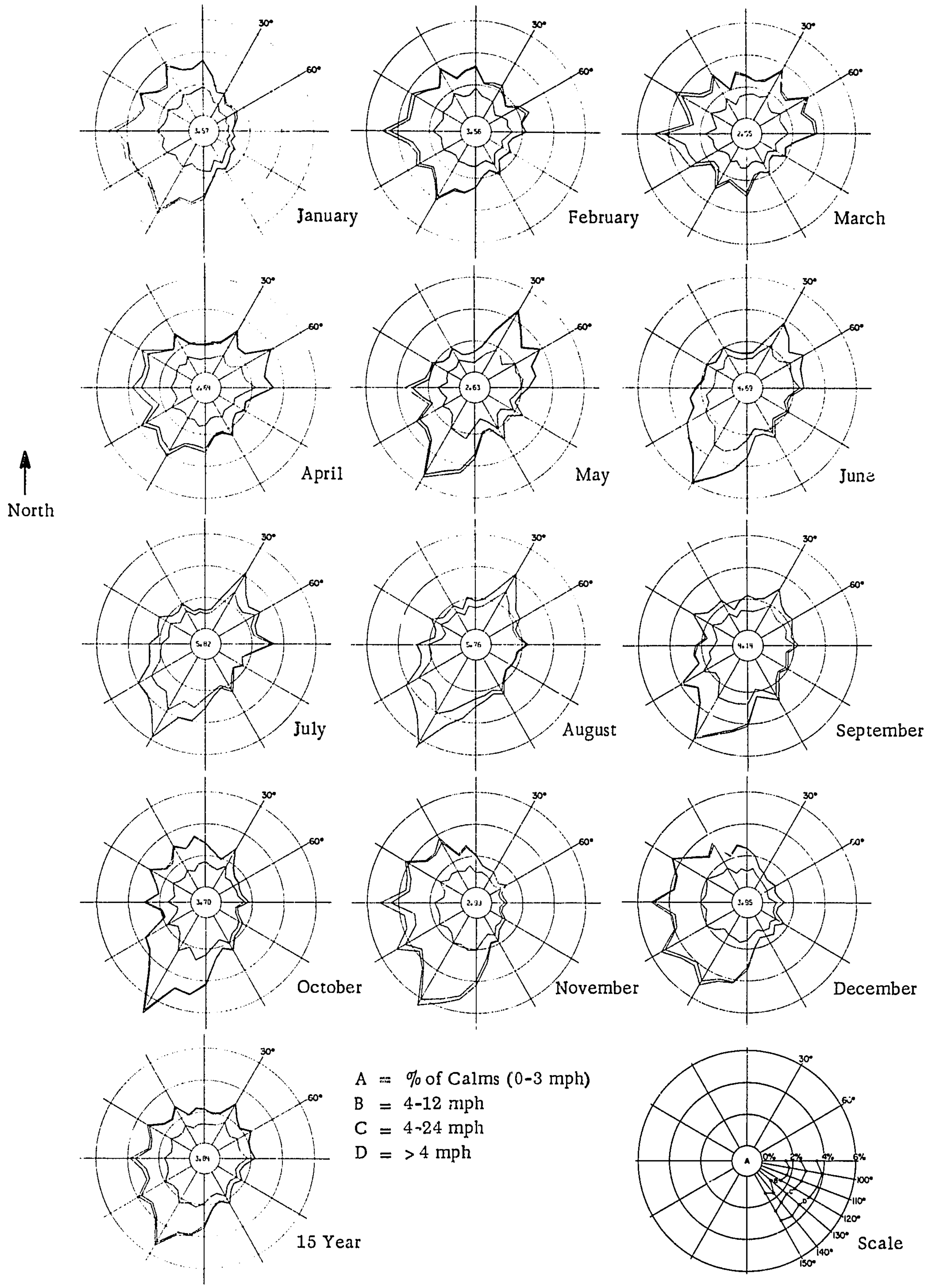


Figure 12. Wind Roses Based on Hourly Observations during the Hours 1900-0600 CST. January 1950–December 1964. 19-foot Level

