

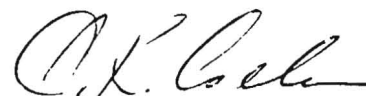
MARINE CLIMATOLOGICAL ATLAS
OF
LONG ISLAND SOUND

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May, 1996

MSRC Special Report No. 114
Reference No. 96-05



Approved by Dean K. Cochran



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ACKNOWLEDGMENTS

We thank Randall R. Young of the Waste Reduction and Management Institute for his assistance during all stages of this project and Hartmut Peters for the heavy use of his computer printer. Support for this project was provided by the Waste Reduction and Management Institute of the Marine Sciences Research Center.



I. INTRODUCTION

Weather and climate are major factors influencing the natural processes occurring in our coastal waters including Long Island Sound (LIS). Sunlight triggers the seasonal cycle of phytoplankton growth. Air temperature, the flow of freshwater, and wind control the development and breakdown of stratification of the Sound's water column. Precipitation generates stormwater runoff which is thought to transport excessive nutrient loads to LIS. These influences, in a variety of combinations, can possibly exacerbate hypoxic (low dissolved oxygen) events in the Sound.

While the importance of weather and climate on processes in the Sound is recognized, little effort has been made in understanding the nuances of the complex linkages between the atmosphere and the Sound. To further this understanding, we have summarized much of the existing data available from the National Oceanic and Atmospheric Administration's archives for the two weather stations with long-term observations bordering the Sound: LaGuardia Airport in New York City and Sikorsky Airport in Bridgeport, Connecticut. The data compiled in this atlas cover the period 1948-1992. This is a period of time over which we have experienced some major variability in weather and climate such as the drought of the 1960s, the cold winters of the late 1970s, and the warming trend in the late 1980s and early 1990s.

The data are presented graphically in order to assist one in visualizing changes in large data sets. It is presented to stimulate discussion about weather and climate and its relevance to observed changes in coastal processes. If we are to effectively manage our coastal waters, we must first understand what drives the natural processes within them. This atlas should be used in conjunction with the Marine Climatology atlas produced by Lettau *et al.* (1976).

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II. DATA SOURCES

The data used in the following analyses are part of the National Climatic Data Center's (NCDC) Tape Data Family-14 (TDF-14) and Surface Airways Hourly (TD-3280) archives and the National Oceanic and Atmospheric Administration's (NOAA) Monthly Weather Summaries. The TDF-14 and TD-3280 archives bring together weather observations from numerous sites in the United States and report a variety of weather information. Included in the present work are observations of wind speed and direction, wet and dry bulb air temperature, sea level atmospheric pressure, cloud cover, and the occurrence of precipitation of various types and intensities. The NOAA Monthly Summaries provided monthly precipitation amounts.

To characterize the meteorological conditions affecting Long Island Sound, we focused on observations from LaGuardia Airport in New York City at the western end of the Sound and Sikorsky Airport in Bridgeport, Connecticut along the north shore of the Sound (Fig. 1). The study utilizes observations made at the two sites from July 1948 to December 1992. The observations were initially made at hourly intervals, switched to 3-hourly intervals in 1971 at LaGuardia and 1965 at Bridgeport, and finally returned to hourly intervals in 1981 at both stations. In addition, the Bridgeport station reported no data during nighttime hours (typically 21:00 to 04:00 local time) from 1953 to 1960 and after 1981.



III. METHODS OF ANALYSIS

The results to be presented are divided into two parts. Following Lettau *et al.* (1976), we first present, in section IV, mean monthly averaged values of selected meteorological quantities over the entire 45 year record. This is intended to illustrate the basic seasonal climatology at each of the two stations. Section V focuses on long term changes in these meteorological variables. Here we calculate individual averages for each month of the record and present them in the form of contour plots on month-year axes. In some cases we calculate a monthly anomaly, which is defined as the difference between a particular monthly value and the average for that month over the entire record.

III.a. Wind

Knowledge of the wind field over a water body is of crucial oceanographic importance. It affects the transfer of heat, momentum, and chemical species across the air-sea interface and is also useful in predicting the wave climate and the movement of floatables on the sea surface. Wind direction observations before 1964 were recorded in 22.5 degree intervals with 16 such "points" defining the full 360 degree azimuthal range of the wind. From 1964 to 1992, wind directions were observed in 10 degree intervals. For consistency, these values were converted to the prior 16 point code and this convention is used in all of our results. In this report, we adhere to the meteorological convention in that wind directions refer to the direction from which the wind blows.

Section IV presents several measures of the average winds during each month at the two stations. Wind speed histograms and wind roses show the frequency of occurrence of wind of different strengths and different directions respectively. We also show in wind rose form the average wind speed as a function of wind direction. The climatological or resultant wind vector can be calculated by assuming that wind observations represent sequential displacements of an air parcel. The resultant wind is the vector representing the sum of displacements of the parcel divided by the total time over which the displacement occurs (Lettau *et al.*, 1976). For the case of the resultant wind vectors presented in section IV, the sums for each month were performed over the entire 45 year record for that particular month. The magnitude of the resultant wind vector must be less than or equal to the average speed calculated without regard to direction. The ratio of the resultant wind magnitude to the average speed, known as the persistence, is a measure of the steadiness in direction of the wind (Lettau, *et al.*, 1976). A value of 100% indicates that the wind blows steadily from a particular direction, while a value of 0% indicates that the wind direction is completely random. The wind persistence is calculated for the two stations and is plotted versus month in section IV.

In addition to monthly wind values averaged over the entire record, we also present the diurnal variability of the wind. The average diurnal variability of wind speed is shown in plots of average wind speed as a function of time of day. Average diurnal variability of wind direction is illustrated by the presentation of wind direction histograms for each of four 6-hour periods during the day. The diurnal variability of the



resultant wind was investigated by computing the resultant for specific time periods during the days of a particular month. The results are presented as a diurnal anomaly, the difference between the resultant for that time period and the mean monthly resultant for that month.

Long term changes in monthly averaged winds are presented as contour plots in section V. Here we plot average wind speed and persistence for each individual month of the 45 year record. We also present plots of monthly anomalies for these quantities.

III.b. Air Temperature

From an oceanographic point of view, air temperature is an important meteorological variable because of its influence on heat transfer between the atmosphere and ocean. Temperature observations were recorded in degrees Fahrenheit and were converted to Celsius for this report. In section IV, cumulative frequency distributions of wet and dry bulb temperature for each month are presented. The monthly cumulative frequency at any given temperature represents the percentage of observations during a particular month that fall below that temperature. The width of the frequency distribution is a measure of the variability of temperature during that month. The effect of wind direction on the observed dry bulb air temperatures was investigated by computing the average temperature for each of the 16 wind directions for each month over the whole record.

Long term changes in wet and dry bulb air temperature are presented in two ways in section V. Both monthly averaged temperature and monthly averaged temperature anomaly are contoured versus month and year. The temperature anomaly for a month is calculated by subtracting the mean monthly average from the average over that same month.

III.c. Sea Level Atmospheric Pressure

Sea level pressure (millibars) is the station atmospheric pressure corrected to sea level. Sea level pressure is presented in a similar fashion as temperature. We show the cumulative frequency distributions of pressure for each month (section IV), as well as monthly average and monthly anomaly sea level pressure contour plots (section V).

III.d. Sky Cover

Total sky cover (tenths) is the fraction of the celestial dome that is covered by clouds. Total opaque sky cover is the fraction covered by clouds through which the sky or higher clouds cannot be seen. We have plotted both of these quantities as monthly averages for the two stations in section IV. Because of the similarity of the results (average opaque sky cover is slightly lower than total sky cover), only total sky cover is



plotted in section V. There we contour monthly averaged total sky cover and anomaly (computed as for temperature and pressure) versus month and year.

III.e. Precipitation

The NCDC's weather observations note the presence or absence of different types of precipitation. These include rain, snow, sleet, freezing rain, ice pellets, drizzle, showers, and thundershowers. These types are subdivided into the categories light, moderate, and heavy. The precipitation data contained in the NOAA Monthly Weather Summaries are monthly precipitation amounts, in inches of liquid precipitation.

We present, in section IV, the average frequency of occurrence of different types and intensities of precipitation for each month. Here we count all types of frozen precipitation as snow. Also, since the number of observations of light intensity precipitation far outstrips the number of observations of moderate and heavy precipitation, we have chosen to group the latter together. Thus, in the plots in section IV, heavy precipitation actually refers to either heavy or moderate precipitation. The frequency of occurrence of different types of precipitation as a function of wind direction for each month is also given in section IV. The types of precipitation analyzed here are rain, drizzle, and snow (all frozen precipitation). Finally, we compute average monthly precipitation amounts at the two stations.

Long term precipitation patterns are investigated by plotting monthly precipitation versus month and year in section V. We plot monthly anomalies in addition to monthly amounts over the entire record.



IV. MEAN MONTHLY CLIMATOLOGY

IV.a. Wind

IV.a.1. Wind Direction and Speed

The monthly wind roses shown in Figures 2 and 3 display the frequency of observation of wind blowing from a given direction. A distinct seasonal cycle is apparent at both stations. Winds from the northwest quadrant dominate in winter while summertime winds most frequently blow from the south and southwest. Spring and fall winds tend to be more variable in direction. Although a similar seasonal cycle exists at both stations, some differences are nonetheless apparent. At LaGuardia, northeast winds are observed fairly frequently (~ 10%) from late winter through late summer/early fall. At Bridgeport, a similar but much weaker pattern is present, with the preferred direction shifting towards easterly starting in the spring. At LaGuardia in summer, the most frequently observed wind direction is southerly, while at Bridgeport the pattern is rotated such that southwesterly winds are most frequently observed. These differences are likely due to small scale geographic factors such as the trend of the coastline and the proximity of urban centers.

Figures 4 and 5 show the average wind speed plotted versus the wind direction. During summer and fall, the wind speed varies little with direction and averages about 10 knots. In winter and early spring at LaGuardia winds from the northwest quadrant strengthen to about 15 knots. At Bridgeport, a less pronounced strengthening of winds from this quadrant is evident.

Wind speed histograms (Figures 6 and 7) show the percentage of wind observations in each of 9 speed ranges as well as the overall average speed for each month. At LaGuardia in winter, the histogram exhibits a broad peak at 10-15 knots while in summer the peak is narrower and displaced toward lower speed (6-10 knots). The average wind speed reaches a maximum of 12.5 knots in March and a minimum of 9.1 knots in midsummer. At Bridgeport, a similar pattern is observed but with wind speeds slightly reduced.

IV.a.2. Resultant Wind and Persistence

The resultant wind is the vector average of all the wind observations made over a given time period (here 45 months). Figures 8 and 9 exhibit a clear seasonal pattern that is similar at the two stations. Wintertime resultant winds are from approximately the northwest at 5-7 knots. In summer, the resultant vectors weaken to < 2.5 knots and rotate to the southwest. Spring and fall are seen to be periods of transition between the winter and summer patterns.



The persistence or steadiness in wind direction at our two stations is shown in Figures 10 and 11. Generally, persistence is highest (> 40%) in winter (indicating relatively steady winds) with a secondary maximum (> 20%) occurring in midsummer. Late spring and late summer/early fall are periods of low persistence (< 20%), indicating that the wind is directionally variable. In general, summertime persistence values at Bridgeport are 5-10% higher than those at LaGuardia. This may be due to the lack of nighttime observations at Bridgeport during part of the record (see section 2). During such time periods, diurnal wind variations are inadequately sampled, resulting in a bias towards daytime winds.

IV.a.3. Diurnal Wind Variations

The diurnal variation in wind speed is given in Figures 12 and 13. A diurnal cycle is evident at both stations during all months of the year. In summer, the range of the diurnal cycle is about 5 knots with the maximum wind speed occurring in mid to late afternoon (1500-1700 Local Standard Time) and the minimum in early morning (~ 0500 LST). In winter, the range is approximately half the summer value with the maximum occurring early in the afternoon (~ 1300 LST).

Figures 14 and 15 show the diurnal variation in wind direction presented as histograms for each of 4 separate six hour intervals during the day. In winter, there is no apparent diurnal cycle at either station. The major feature of the histograms during this season is the presence of a broad peak centered on the northwest quadrant. In spring, summer, and early fall, however, a clear diurnal cycle is evident. Winds during the morning hours are observed to be primarily from one of two broad directions: southwest or northeast. During the afternoon and evening hours at LaGuardia, the wind is observed to be southerly about 20% of the time with all other directions far less frequently observed. At Bridgeport, the distributions during this time period are broader with the most commonly observed wind being southwesterly.

A final illustration of the diurnal cycle in wind is given in Figures 16 and 17. Here we present the diurnal anomaly of the resultant wind for each of 8 three hour periods during the day. During the winter at both stations, the diurnal cycle is small (< 2 knot range) but a consistent clockwise rotation of the wind vector is evident. During the summer, a larger amplitude cycle is evident (~ 6 knot range). Compared to winter, the ellipse is more rectilinear and the sense of rotation of the wind vector is reversed. The long axis of the ellipse is mainly north-south with increased southerly wind during the afternoon and evening and increased northerly wind during the overnight and morning hours. This seems consistent with the classical sea breeze/land breeze diurnal cycle. The spring and fall months represent transitions between these two apparently different states.



IV.b. Air Temperature

IV.b.1. Frequency Distributions of Air Temperature

Figures 18 and 19 present cumulative frequency distributions for dry bulb air temperature at LaGuardia and Bridgeport. Using these graphs, the percentage of temperature observations below a certain temperature is given by the cumulative percent for that temperature. Also shown are mean and standard deviation values for each month.

The mean temperature reaches a minimum in January of 0.3 °C at LaGuardia and -0.8 °C at Bridgeport. The maximum mean temperatures of 24.6 °C at LaGuardia and 23.4 °C at Bridgeport are both achieved in July. Overall, average temperatures are approximately 1 °C cooler at Bridgeport than at LaGuardia.

The steepness of the cumulative frequency distribution is a measure of the variability of the temperature about the mean. A steep distribution, corresponding to a low standard deviation, indicates less variability than a flatter distribution. At both of the stations, the standard deviations are highest during the winter months (~5.5 °C) and lowest in the summer (~3.8 °C).

Figures 20 and 21 show wet bulb temperature presented in the same manner as for the dry bulb temperature. Mean wet bulb temperature displays a similar seasonal pattern. Minimum and maximum values occur in January and July respectively. Highest standard deviations occur in winter with lowest values observed during the summer.

From figures 18-21 a mean monthly difference between dry and wet bulb temperature can be calculated. This difference is smallest in winter (~2 °C) and largest in summer (~4 °C). During all months, the difference is greater at LaGuardia than at Bridgeport indicating slightly more humid conditions at the latter station.

IV.b.2. Air Temperature and Wind Direction

We present average temperature versus wind direction for each month in Figures 22 and 23. The basic seasonal pattern is similar at both stations. In winter, warmest temperatures generally occur with southerly to southeasterly winds, while coldest temperatures are observed with northerly to northwesterly winds. The range in temperature from coldest to warmest is large (~7 °C) during this season. In summer, warmest temperatures are observed during westerly to southwesterly winds and coolest temperatures during easterly to northeasterly winds. The range is small (~3 °C) during the summer months. Spring and fall appear to be periods of transition between the summer and winter patterns.



IV.c. Sea Level Pressure

IV.c.1. Frequency Distributions of Sea Level Pressure

Cumulative frequency distributions for sea level pressure are presented in Figures 24 and 25. Once again, there appears to be little difference between the results at the two stations. As for the case of air temperature, a seasonal cycle is evident in both the mean value and the standard deviation (steepness). Mean sea level pressure is slightly higher in winter than in summer, presumably because of the predominance in winter of cold dry air of continental origin. Standard deviations of pressure in winter months (~10mb) are approximately twice as high as those in summer months. This is similar to what is seen in the air temperature results (section IV.b.1) and may be due to the more frequent occurrence of storms during the winter months.

IV.d. Sky Cover

IV.d.1. Mean Monthly Average Sky Cover

Mean monthly average values for total sky cover and total opaque sky cover are shown in Figures 26-29. It is apparent that the seasonal variability in both of these quantities is small compared to the overall mean. The seasonal cycle observed at both LaGuardia and Bridgeport is similar. Lowest total sky cover (Figures 26 and 27) occurs in October (~5/10) and highest occurs broadly from winter through spring (~6/10). Opaque sky cover (Figures 28 and 29) follows a similar seasonal pattern as total sky cover. Values for opaque sky cover are generally slightly lower (~1/20) than corresponding total sky cover values.

IV.e. Precipitation

IV.e.1. Mean Monthly Precipitation Amounts

Plots of average monthly precipitation amounts (Figures 30 and 31) show that, on average, the seasonal variability in precipitation is small compared to the mean value. The seasonal patterns at the two stations are similar, with LaGuardia (overall average = 9.07 cm/month) receiving slightly more precipitation than Bridgeport (overall average = 8.77 cm/month). Highest precipitation occurs in midsummer, with the maximum in August, followed closely by the spring months. Lower precipitation occurs in early summer, early fall, and late winter, with the minimum in February.



IV.e.2. Precipitation Types

Figures 32 and 33 present the frequency of occurrence of different types of precipitation for each month at the two stations. As was seen previously with other variables, the patterns at the two stations are quite similar. Rain is the most frequent type of precipitation during all but the summer months, occurring about 8% of the time during November to January. During the summer months, observations of showers and thundershowers become about as frequent as normal rain observations. In winter, approximately 15% of observations report some type of precipitation, while in summer, the corresponding value is about 7%. Although not reflected in the observations of heavy precipitation, the fact that less frequent summer precipitation produces the maximum amount of precipitation (section IV.e.1) implies that average summer intensities are greater. It is likely that summertime thundershowers are responsible for much of the summer precipitation total.

IV.e.3. Precipitation and Wind Direction

The frequency of occurrence of precipitation for different wind directions is presented in the form of bar graphs in Figures 34 and 35. On these graphs, different degrees of shading represent different classes of precipitation. The frequency of occurrence of any type of precipitation is given by the total height of the bar. During all seasons at LaGuardia, winds from the easterly half (north-east-south) are much more frequently accompanied by precipitation than are those from the westerly half (north-west-south). In winter, snow is proportionally more frequent with westerly and northwesterly winds than with easterlies. The distributions at Bridgeport are somewhat more strongly peaked, otherwise the patterns are quite similar.



V. LONG TERM CHANGES

V.a. Wind

V.a.1. Wind Speed

Figures 36 and 37 present respectively, the monthly averaged wind speed and the associated anomaly for LaGuardia from 1949 to 1992. The anomaly is defined as the difference between a monthly averaged value and the value for that month averaged over the entire record. Several features stand out in these plots. There appears to be variability in the wind speed over long (~10 year) periods. Broadly speaking, the winds from 1949 to 1961 were relatively strong, while the period from 1961 to 1979 was characterized by lighter than normal winds. Following 1979 was an approximately 5 year period in which wind strength increased until finally decreasing somewhat. The anomaly plot shows that in addition to the long period change, there is substantial year to year variability in monthly averaged wind speed. For example, the summer of 1975 was calmer than normal, while the summer through fall period of 1981 was windier than normal. Many other such anomalous periods are evident in Figure 35.

Figures 38 and 39 present corresponding plots for Bridgeport. The year to year variability at Bridgeport has certain similarities to that observed at LaGuardia. For example, the patterns during the 1975 and 1981 summers are similar. Surprisingly, the long term behavior is at odds with the pattern observed at LaGuardia. The Bridgeport data indicate weaker winds before 1956, with relatively stronger winds during the 1961 to 1979 period referred to above. The reason for this discrepancy between the two stations is not obvious, although one possibility is movement of the measuring instrument. At present, we have no information on this. The discrepancy appears not to be due to the lack of nighttime observations between 1953 and 1960 and after 1981. Due to the diurnal variation in wind speed (section IV.a.3), the effect of this sampling procedure would be to bias the monthly averages towards higher daytime wind speeds.

V.a.2. Wind Persistence

Contour plots of wind persistence (Figures 40-43) indicate that, contrary to what was observed in wind speed, the two stations behave similarly with respect to this quantity. This reason for this is also unclear. The seasonal pattern noted in section IV.a.2 is also apparent in this presentation. Anomalous persistence patterns often linger for several months and are observed at both stations. Examples include: a) higher than normal persistence from spring through fall, 1976, b) lower persistence during the summers of 1986 and 1987, c) higher persistence in the summer-fall of 1988.