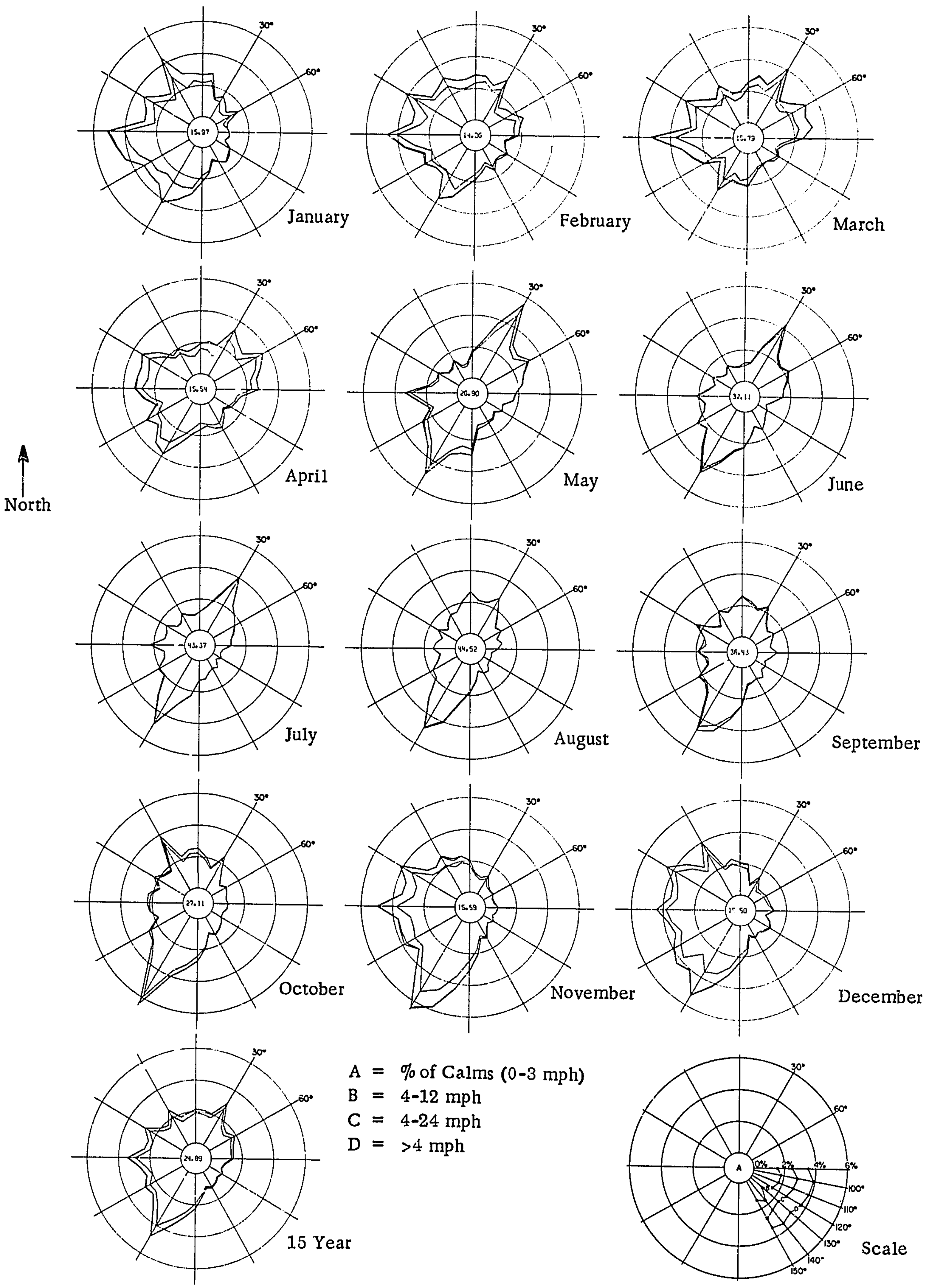


Figure 13. Wind Roses Based on Hourly Observations during the Hours 1900-0600 CST. January 1950–December 1964. 150-foot Level