V.b. Air Temperature

V.b.1. Monthly Averaged Air Temperature

Long term changes in monthly averaged dry bulb temperature and monthly dry bulb temperature anomaly for our two stations are presented in Figures 44-47. The temperature plots are dominated by the seasonal cycle. Temperature anomaly data from Bridgeport show cooling ($\sim 1^{\circ}\text{C}$) during the period from 1960 to 1980 that is not as apparent at LaGuardia. Notwithstanding this discrepancy, the observed year to year variability is probably valid since many of the same features are seen at the two stations. Among the notable perturbations in recent years are an anomalously warm spring/early summer in 1976, a cool summer in 1978, and a series of cold winters from 1977 to 1979.

Monthly averaged wet bulb temperature and monthly wet bulb temperature anomaly are plotted in figures 48-51. The monthly averaged wet bulb temperatures (figures 48 and 50) are dominated by the seasonal cycle as were dry bulb temperatures. The cool period from 1960 to 1980 that was present in the dry bulb anomaly at Bridgeport is apparent in the wet bulb anomaly at both stations.

V.c. Sea Level Pressure

V.c.1 Monthly Averaged Sea Level Pressure

Contour plots of monthly average sea level pressure values and anomalies (Figures 52-55) show strong correlations between LaGuardia and Bridgeport. The seasonal pattern noted in section IV.c is apparent.

V.d. Sky Cover

V.d.1. Monthly Averaged Sky Cover

Monthly averaged total sky cover and the associated anomaly are plotted in Figures 56-59 for LaGuardia and Bridgeport. Opaque sky cover is not shown due to its similarity with the total sky cover data presented here. The patterns at the two stations are broadly similar. The seasonal cycle discussed in section IV.d is also seen in this presentation. The year to year variability in sky cover for a particular month (shown in the anomaly plots) is large. In fact, the range of variability (-3 to $+3$) is as large as the mean monthly average values presented in section IV.d ($\sim 5-6$). The anomaly plots also show that patterns of anomalous monthly sky cover often persist for several months or even years. For example, the years 1962-1964 had generally low sky cover and were



followed by a period of higher sky cover. Low sky cover generally characterized the winter/late spring period of 1976-1978.

V.e. Precipitation

V.e.1. Monthly Precipitation Amounts

We plot monthly precipitation amounts and anomalies in Figures 60-63. At both stations we see similar patterns in both amount and anomaly especially over long time scales. For example, a period of drought during the 1960s followed by wetter years in the early 1970s is apparent in both the LaGuardia and Bridgeport data. As was the case for sky cover, the year to year variability in monthly rainfall amount is very large, especially in summer. Summer anomalies range from +38 to -15, indicating that the mean monthly values presented in section IV.e.1 may be unduly affected by large, infrequent precipitation events.



VI. REFERENCES

Lettau, B., W. A. Brower Jr., and R. G. Quayle, *Marine Climatology*, MESA New York Bight Atlas Monograph 7, New York Sea Grant Institute, Albany, 1976.



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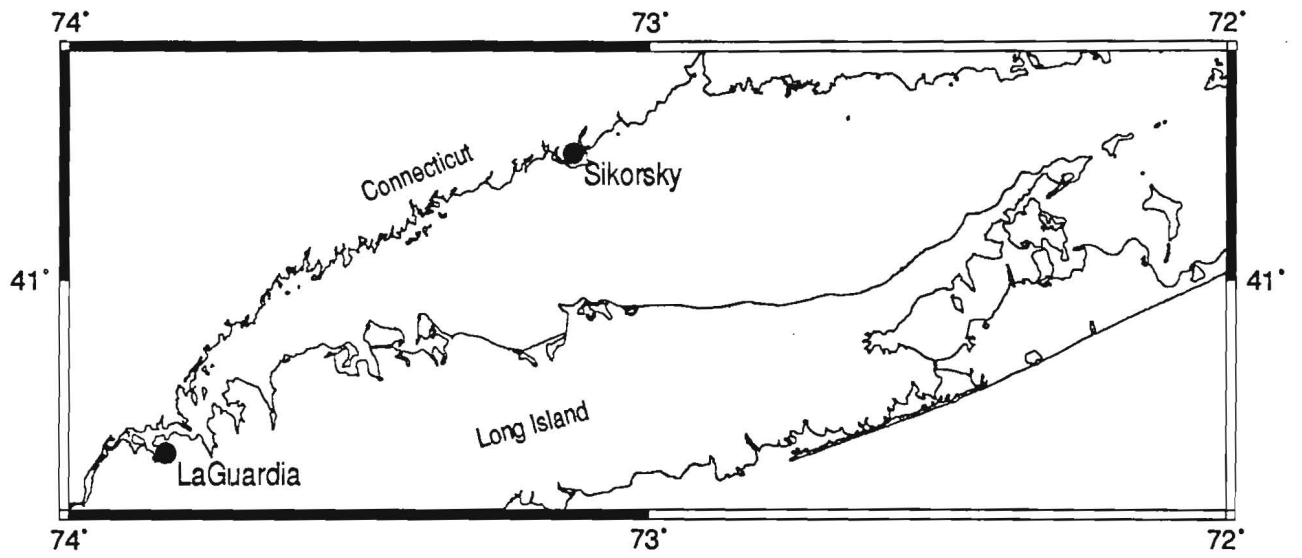
Figure 61. Monthly precipitation anomaly, 1949-1992 at LaGuardia.

Figure 62. Monthly precipitation, 1949-1992 at Bridgeport.

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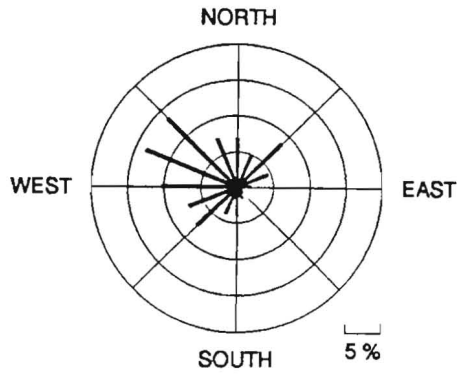
figure 1



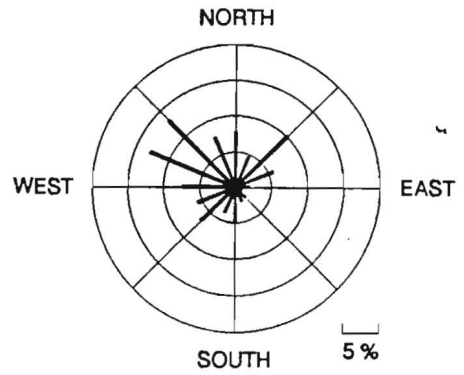


Wind Direction Frequency 7/48-12/92 LaGuardia

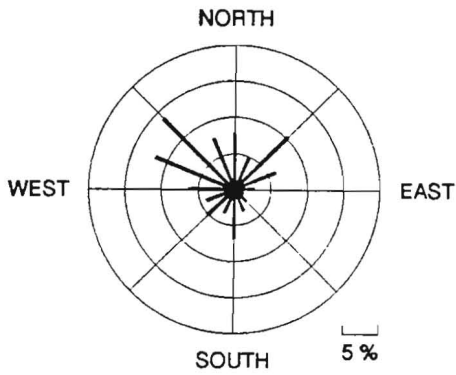
figure 2



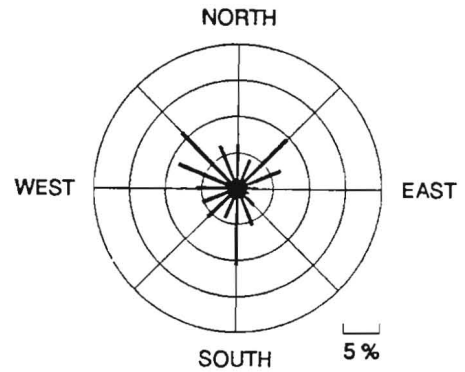
January



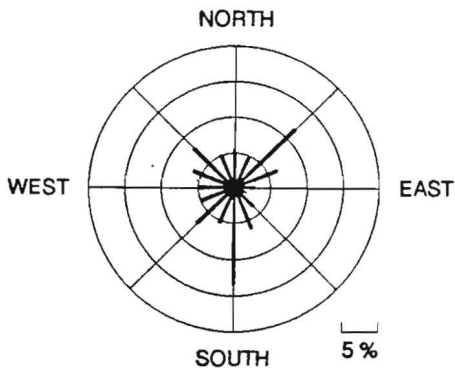
February



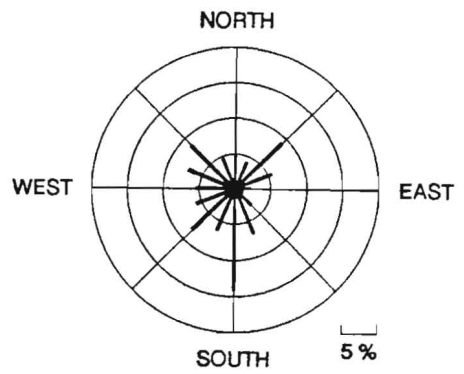
March



April



May

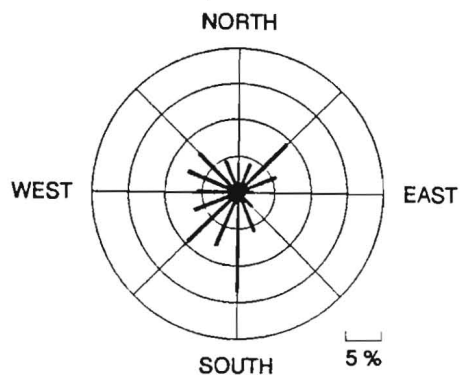


June

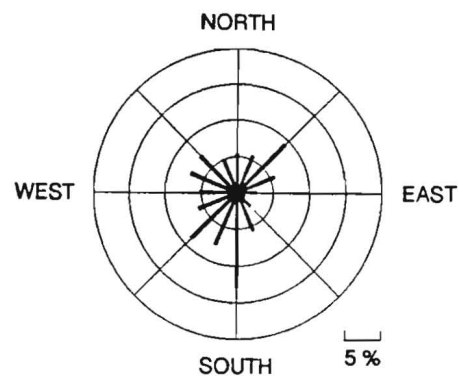


Wind Direction Frequency 7/48-12/92 LaGuardia

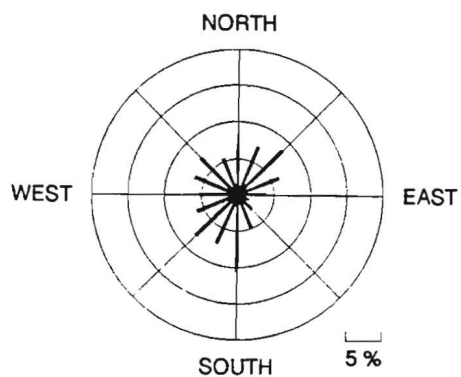
figure 2



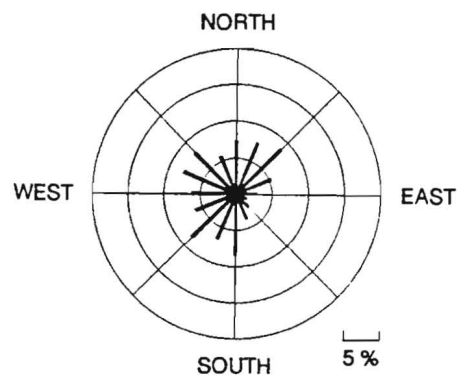
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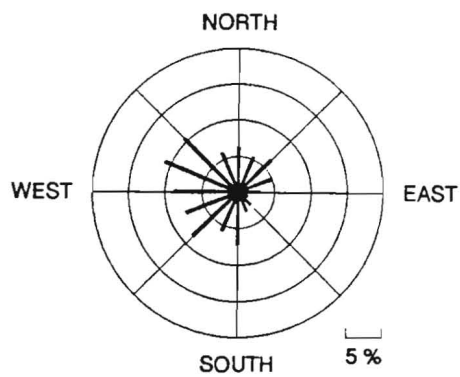
August



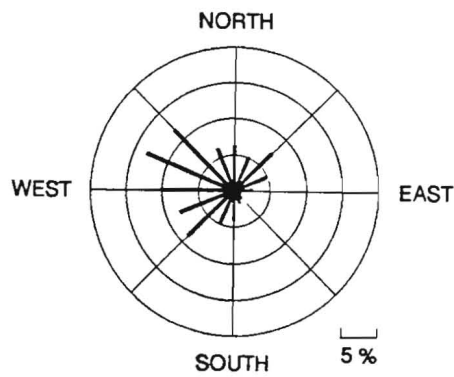
September



October



November

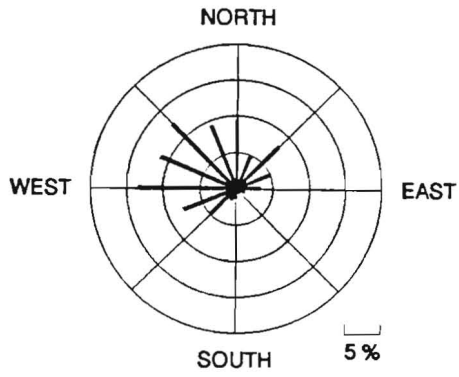


December

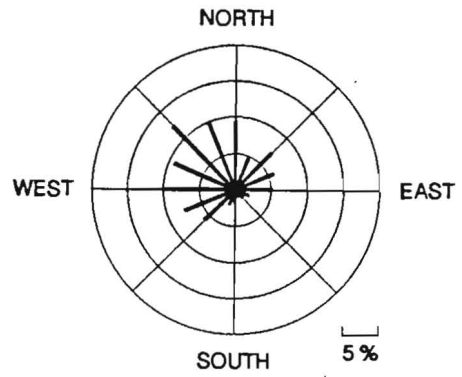


Wind Direction Frequency 7/48-12/92 Bridgeport

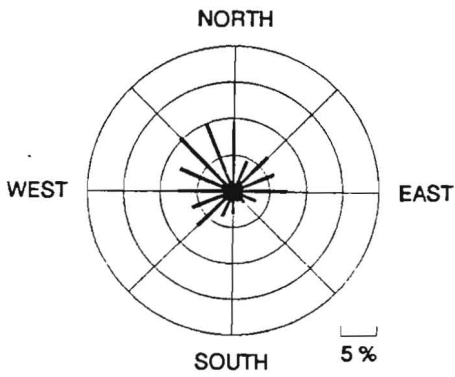
figure 3



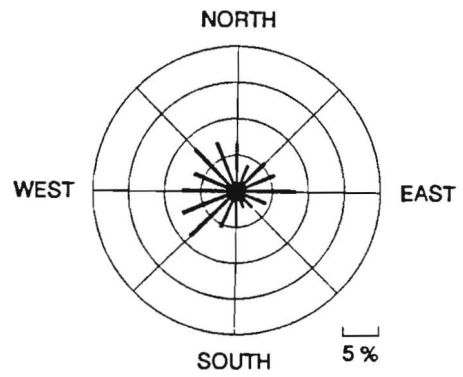
January



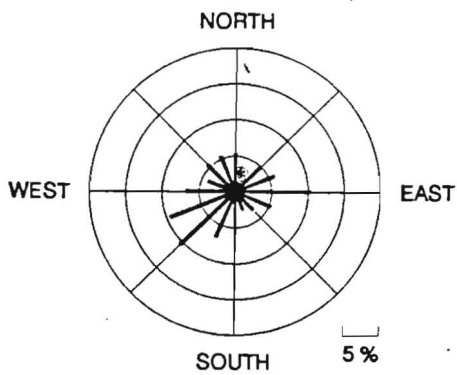
February



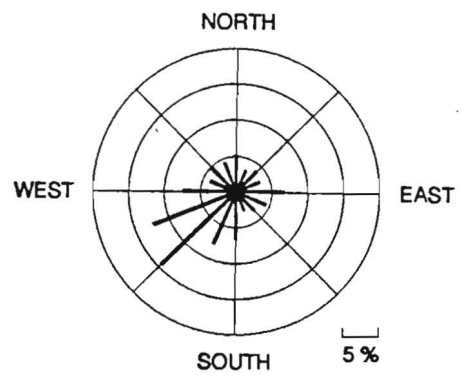
March



April



May

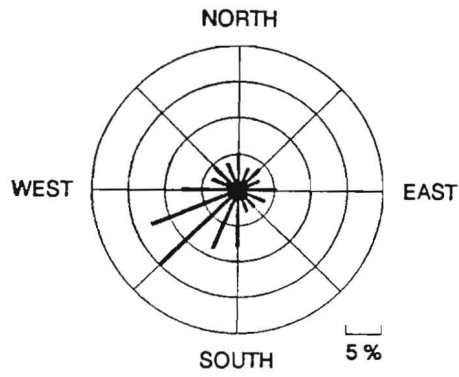


June

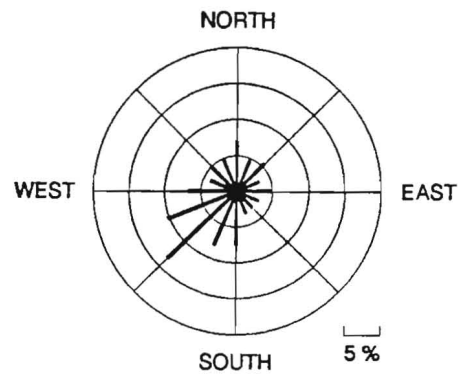


Wind Direction Frequency 7/48-12/92 Bridgeport

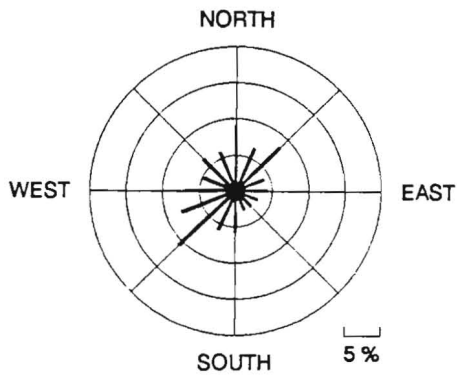
figure 3



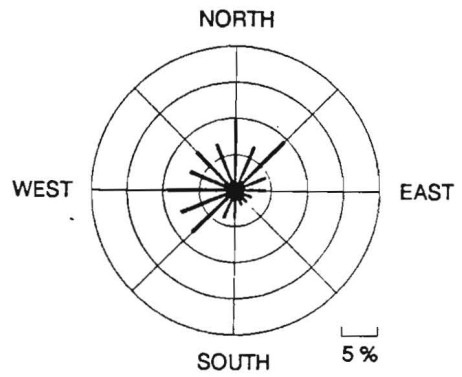
July



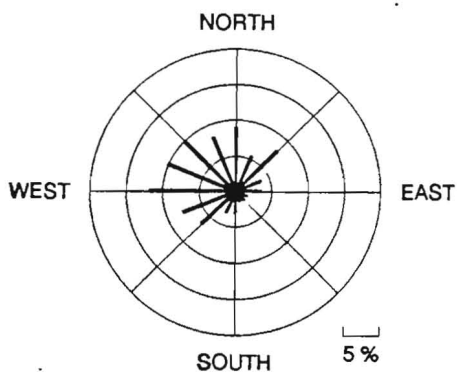
August



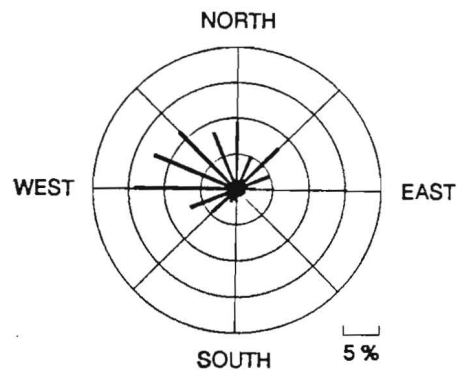
September



October



November



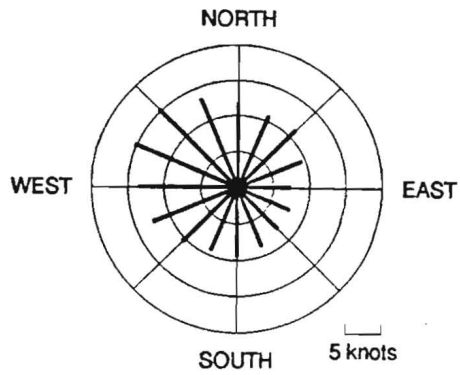
December



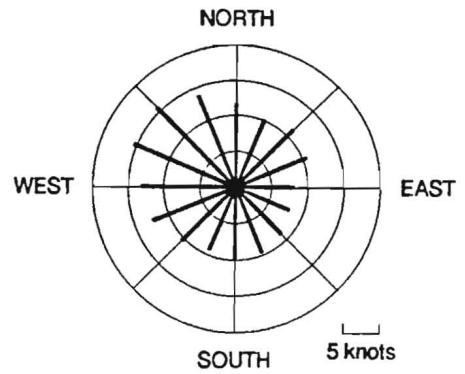
Wind Speed vs. Direction

7/48-12/92 LaGuardia

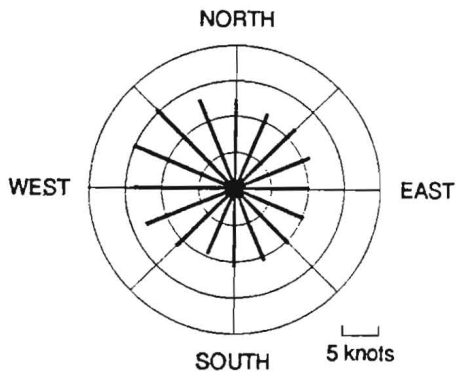
figure 4



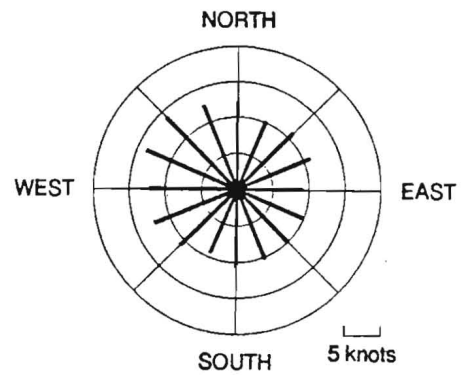
January



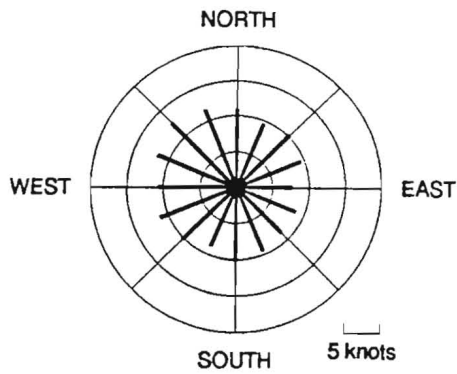
February



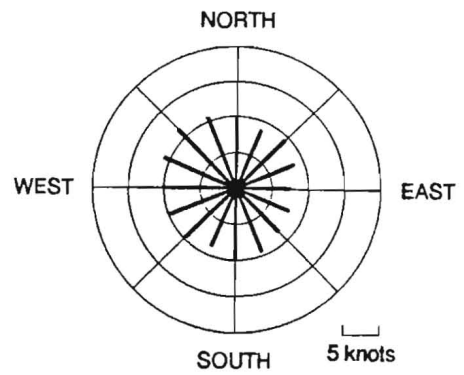
March



April



May

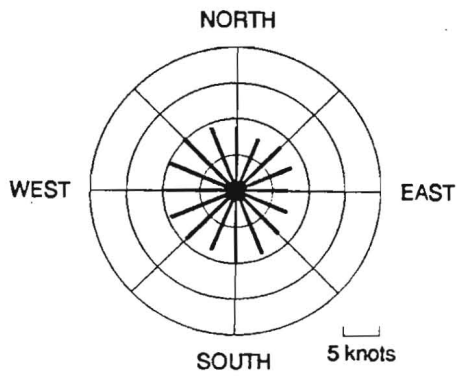


June

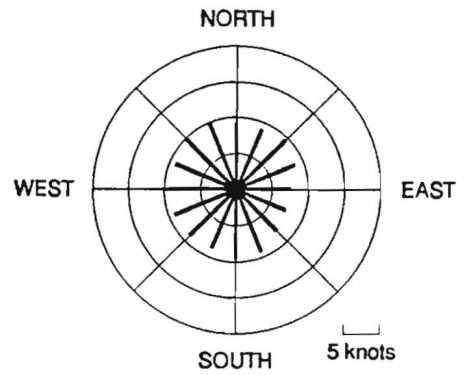


Wind Speed vs. Direction 7/48-12/92 LaGuardia

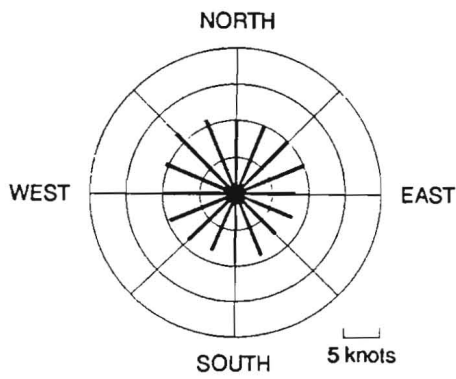
figure 4



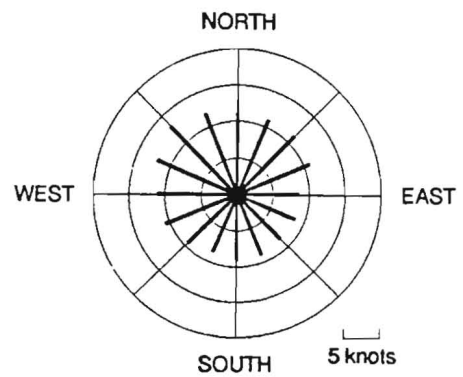
July



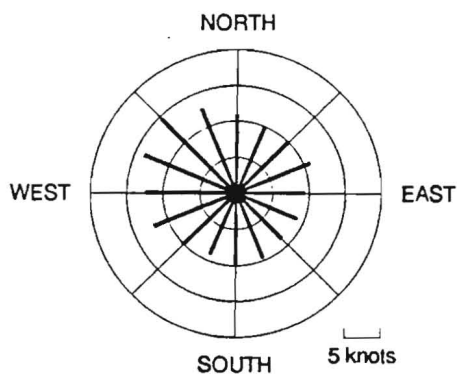
August



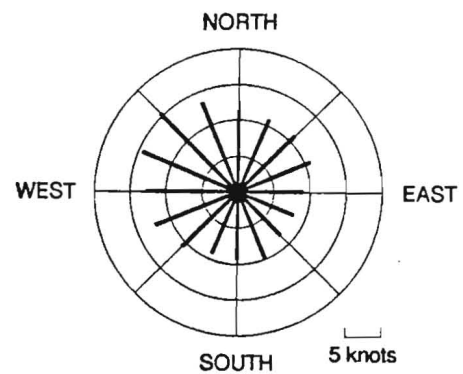
September



October



November

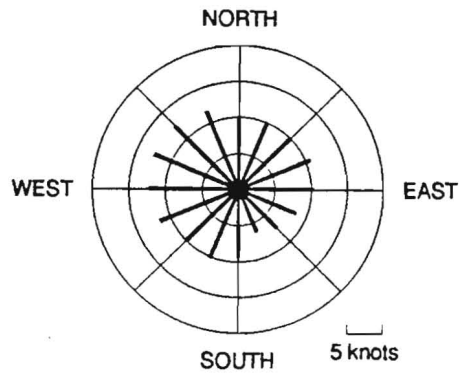


December

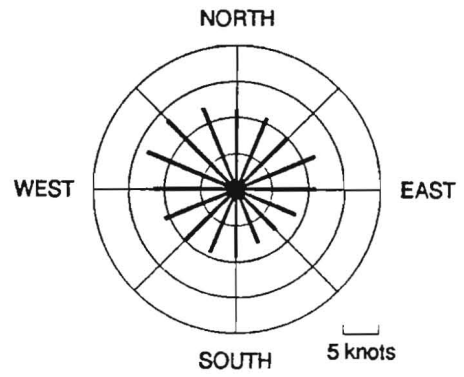


Wind Speed vs. Direction 7/48-12/92 Bridgeport

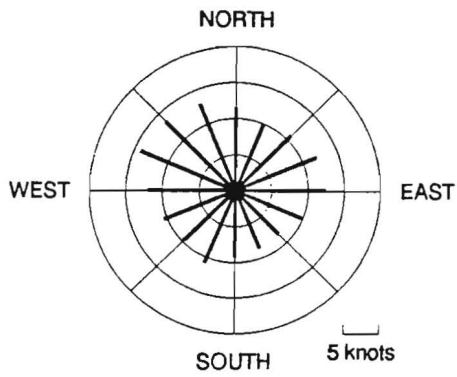
figure 5



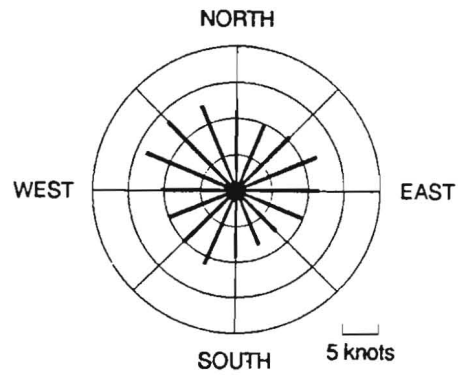
January



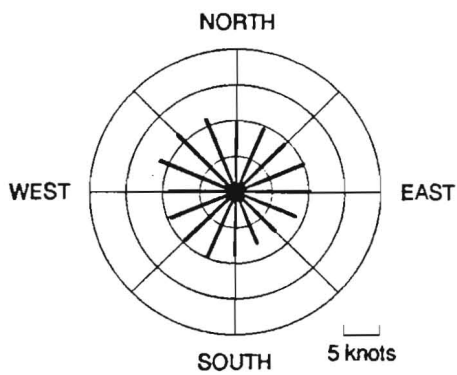
February



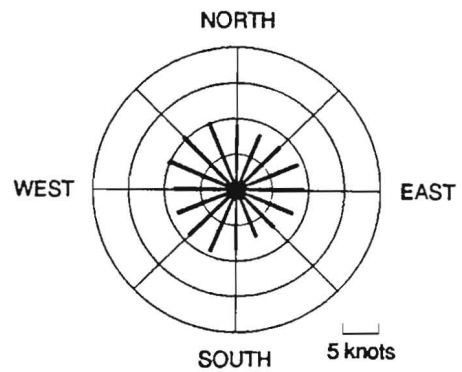
March



April



May



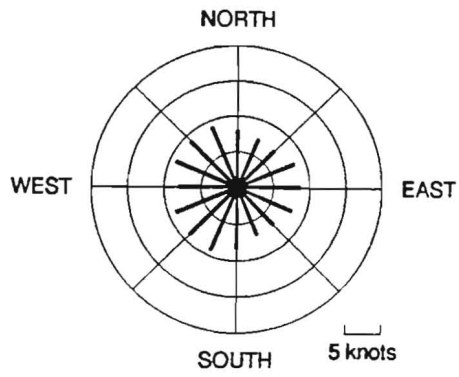
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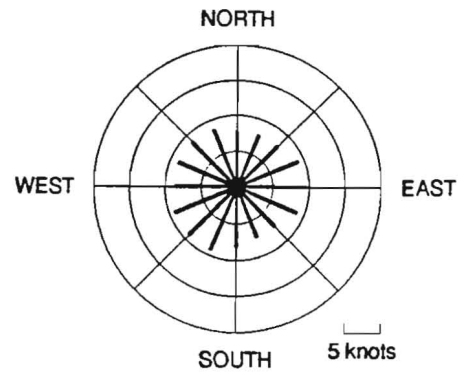
Wind Speed vs. Direction

7/48-12/92 Bridgeport

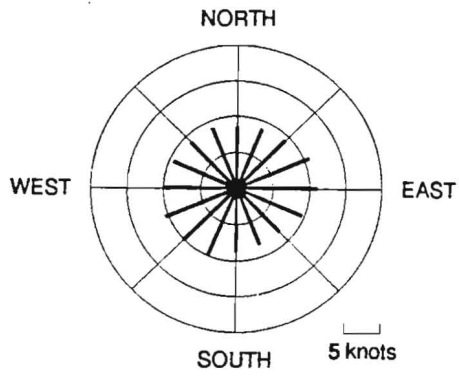
figure 5



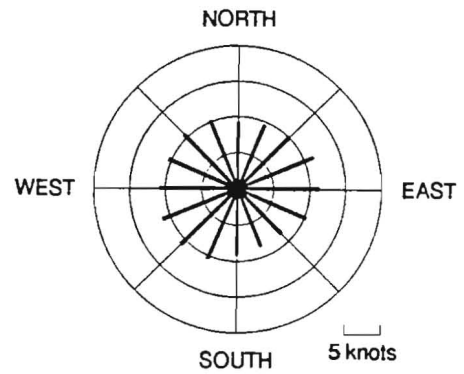
July



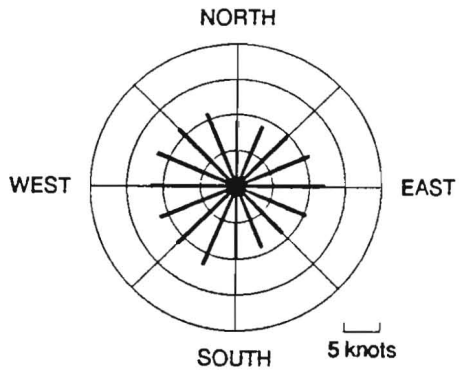
August



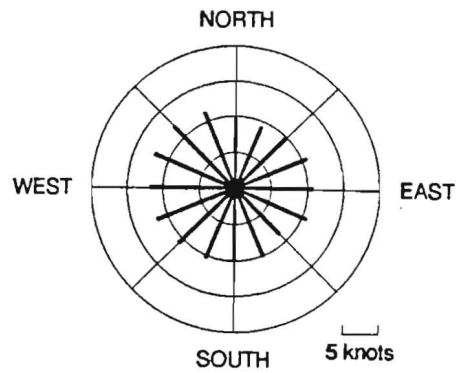
September



October



November



December

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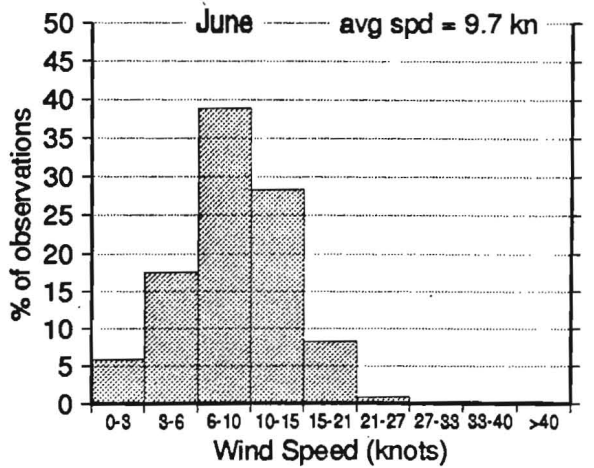
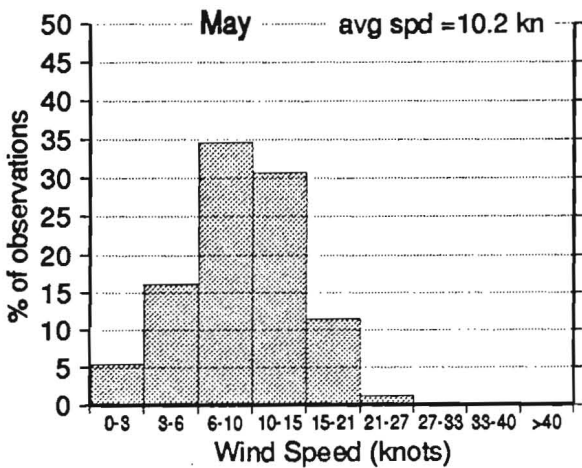
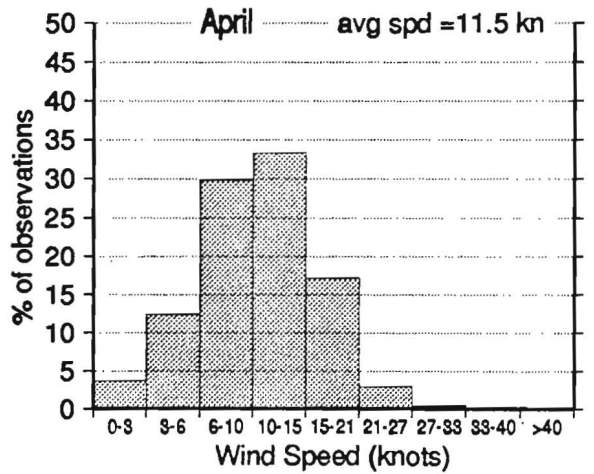
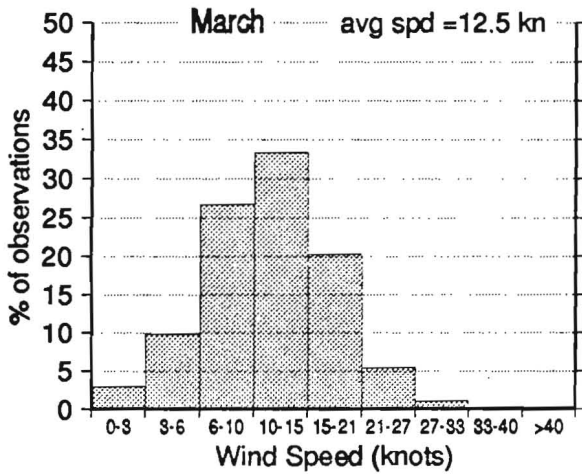
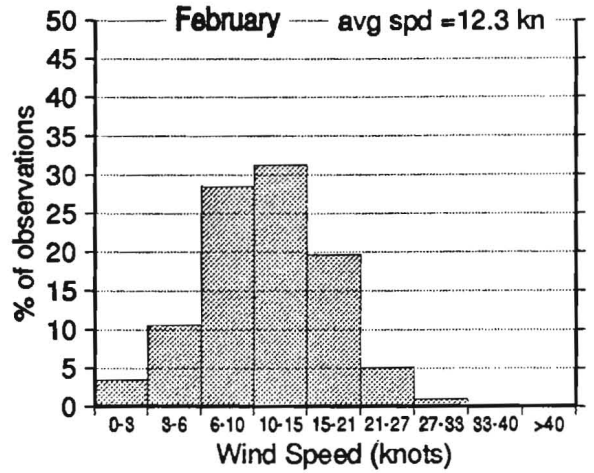
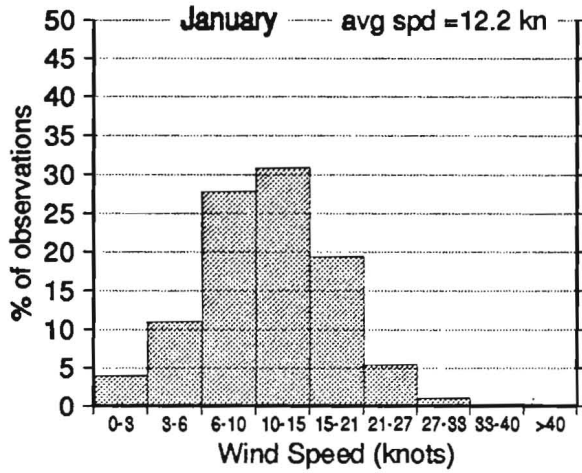
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Wind Speed Histograms 7/48-12/92 LaGuardia