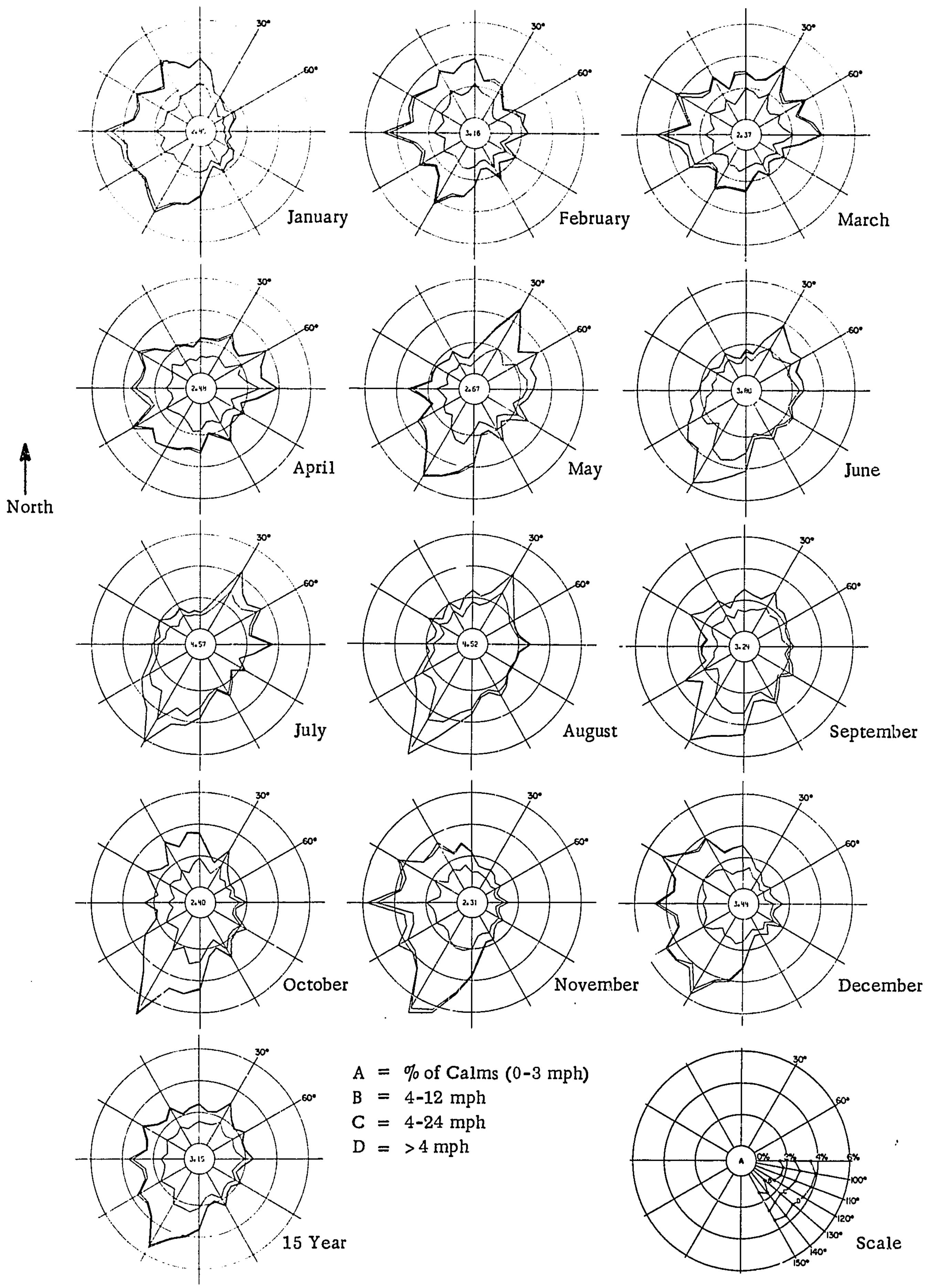


Figure 14. Percentile Distribution of 19- and 150-foot Wind Speed (mph). January 1950–1964

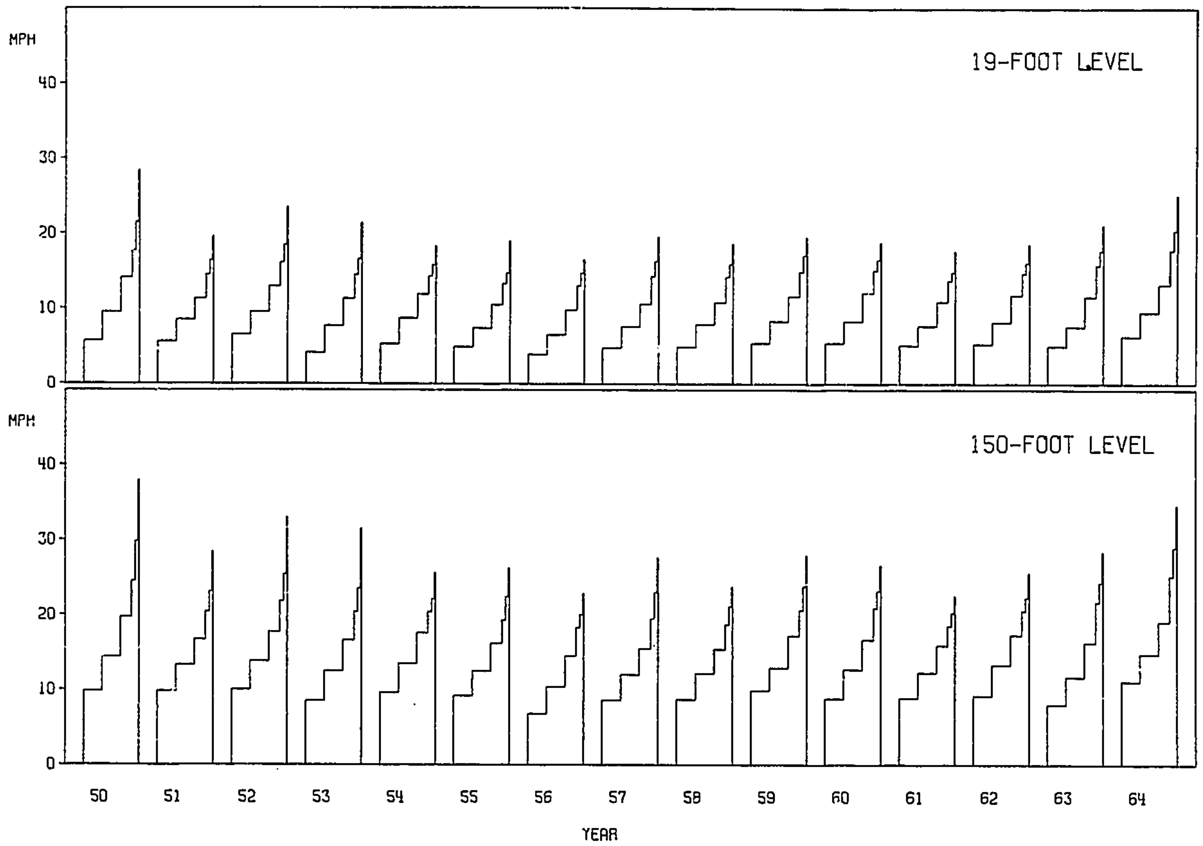


Figure 15. Percentile Distribution of 19- and 150-foot Wind Speed (mph). February 1950–1964