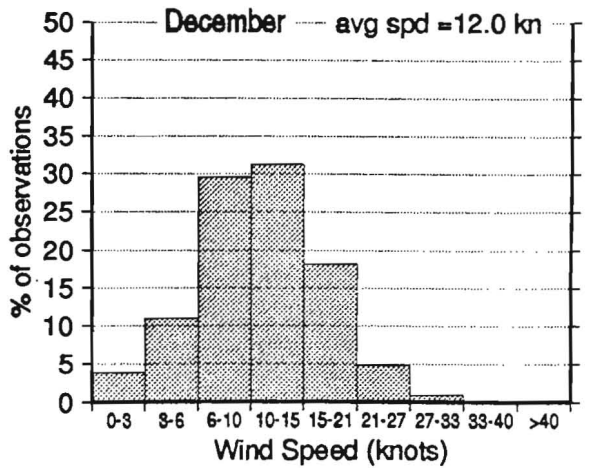
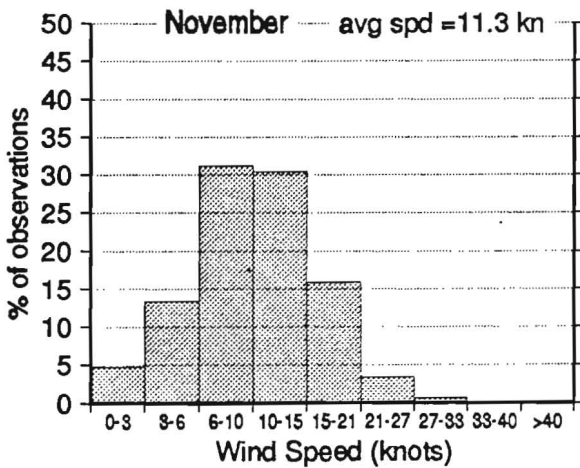
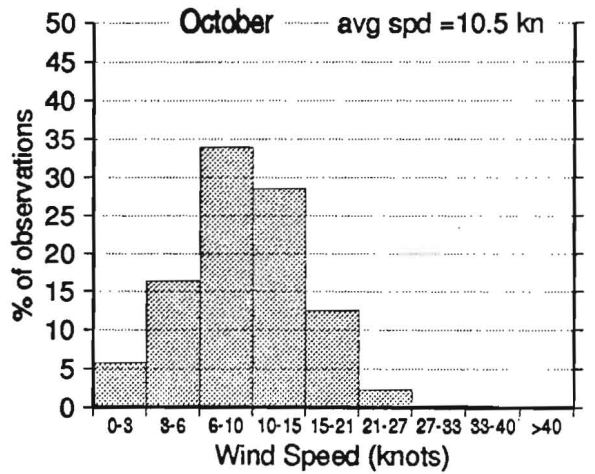
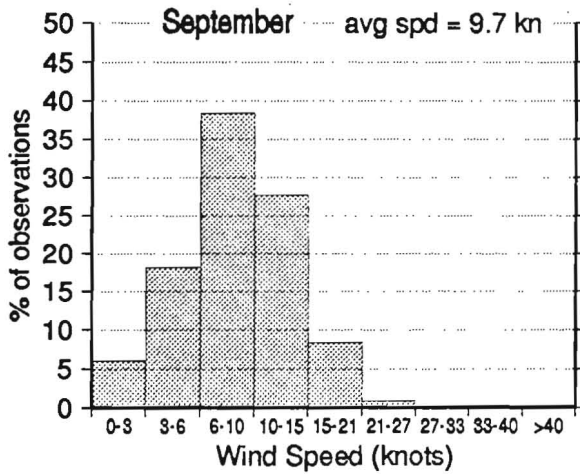
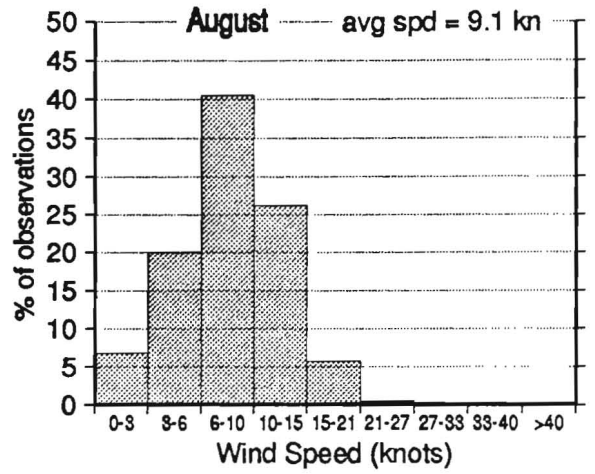
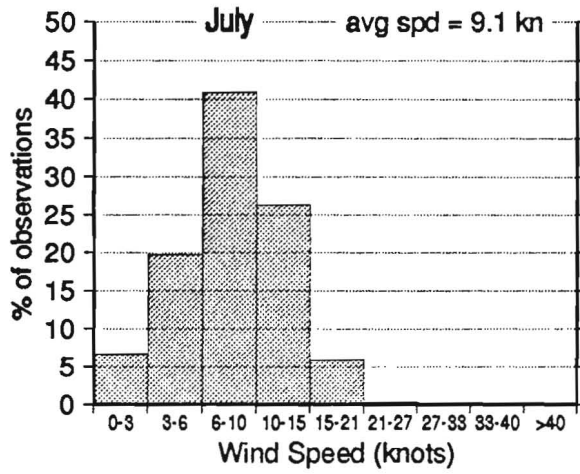
figure 6





Wind Speed Histograms 7/48-12/92 LaGuardia

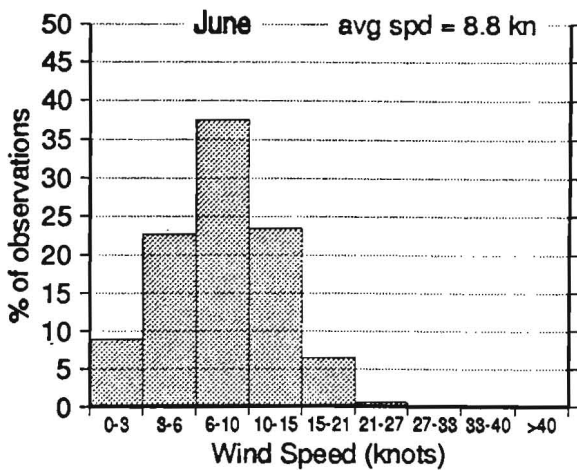
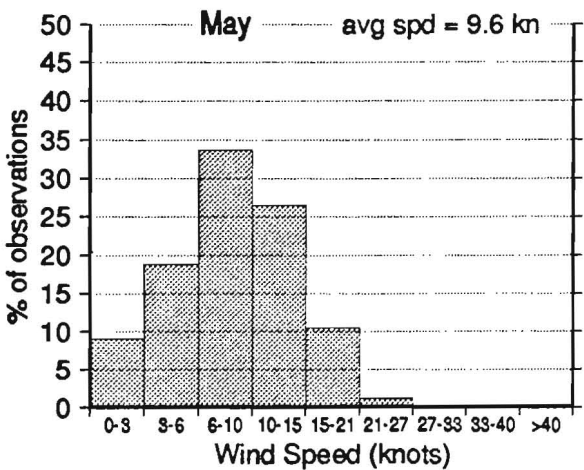
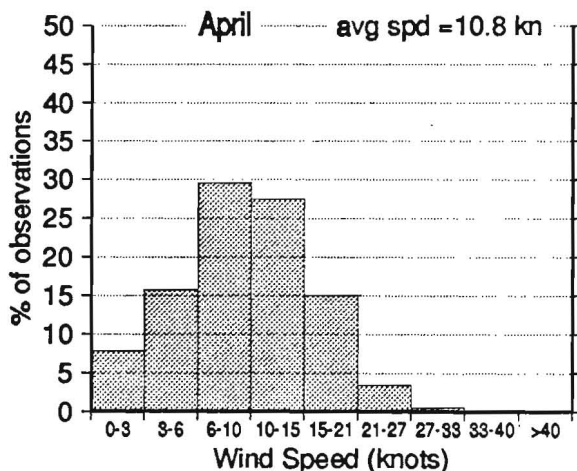
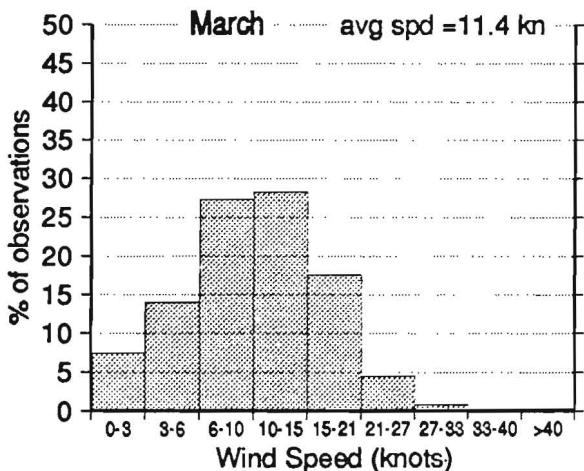
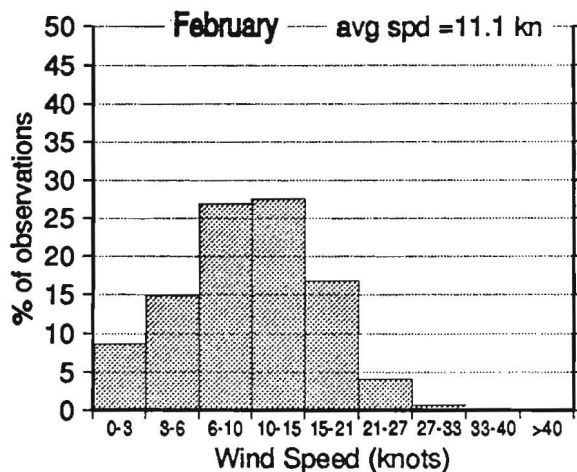
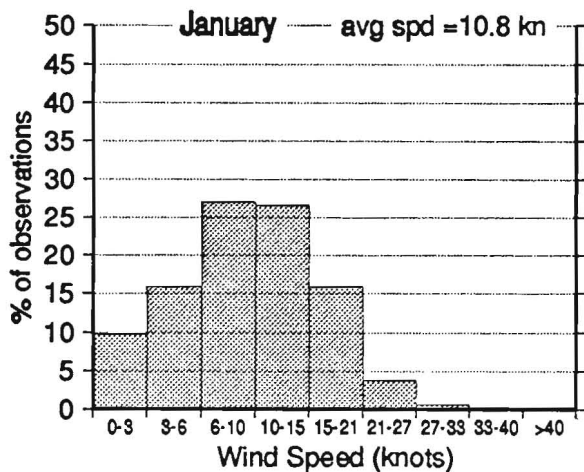
figure 6





Wind Speed Histograms 7/48-12/92 Bridgeport

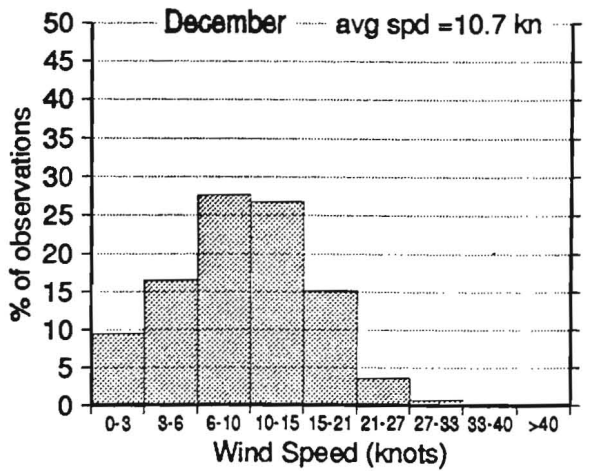
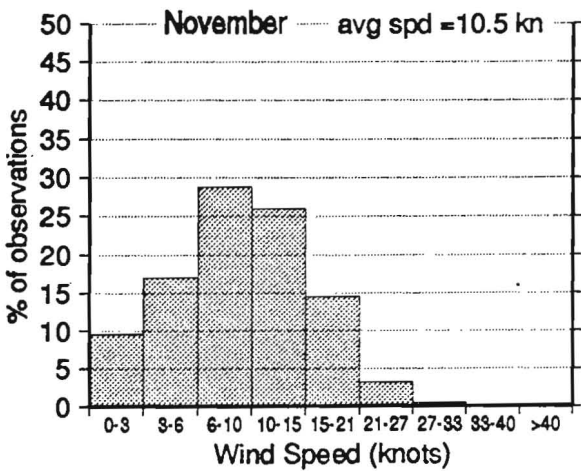
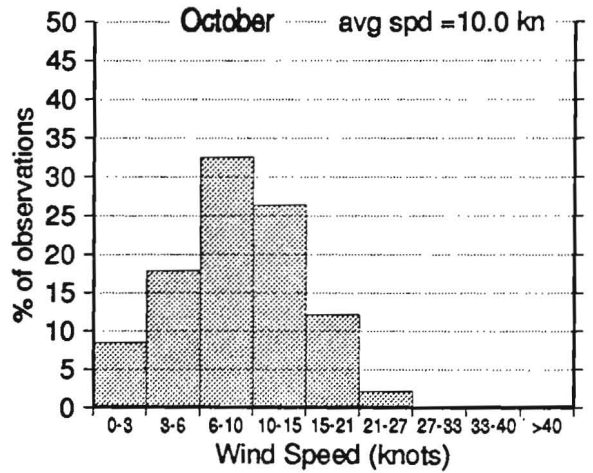
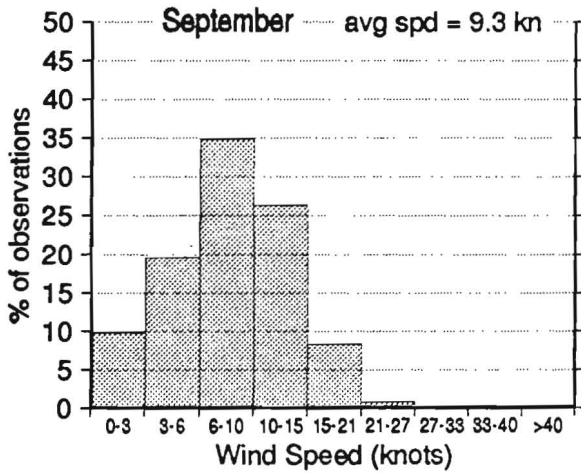
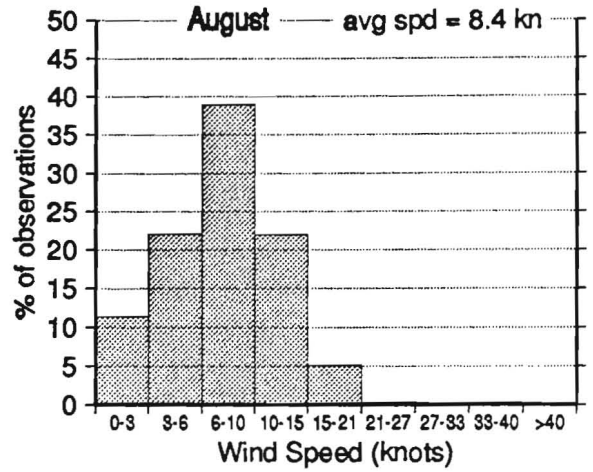
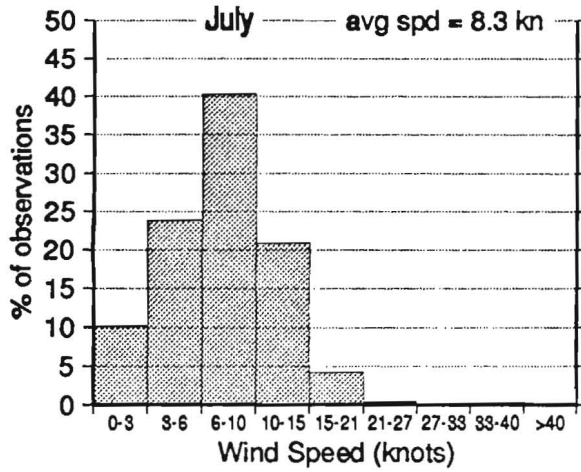
figure 7