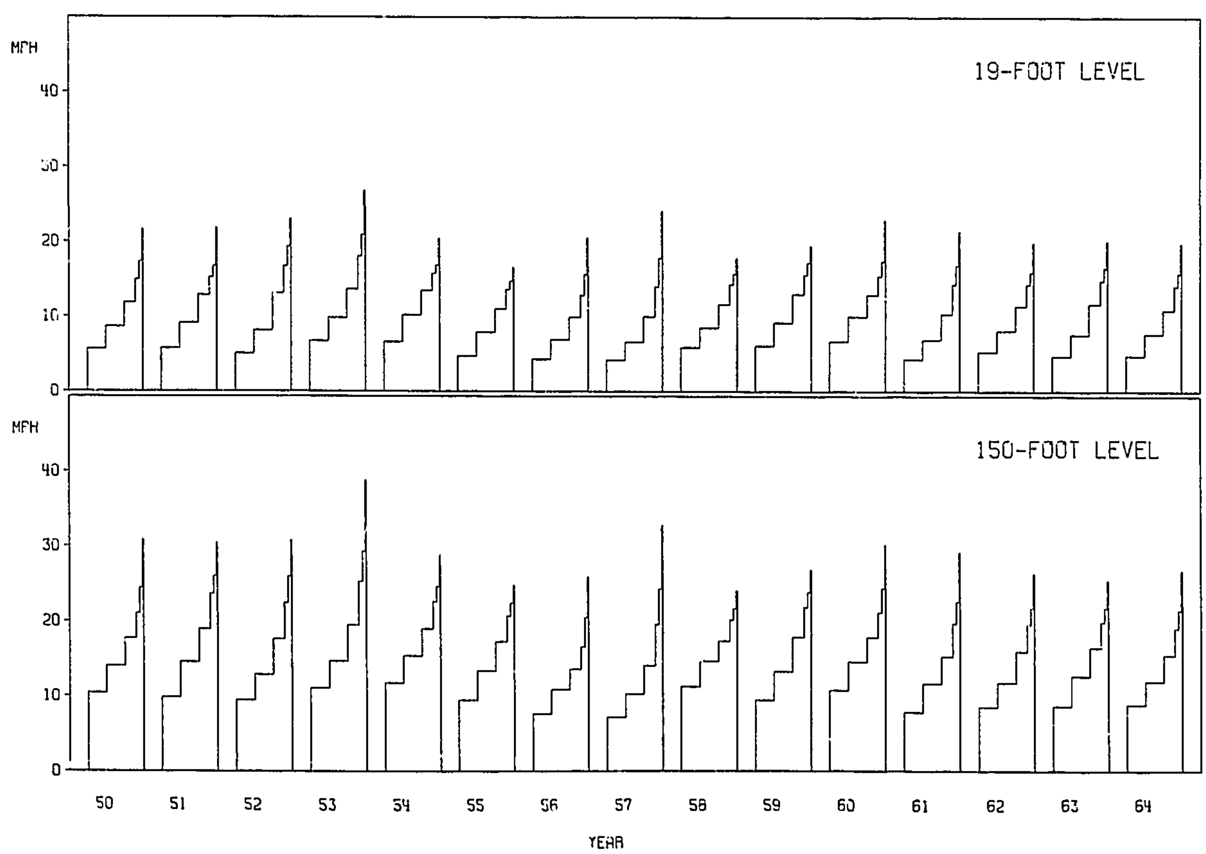


Figure 16. Percentile Distribution of 19- and 150-foot Wind Speed (mph). March 1950–1964