Wind Speed Histograms 7/48-12/92 Bridgeport

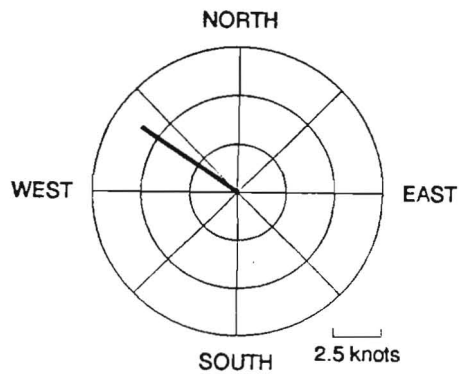
figure 7



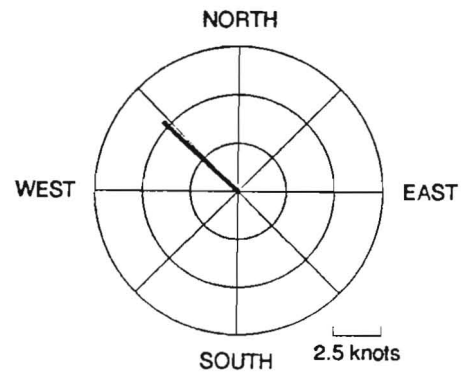


Resultant Wind 7/48-12/92 LaGuardia

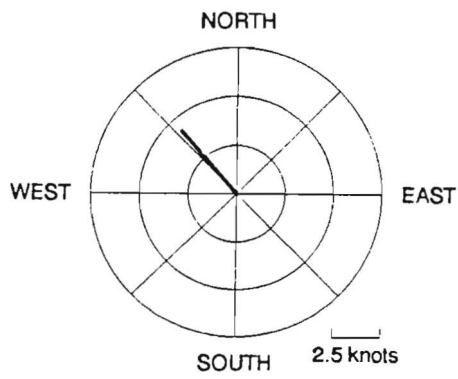
figure 8



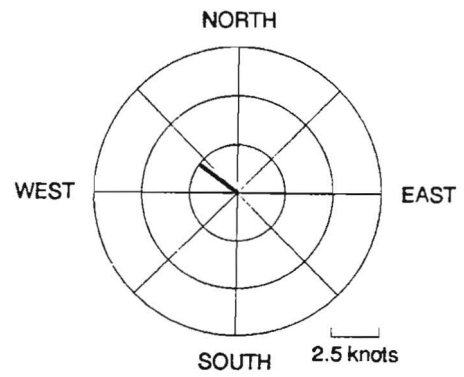
January



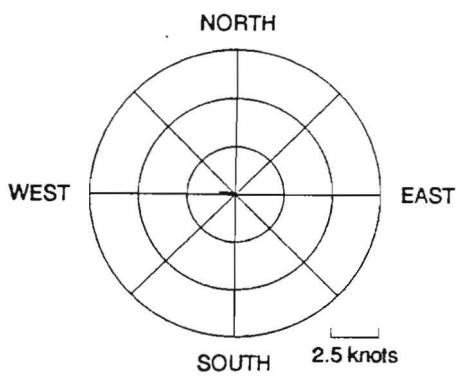
February



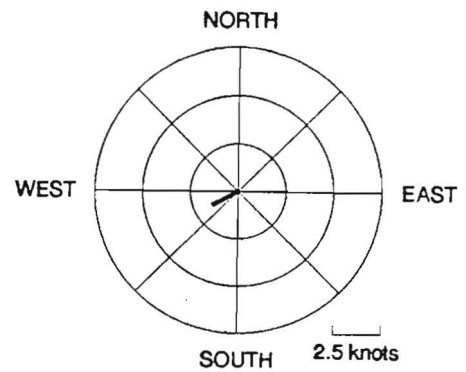
March



April



May

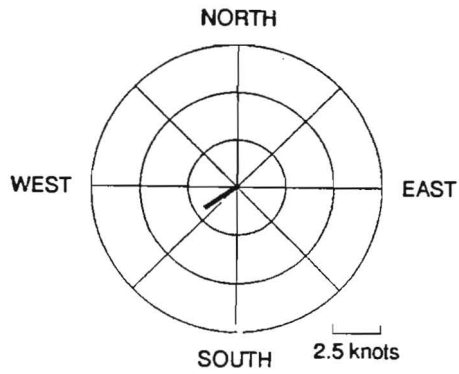


June

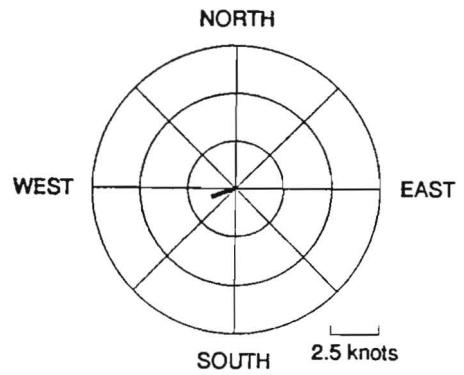


Resultant Wind 7/48-12/92 LaGuardia

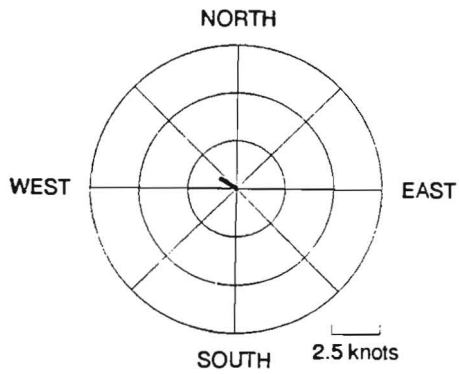
figure 8



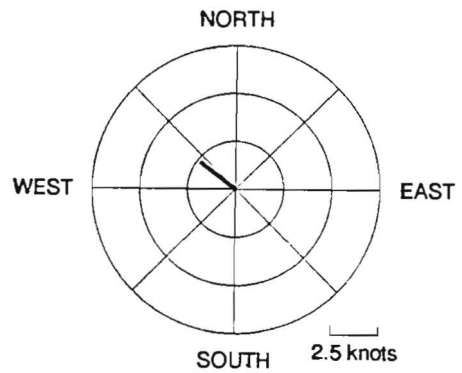
July



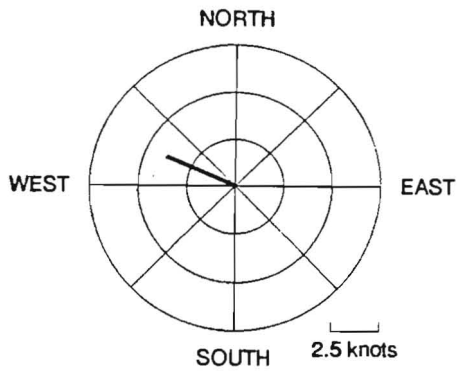
August



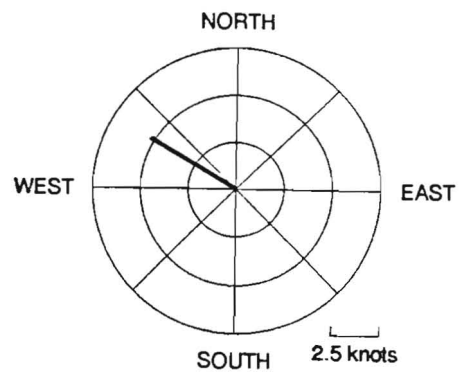
September



October



November

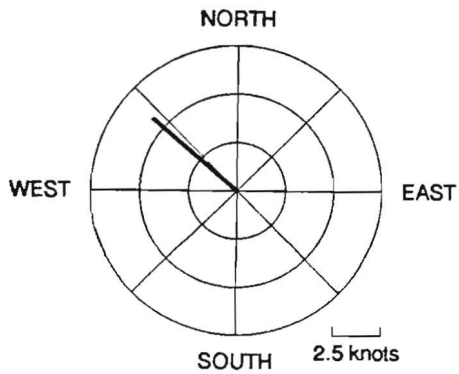


December

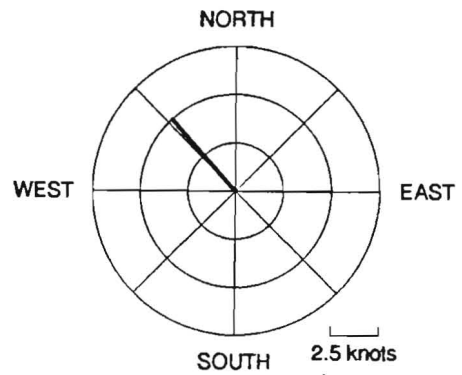


Resultant Wind 7/48-12/92 Bridgeport

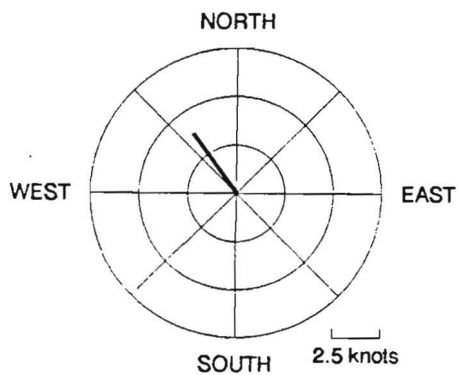
figure 9



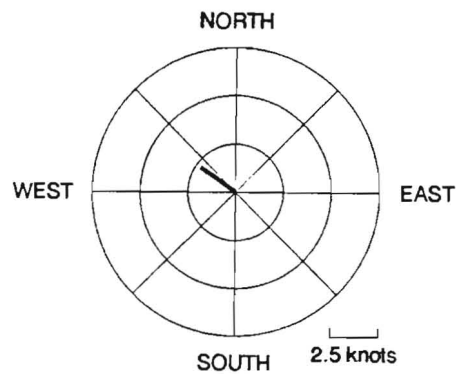
January



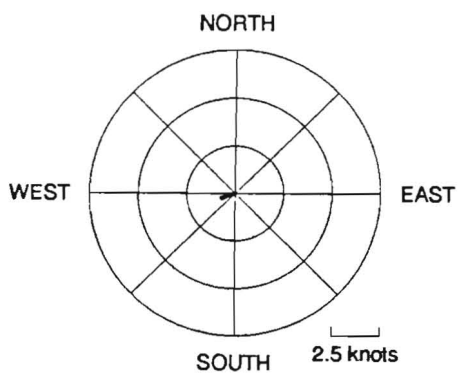
February



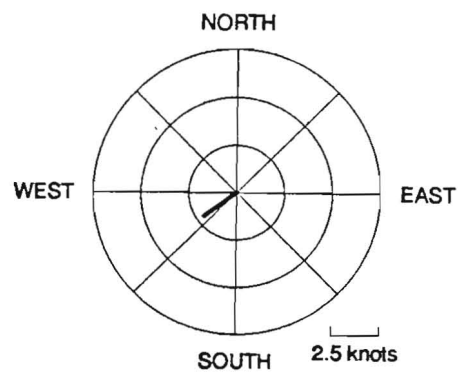
March



April



May

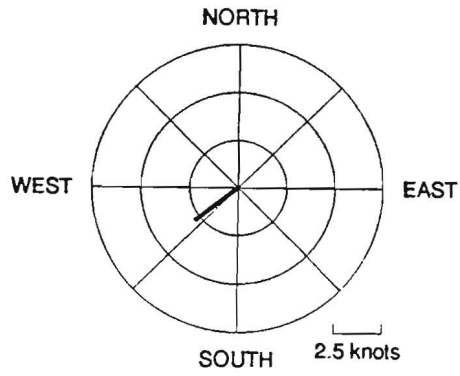


June

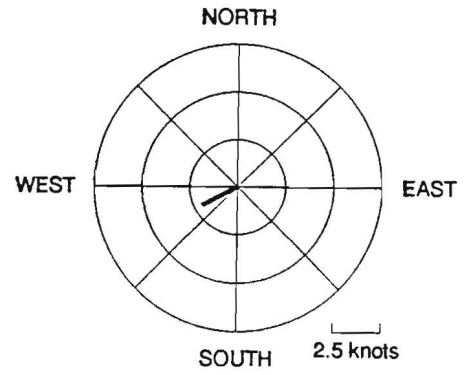


Resultant Wind 7/48-12/92 Bridgeport

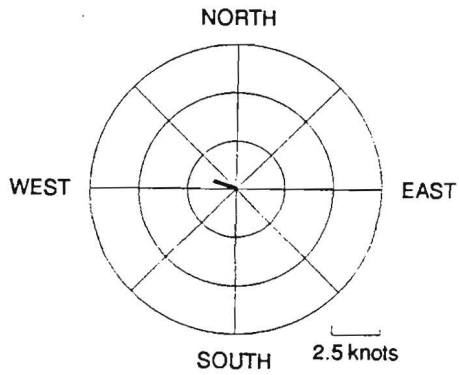
figure 9



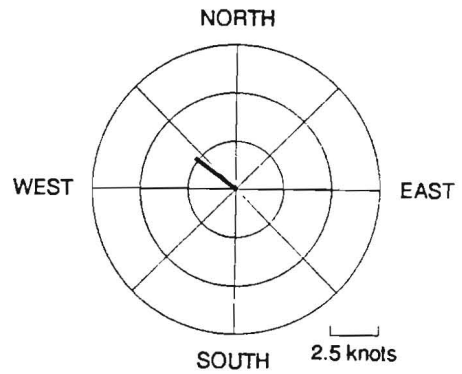
July



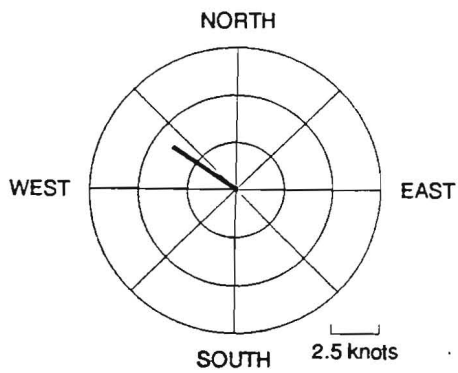
August



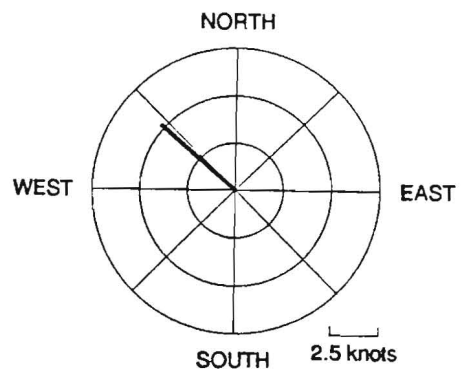
September



October



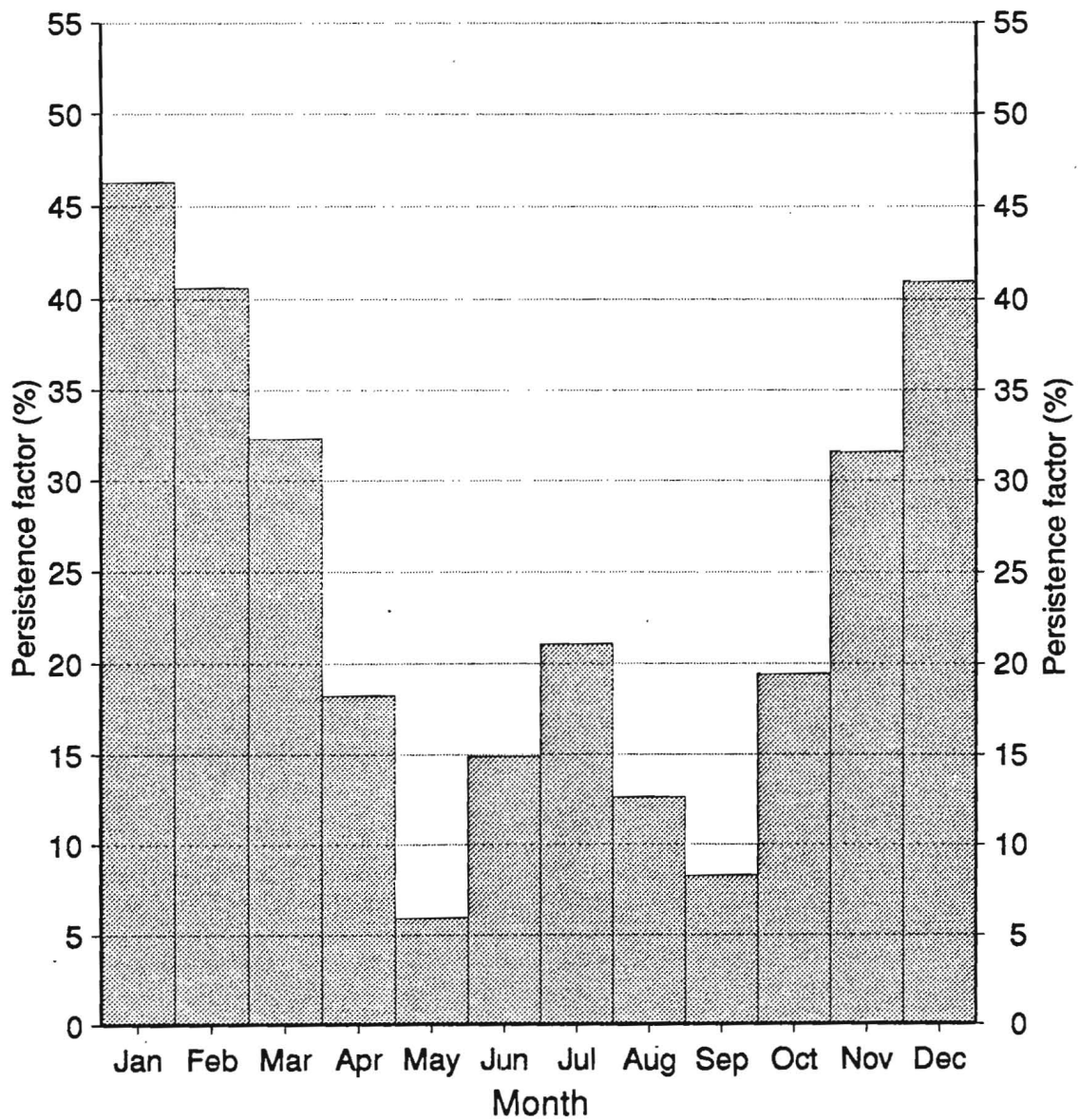
November



December

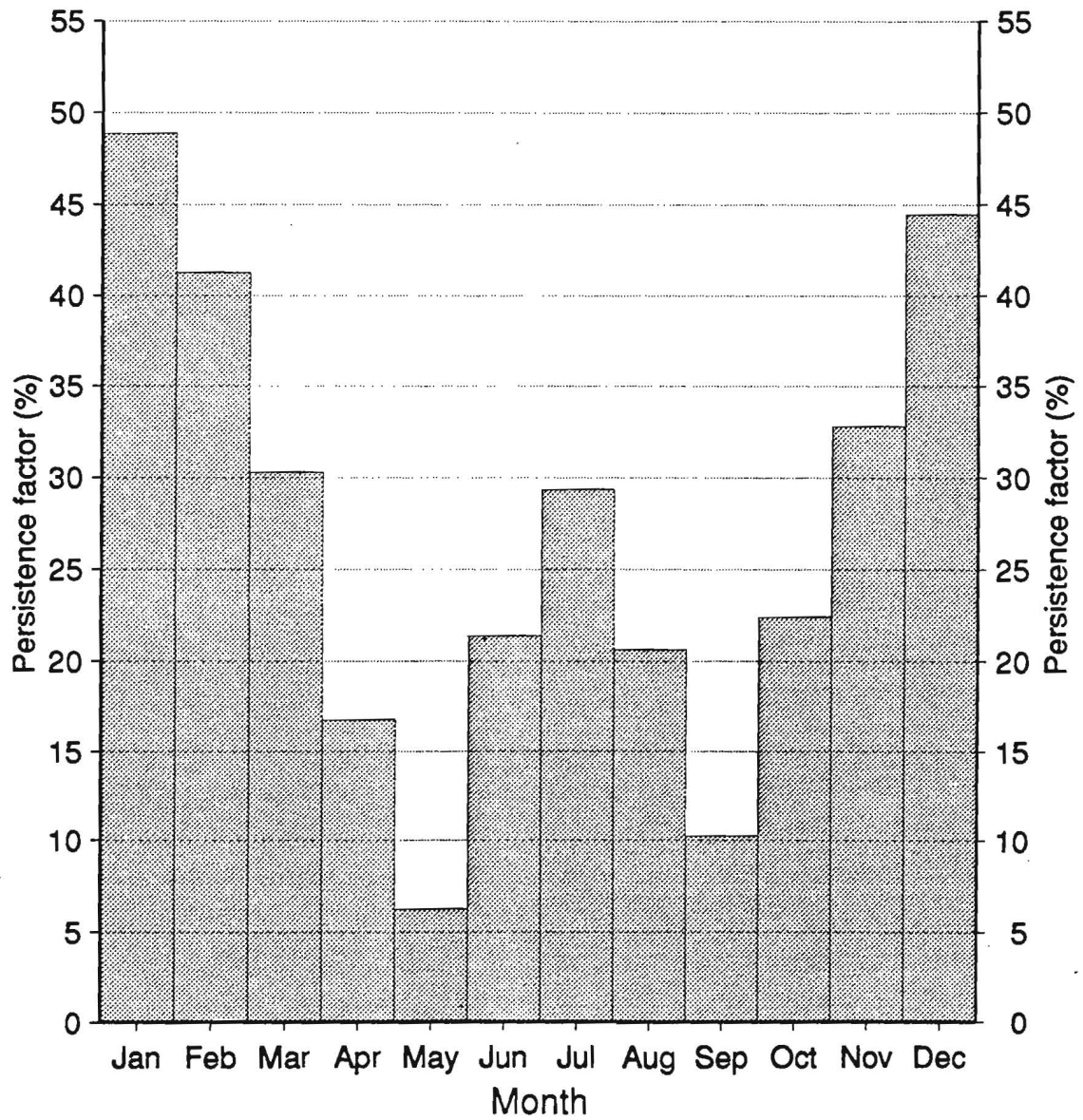


Wind Persistence 7/48-12/92 LaGuardia





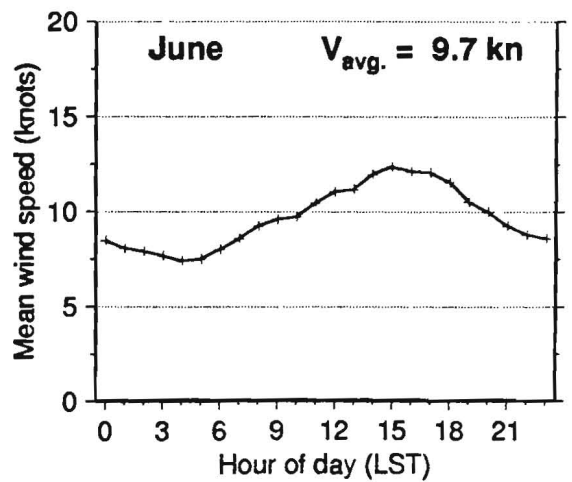
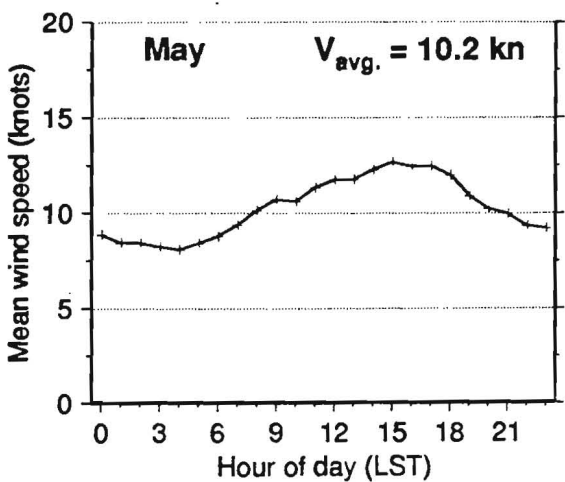
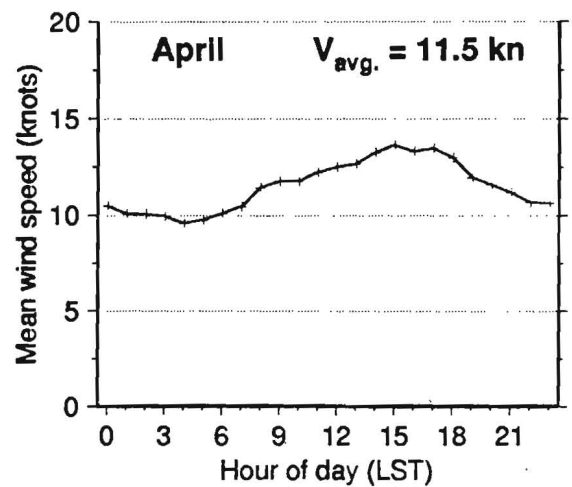
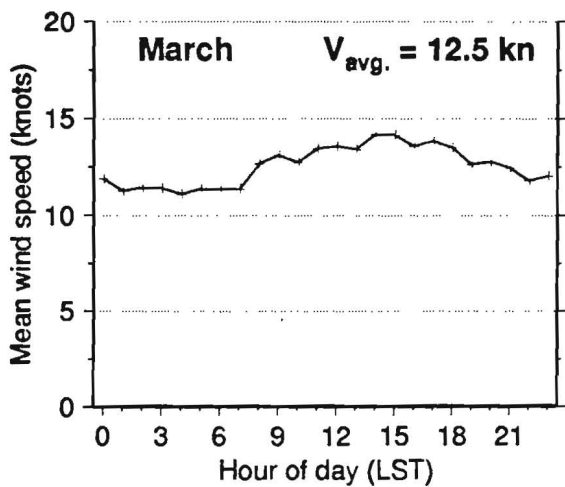
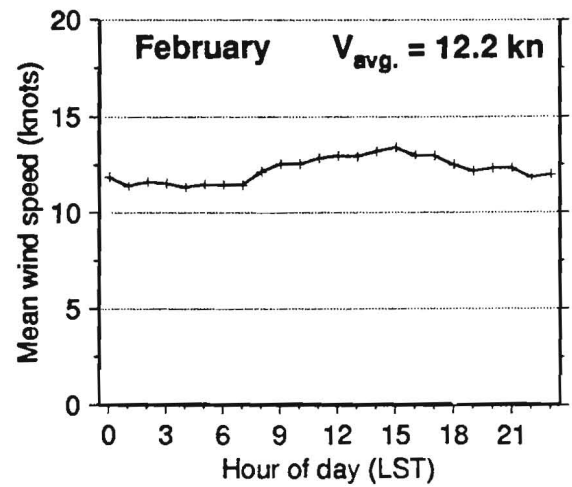
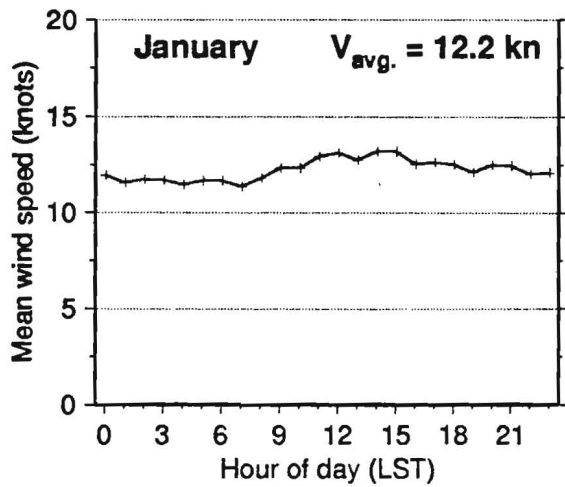
Wind Persistence 7/48-12/92 Bridgeport