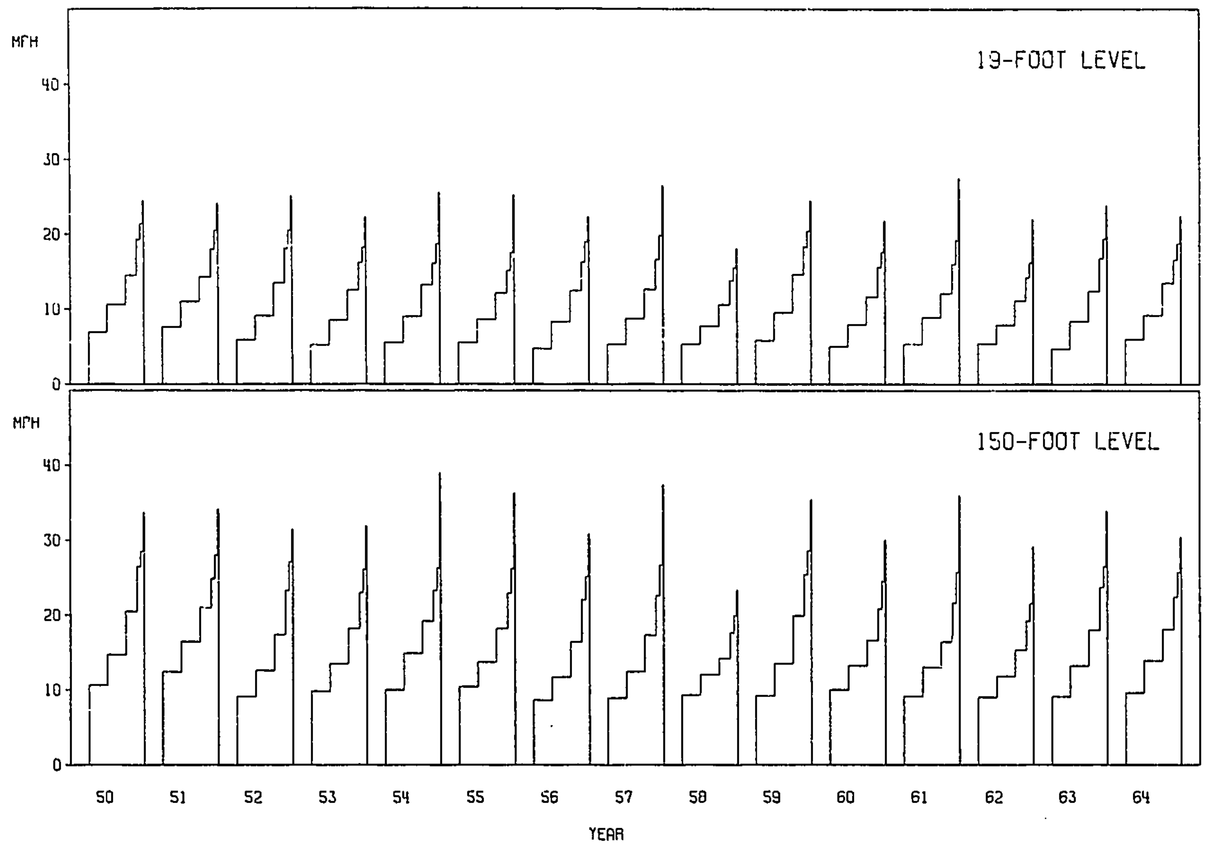


Figure 17. Percentile Distribution of 19- and 150-foot Wind Speed (mph). April 1950–1964

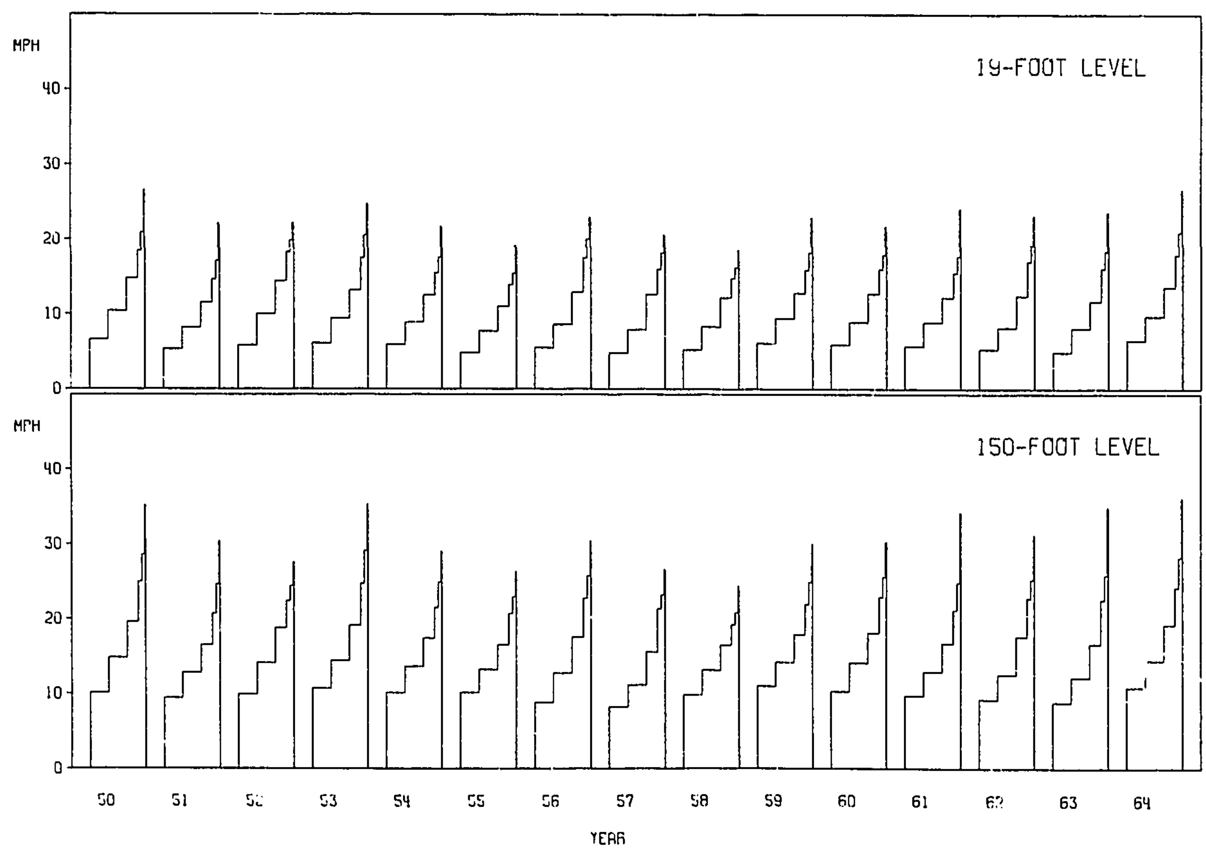


Figure 18. Percentile Distribution of 19- and 150-foot Wind Speed (mph). May 1950–1964

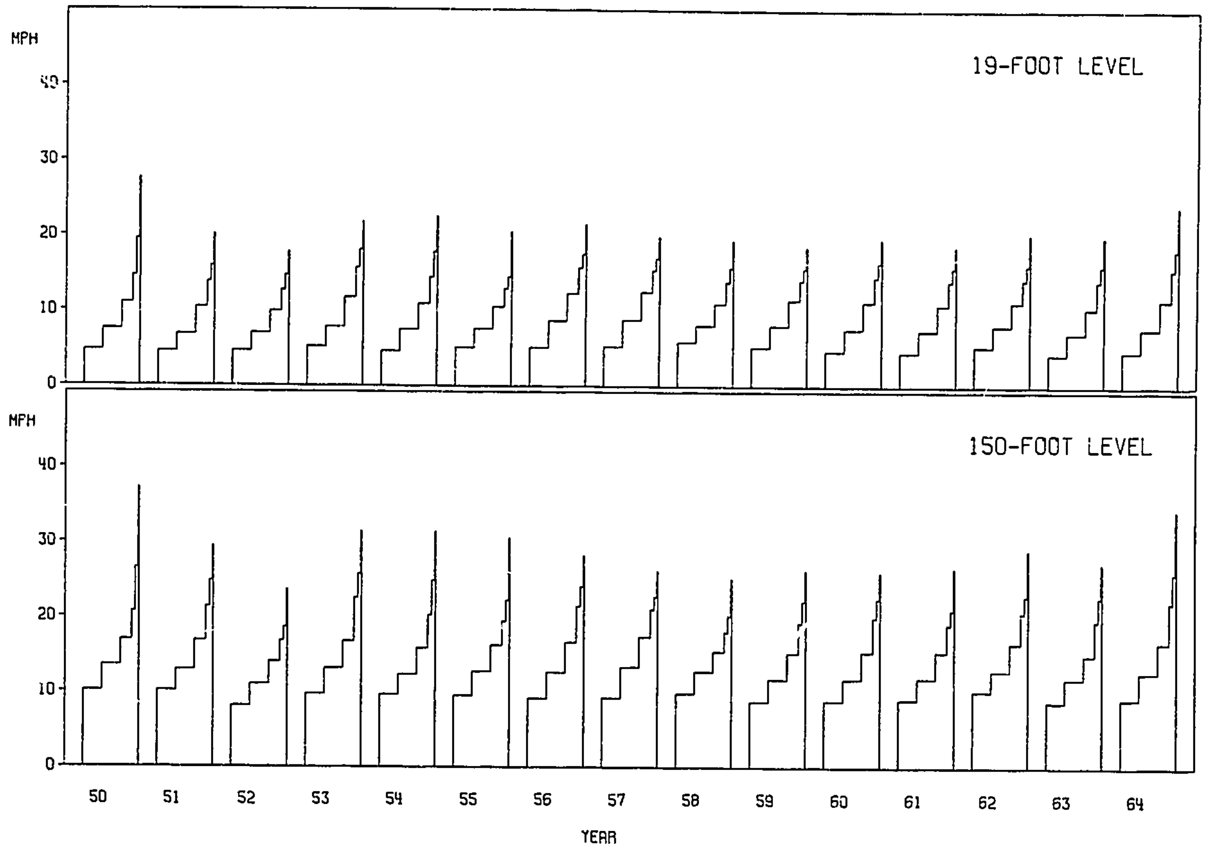


Figure 19. Percentile Distribution of 19- and 150-foot Wind Speed (mph). June 1950–1964

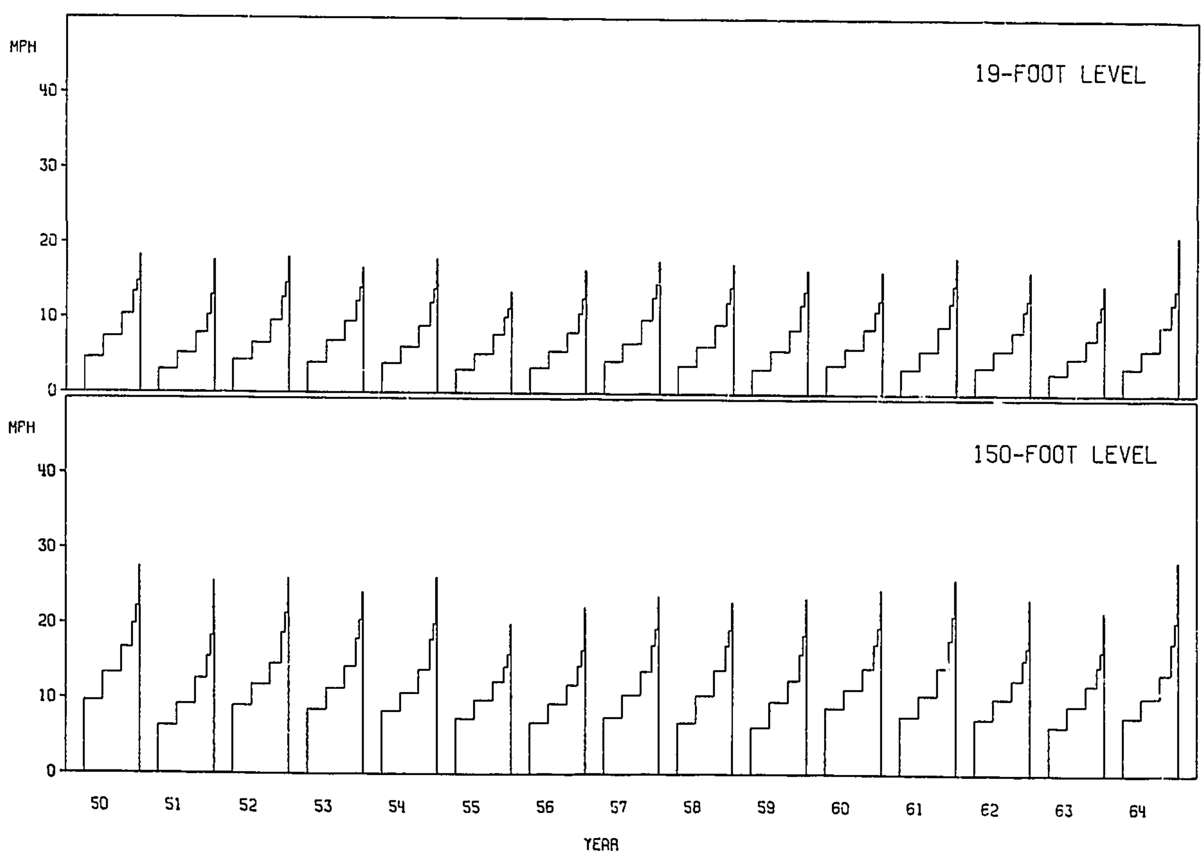


Figure 20. Percentile Distribution of 19- and 150-foot Wind Speed (mph). July 1950–1964