Wind Speed, Diurnal Variation 7/48-12/92 LaGuardia

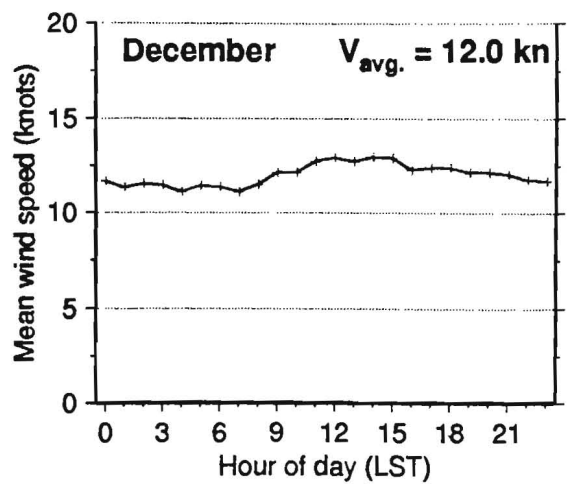
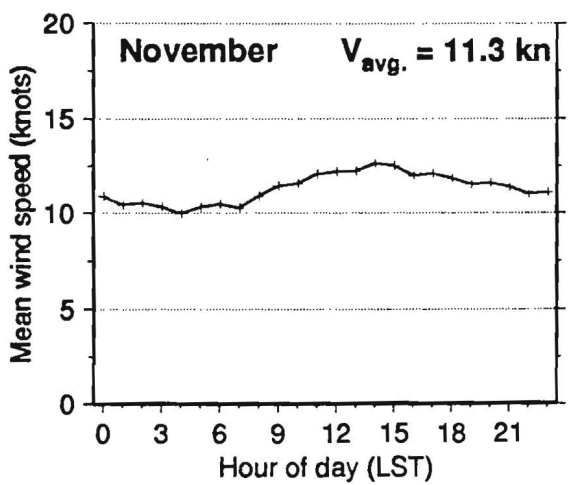
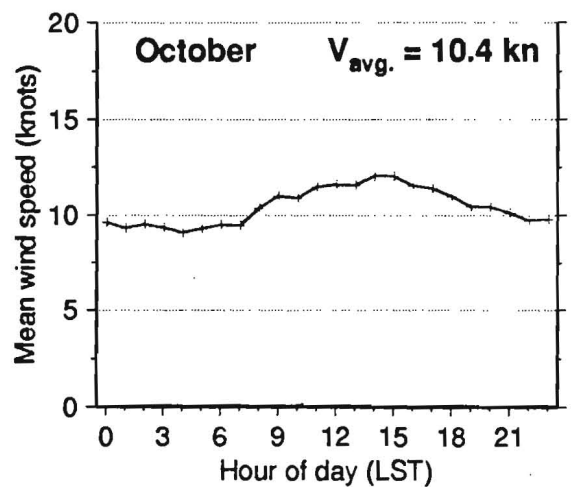
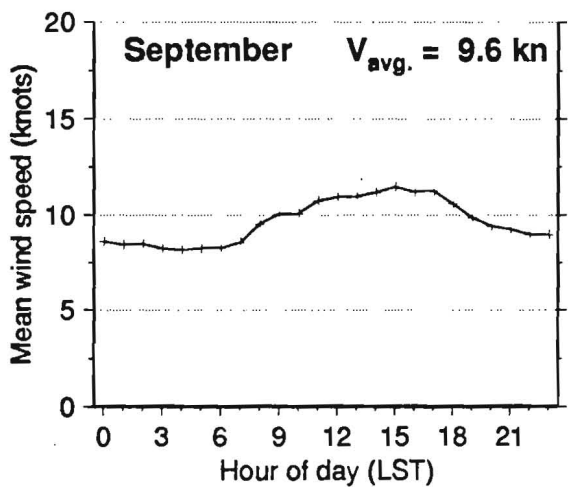
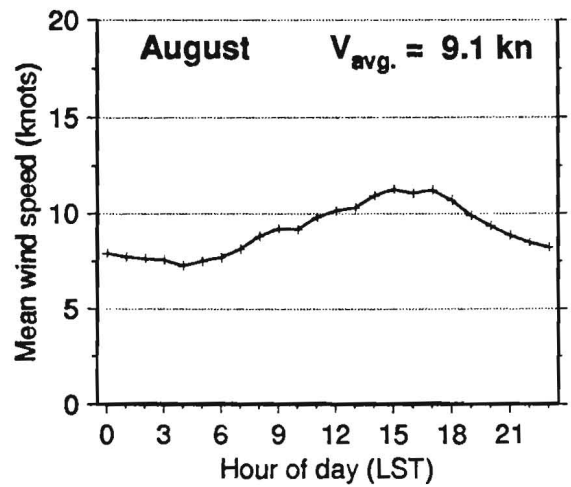
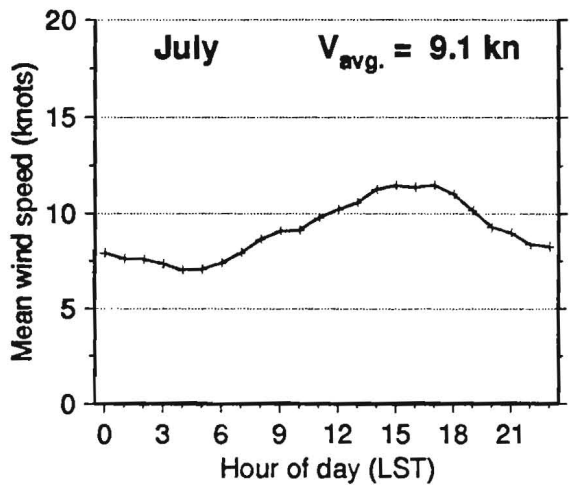
figure 12





Wind Speed, Diurnal Variation 7/48-12/92 LaGuardia

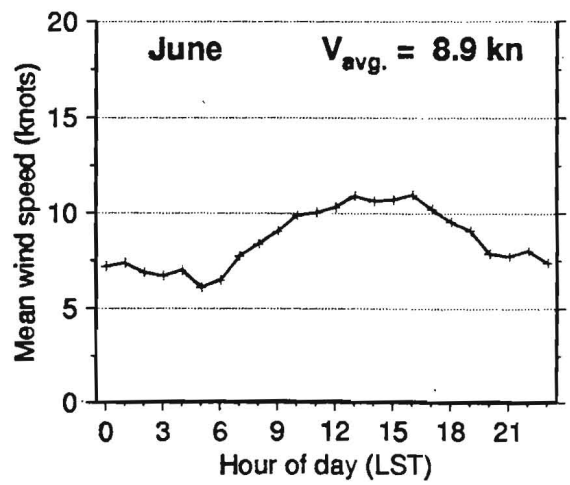
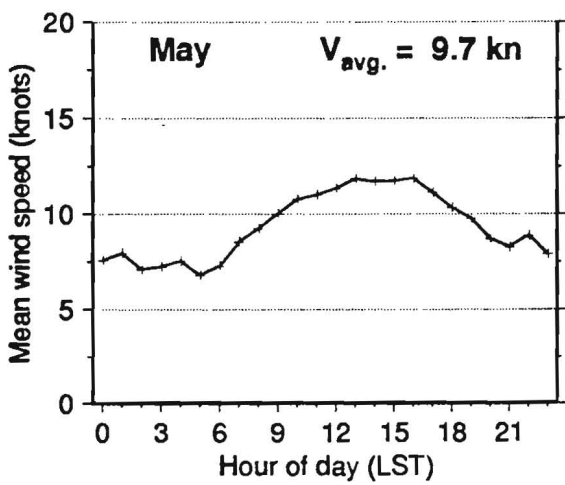
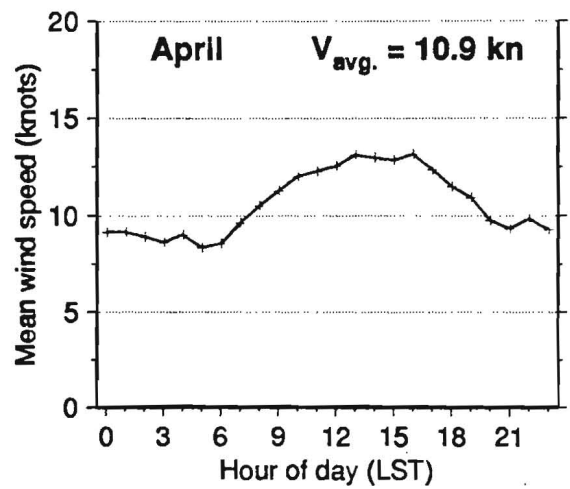
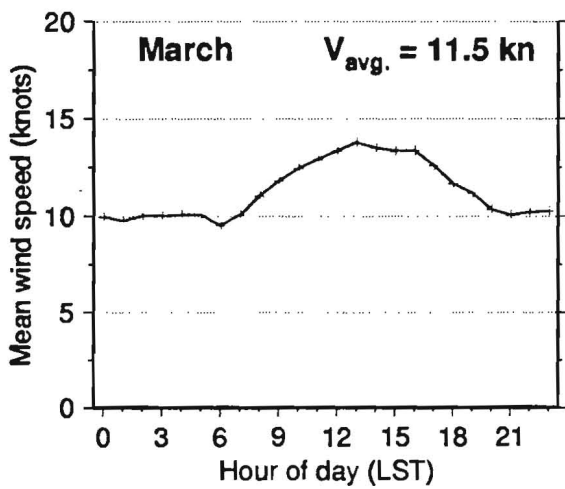
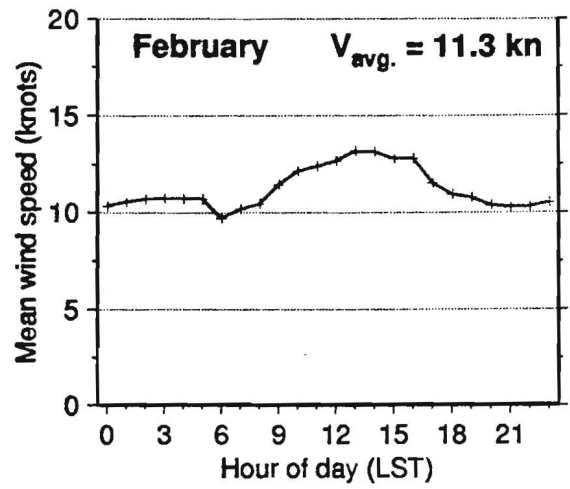
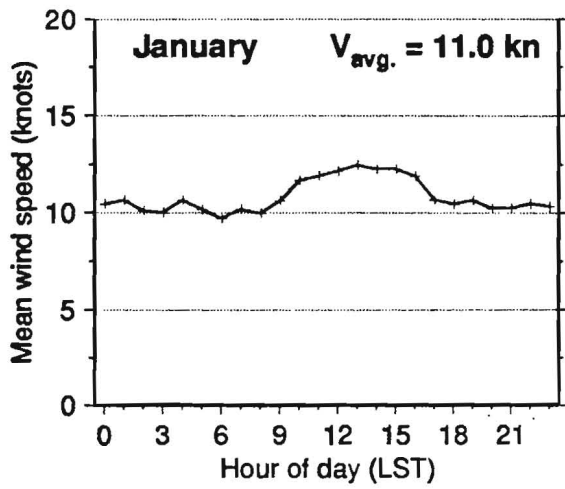
figure 12





Wind Speed, Diurnal Variation 7/48-12/92 Bridgeport

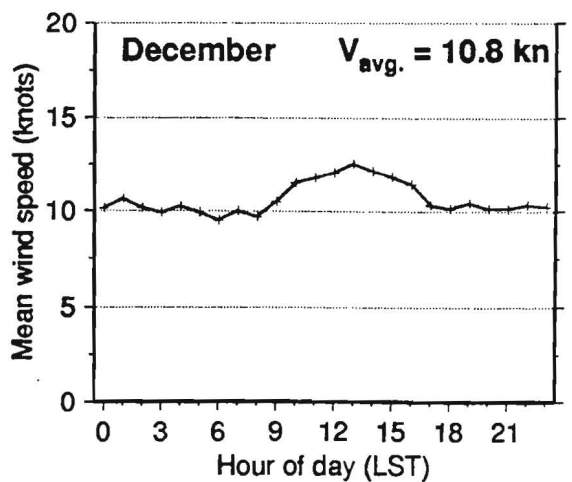
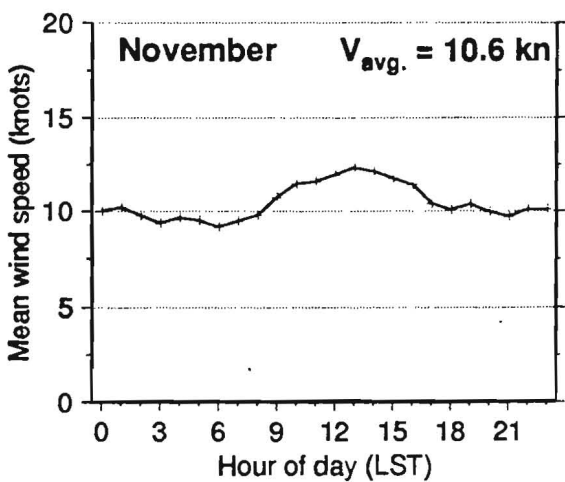
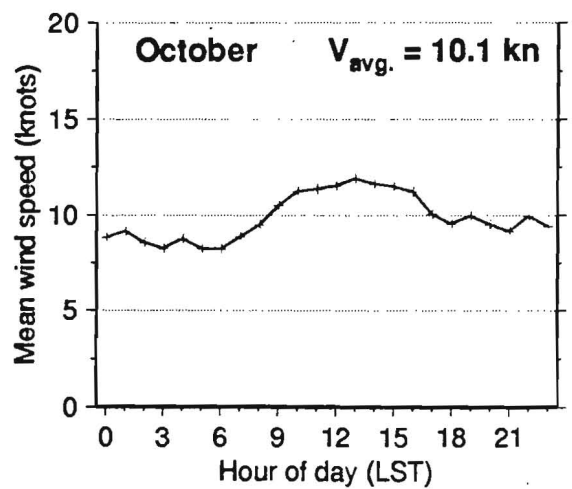
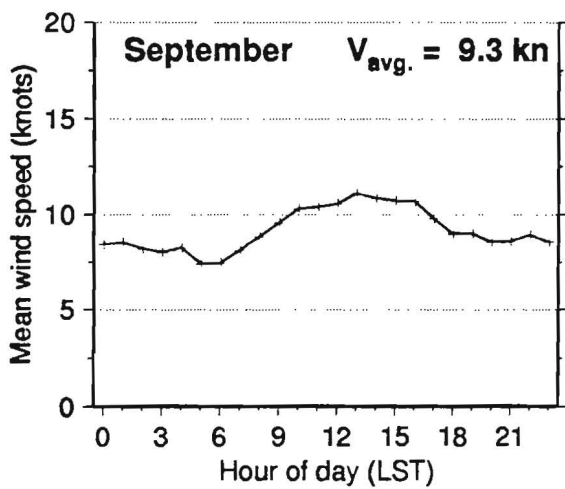
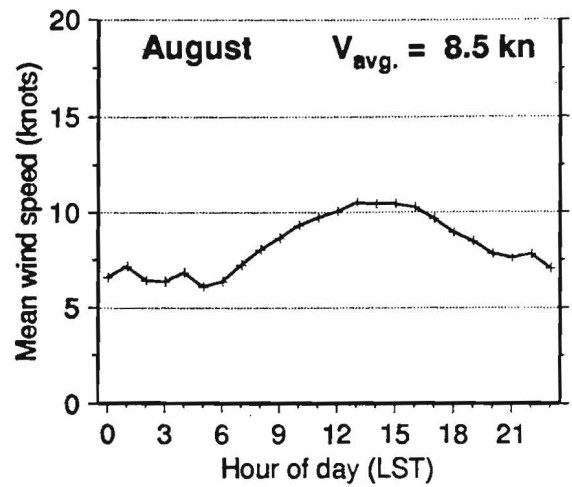
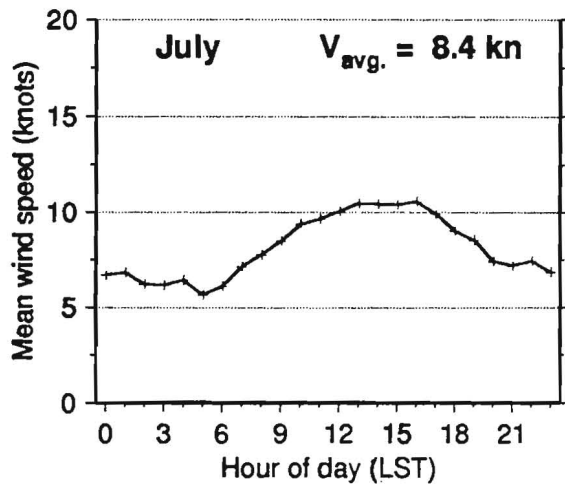
figure 13