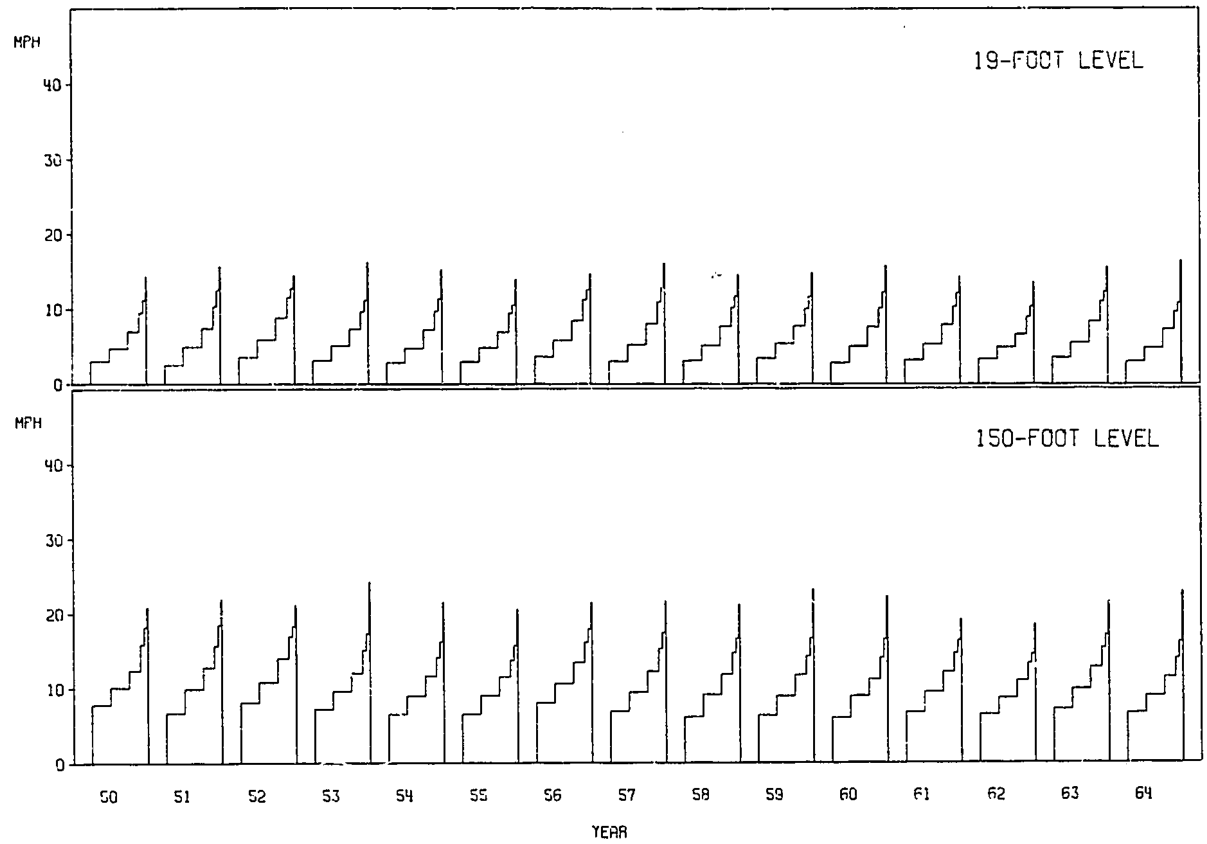


Figure 21. Percentile Distribution of 19- and 150-foot Wind Speed (mph). August 1950–1964