Wind Speed, Diurnal Variation 7/48-12/92 Bridgeport

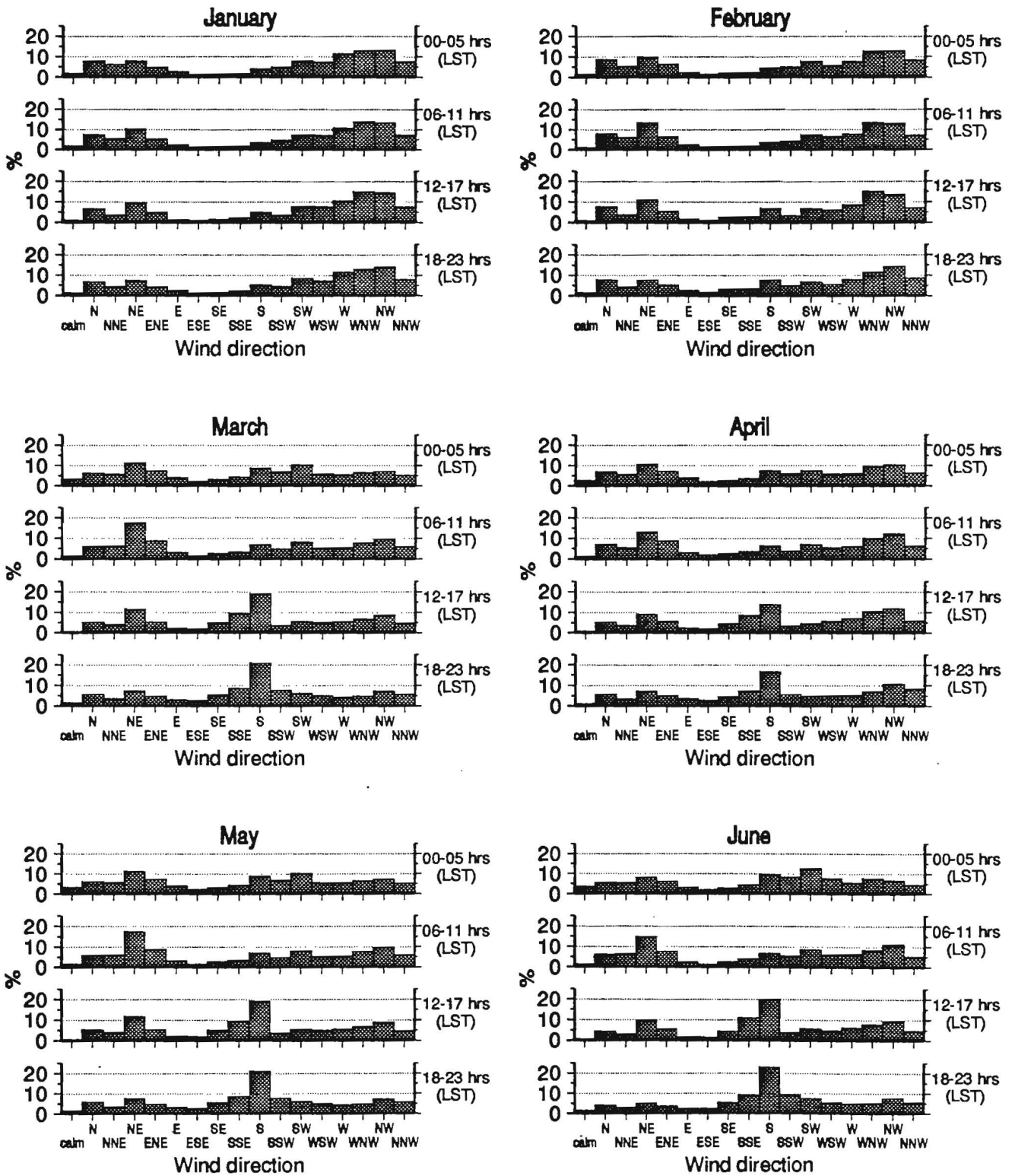
figure 13

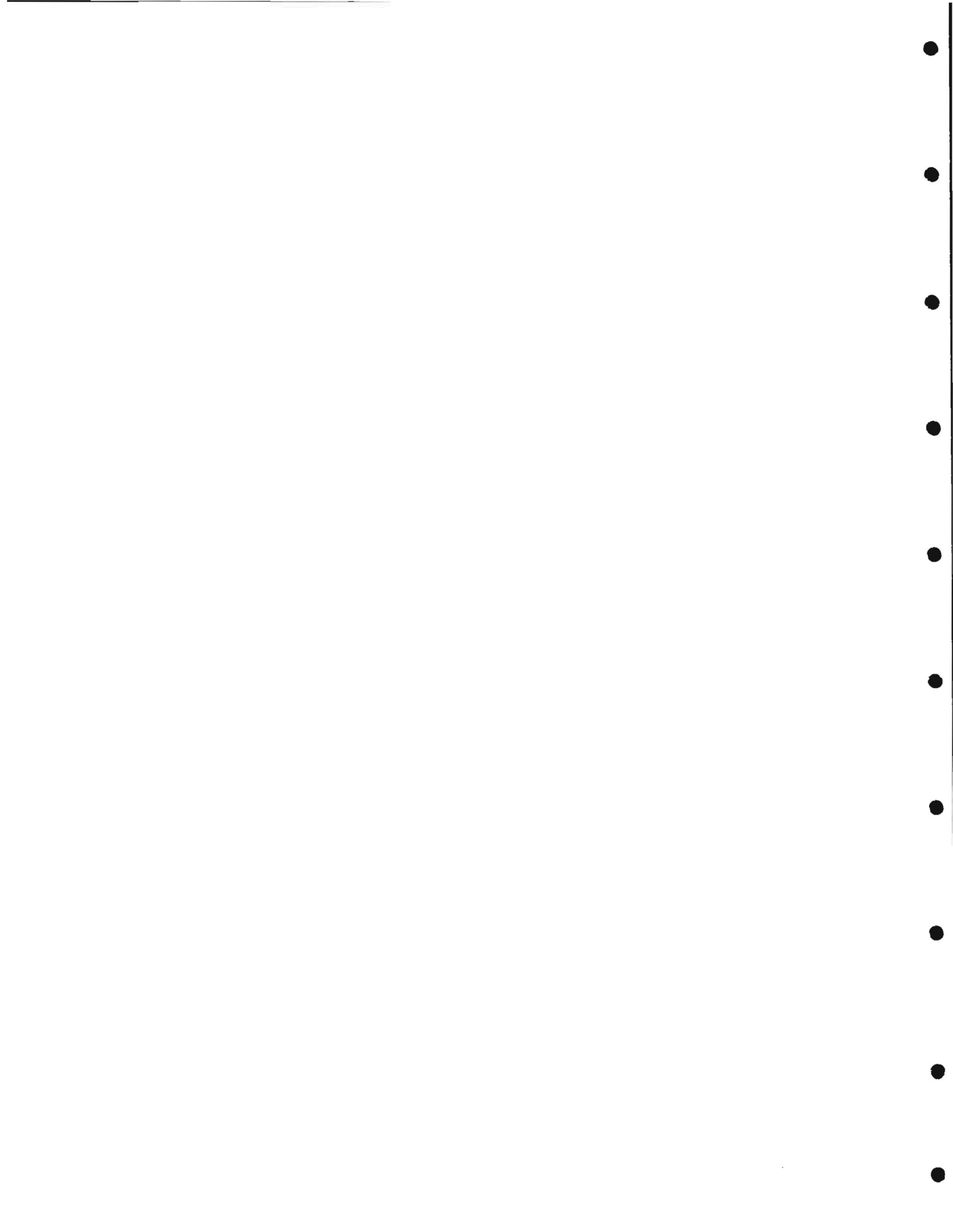




Wind Direction, Diurnal Variation 7/48-12/92 LaGuardia

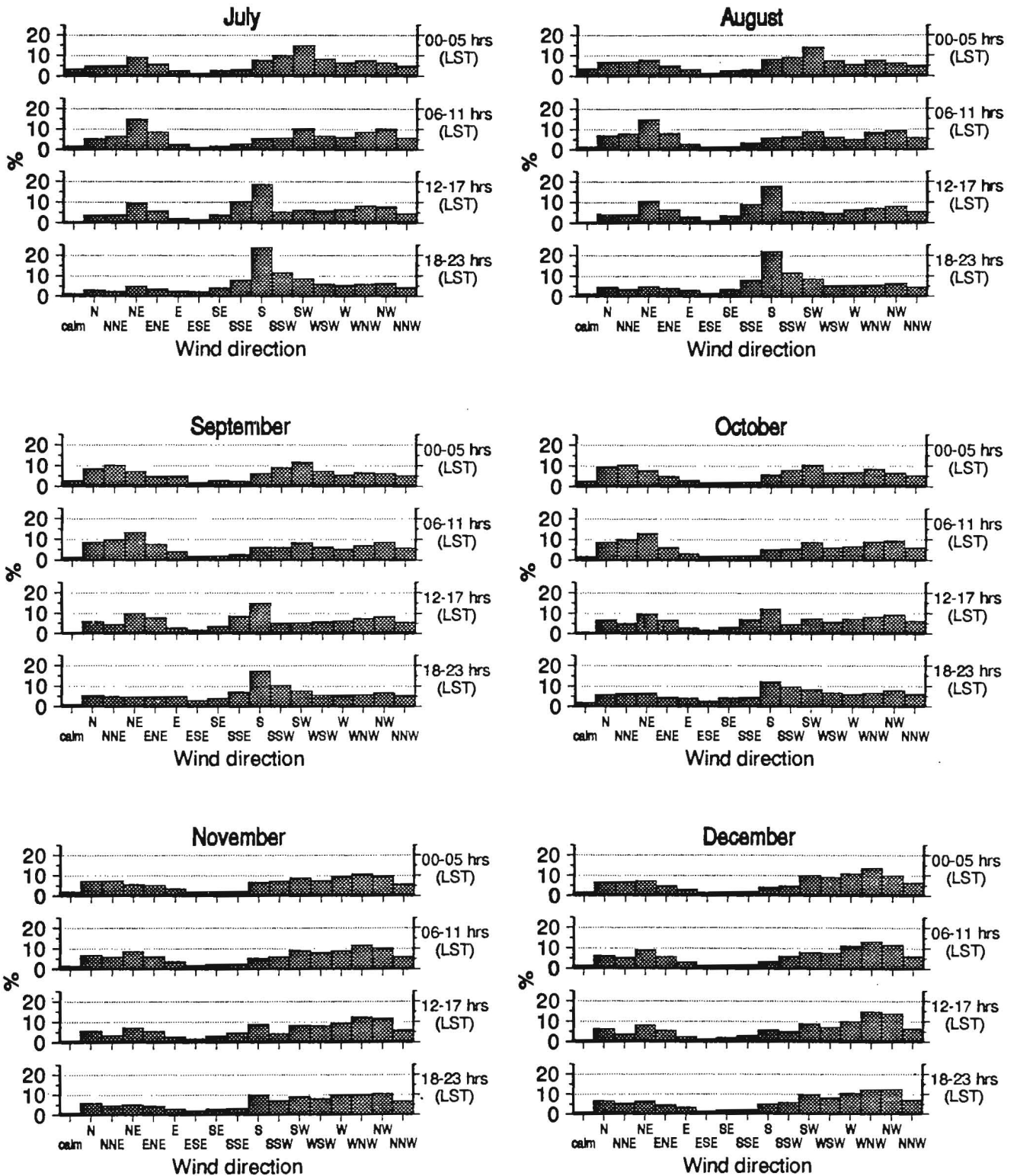
figure 14





Wind Direction, Diurnal Variation 7/48-12/92 LaGuardia

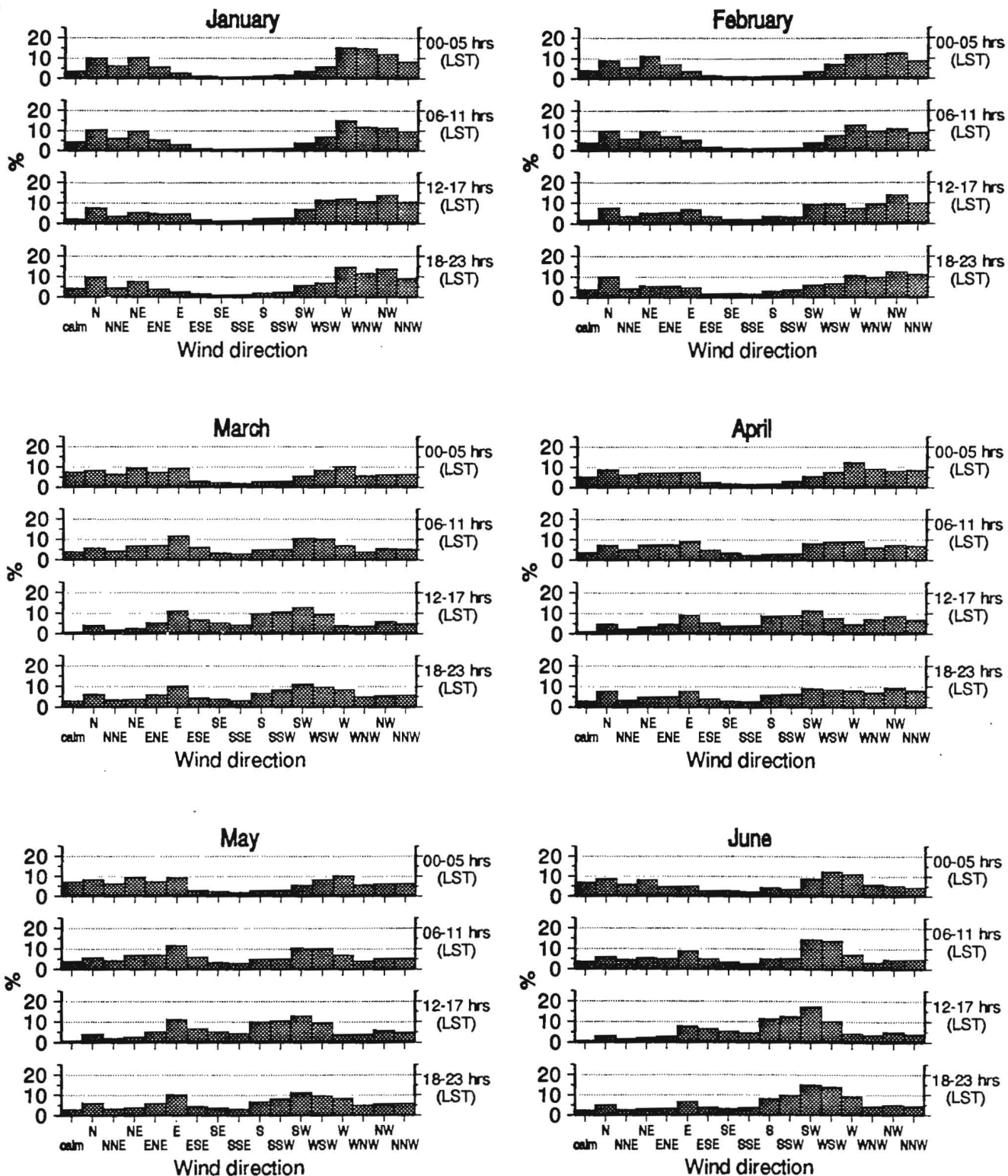
figure 14





Wind Direction, Diurnal Variation 7/48-12/92 Bridgeport

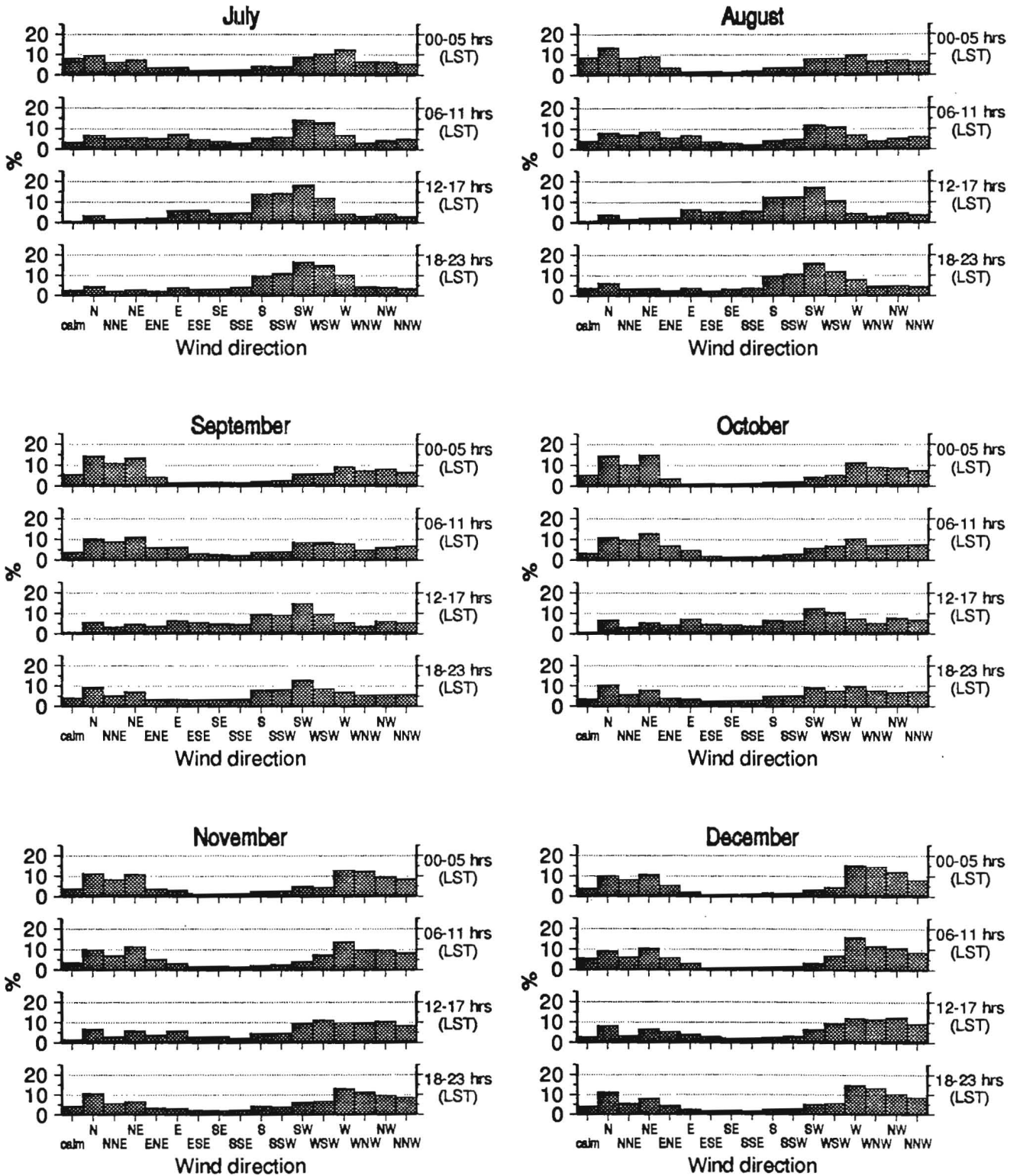
figure 15





Wind Direction, Diurnal Variation 7/48-12/92 Bridgeport

figure 15



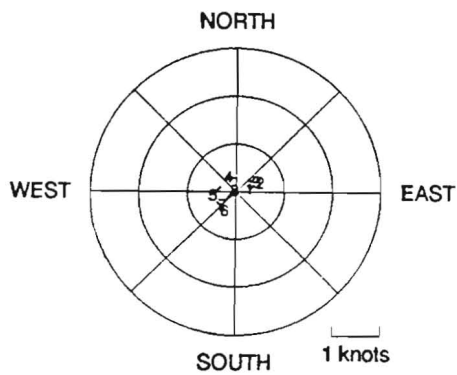


Resultant Wind, Diurnal Anomaly (kn) 7/48-12/92 LaGuardia

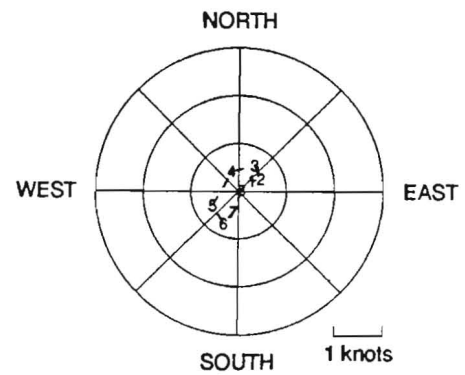
figure 16

TIME PERIODS:

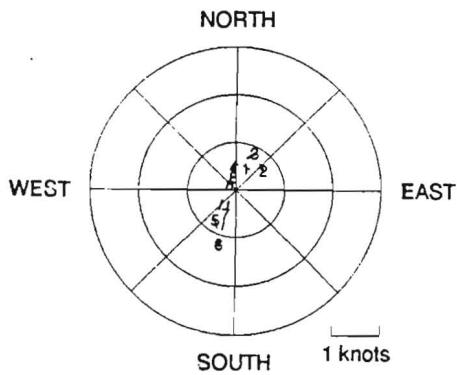
- | | |
|----------------|----------------|
| 1: 01:00-04:00 | 5: 13:00-16:00 |
| 2: 04:00-07:00 | 6: 16:00-19:00 |
| 3: 07:00-10:00 | 7: 19:00-22:00 |
| 4: 10:00-13:00 | 8: 22:00-01:00 |