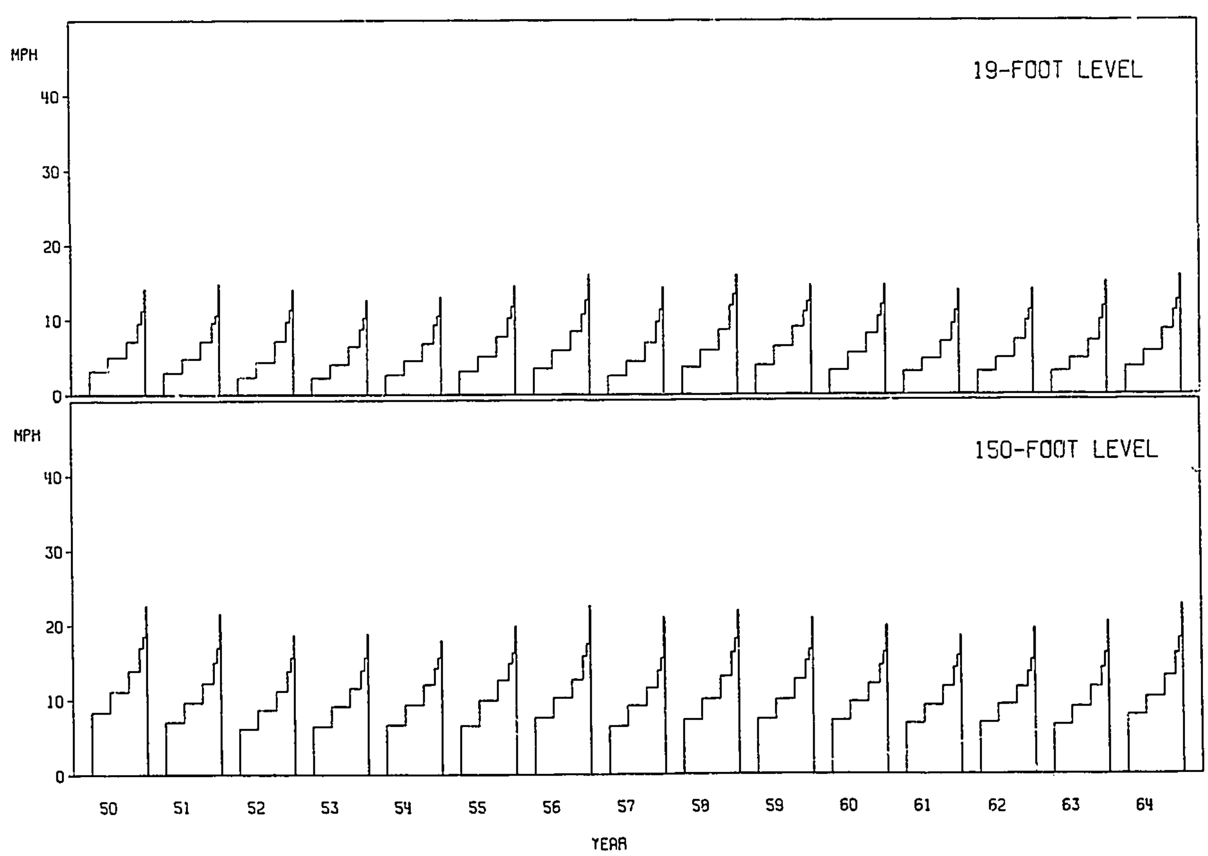


Figure 22. Percentile Distribution of 19- and 150-foot Wind Speed (mph). September 1950–1964

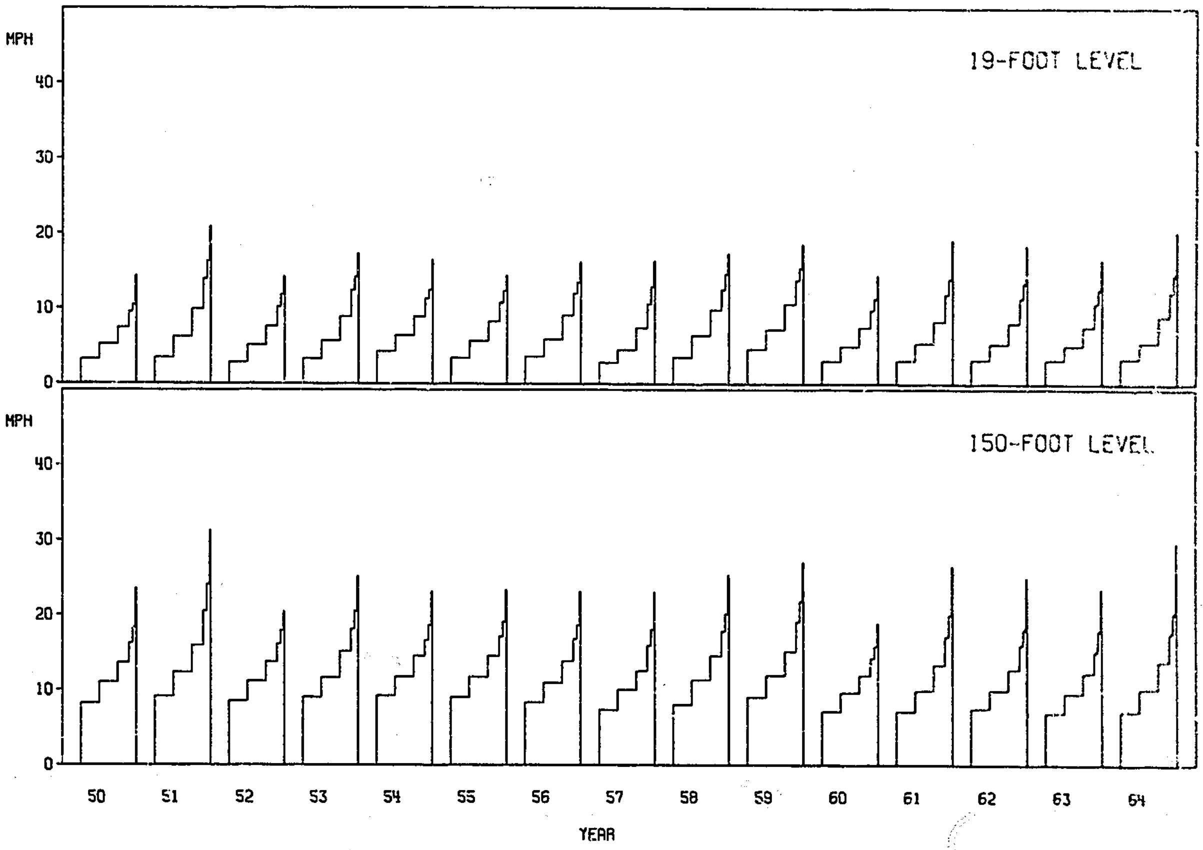


Figure 23. Percentile Distribution of 19- and 150-foot Wind Speed (mph). October 1950–1964