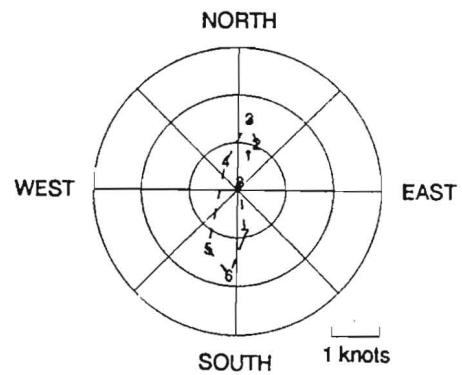
January



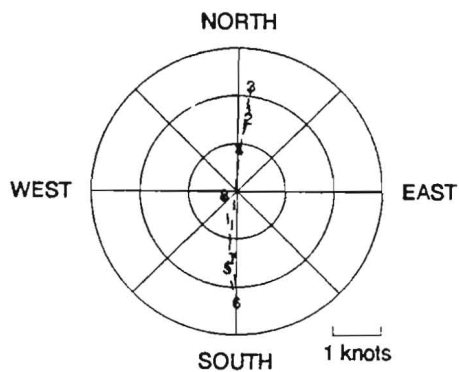
February



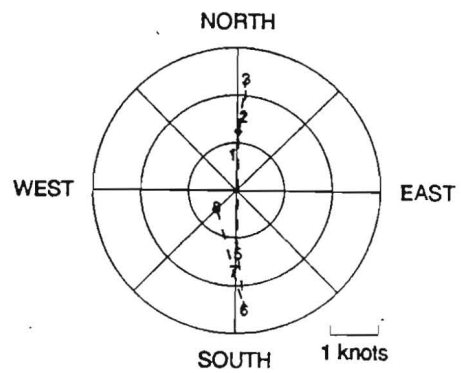
March



April



May



June

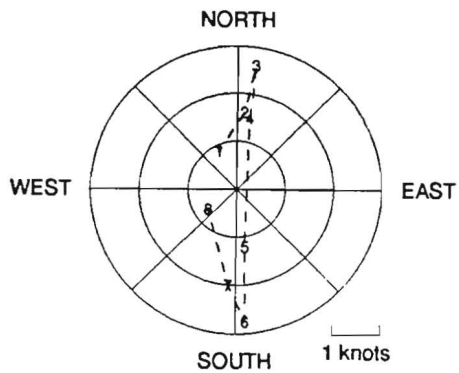


Resultant Wind, Diurnal Anomaly (kn) 7/48-12/92 LaGuardia

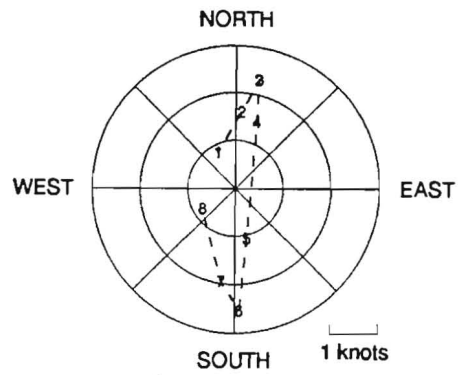
figure 16

TIME PERIODS:

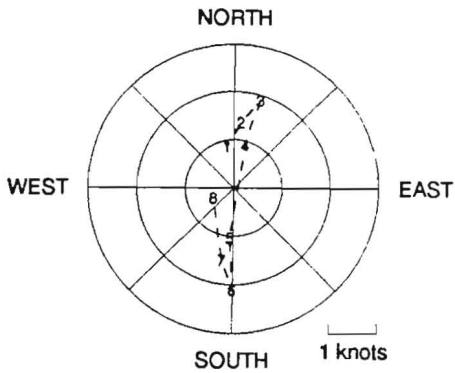
- | | |
|----------------|----------------|
| 1: 01:00-04:00 | 5: 13:00-16:00 |
| 2: 04:00-07:00 | 6: 16:00-19:00 |
| 3: 07:00-10:00 | 7: 19:00-22:00 |
| 4: 10:00-13:00 | 8: 22:00-01:00 |



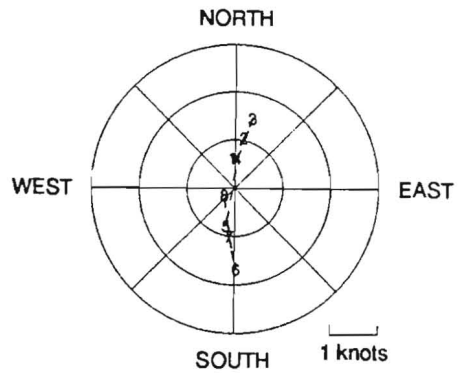
July



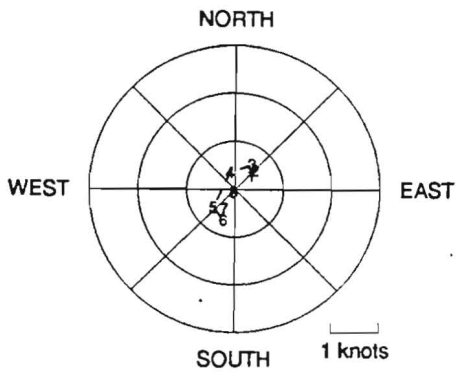
August



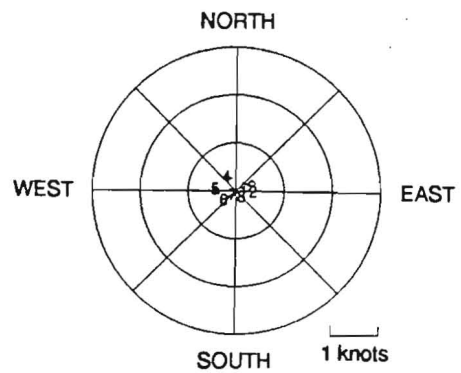
September



October



November



December

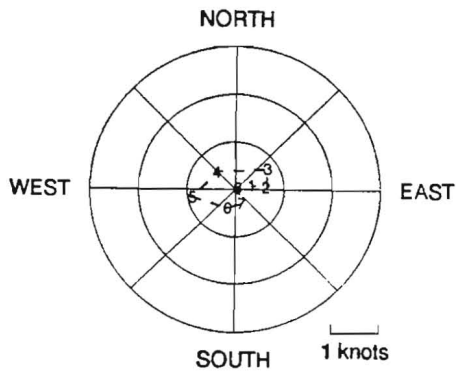


Resultant Wind, Diurnal Anomaly (kn) 7/48-12/92 Bridgeport

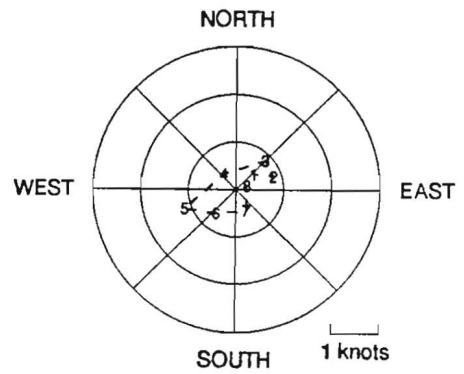
figure 17

TIME PERIODS:

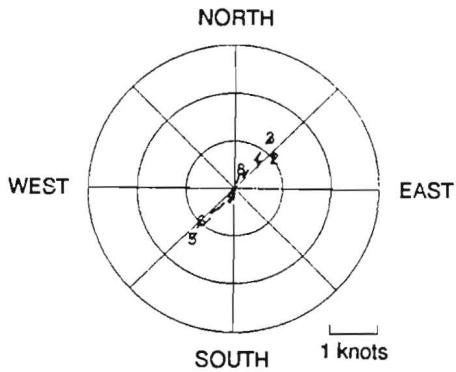
- | | |
|----------------|----------------|
| 1: 01:00-04:00 | 5: 13:00-16:00 |
| 2: 04:00-07:00 | 6: 16:00-19:00 |
| 3: 07:00-10:00 | 7: 19:00-22:00 |
| 4: 10:00-13:00 | 8: 22:00-01:00 |



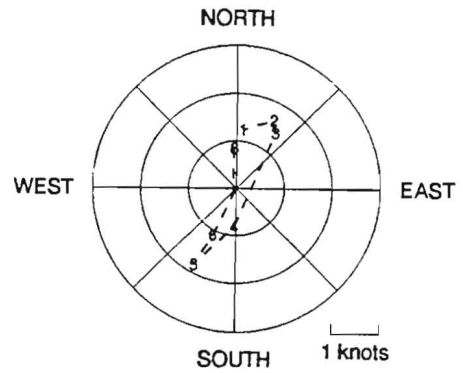
January



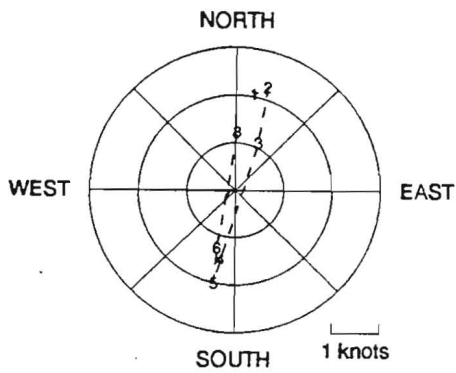
February



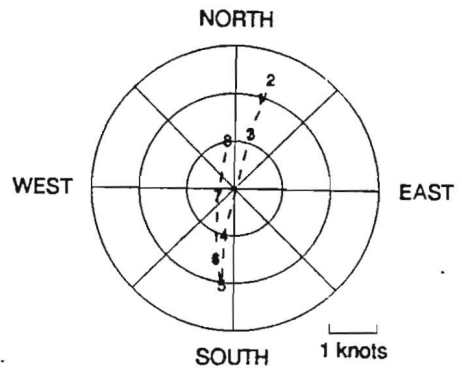
March



April



May



June

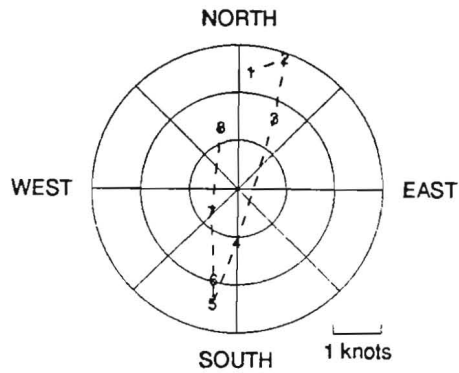


Resultant Wind, Diurnal Anomaly (kn) 7/48-12/92 Bridgeport

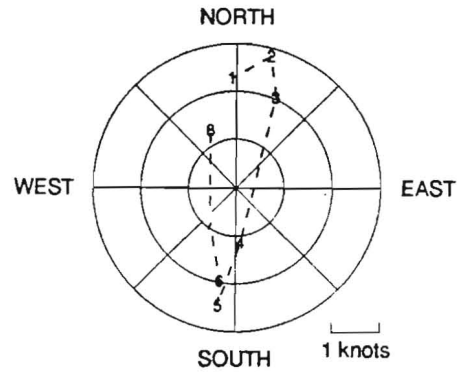
figure 17

TIME PERIODS:

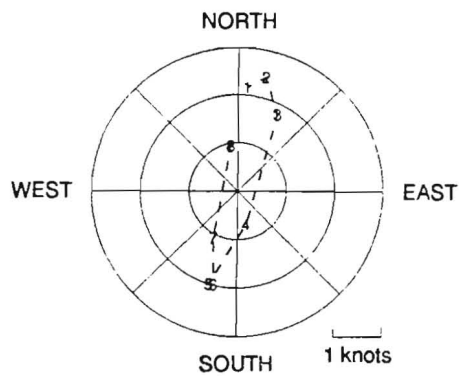
- | | |
|----------------|----------------|
| 1: 01:00-04:00 | 5: 13:00-16:00 |
| 2: 04:00-07:00 | 6: 16:00-19:00 |
| 3: 07:00-10:00 | 7: 19:00-22:00 |
| 4: 10:00-13:00 | 8: 22:00-01:00 |



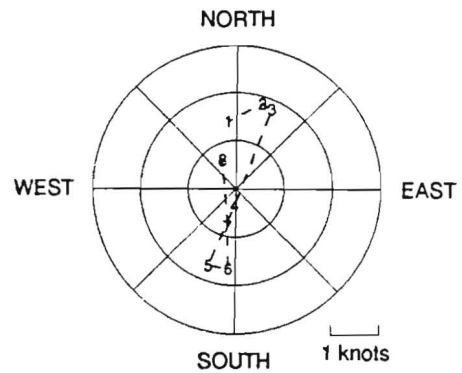
July



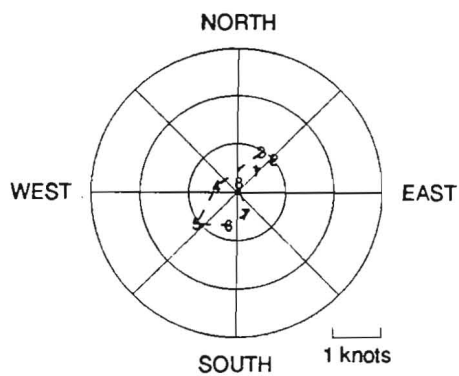
August



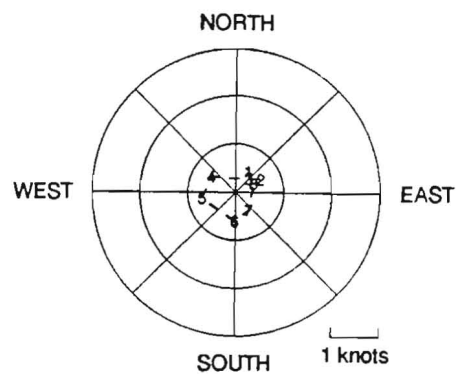
September



October



November

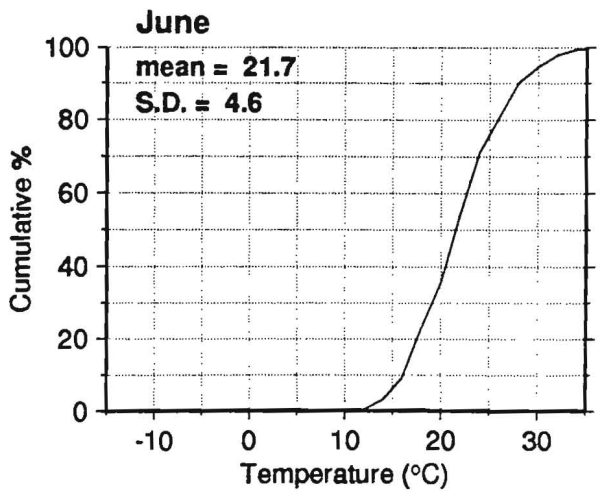
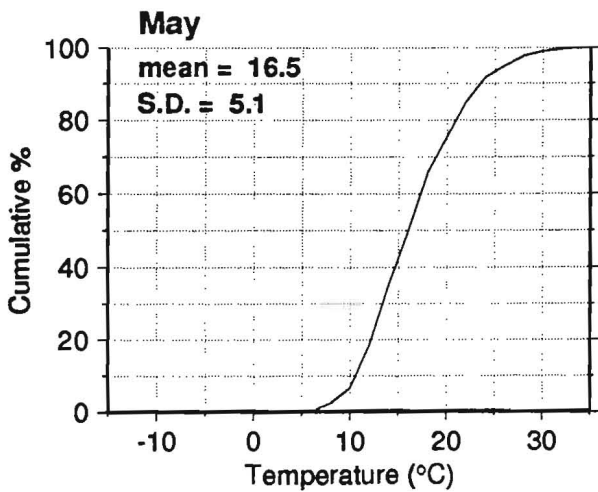
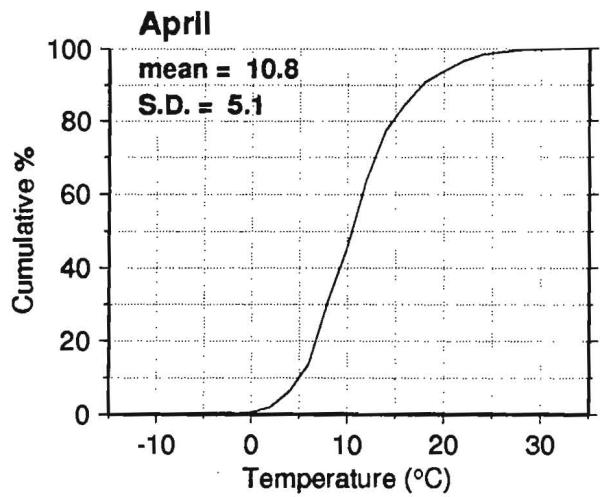
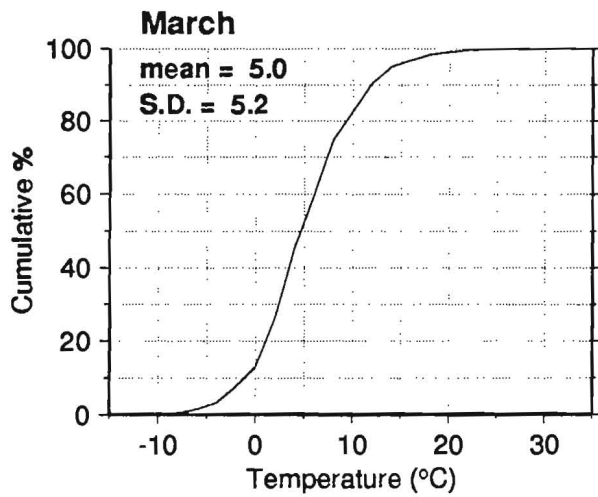
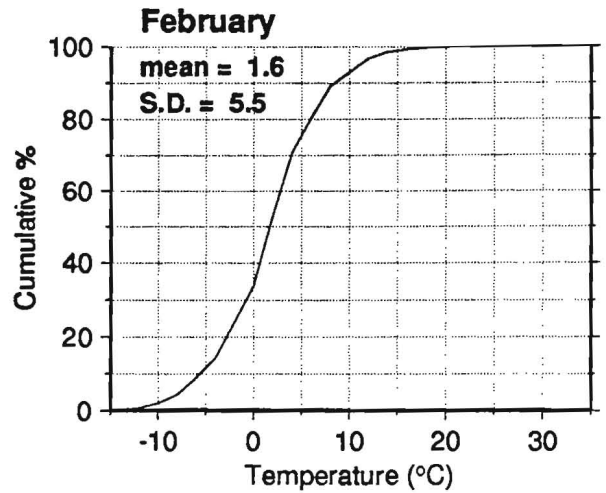
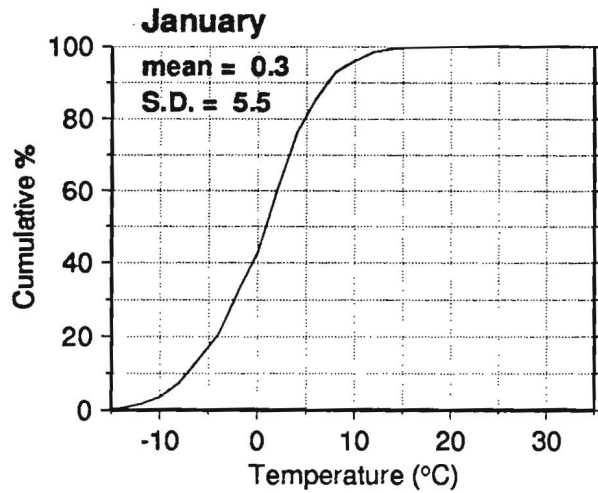


December



Temperature, Cumulative Frequency 7/48-12/92 LaGuardia

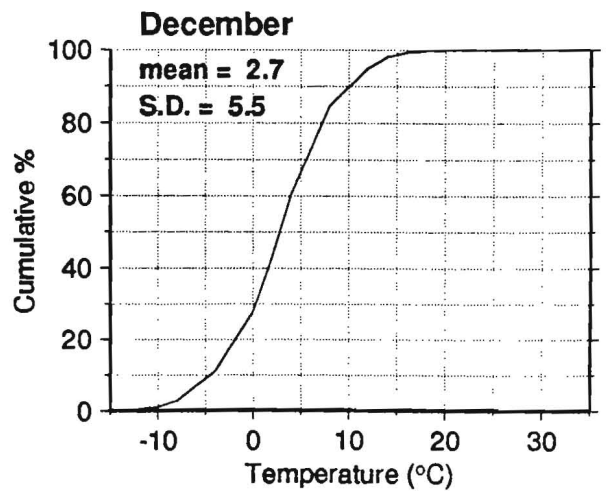
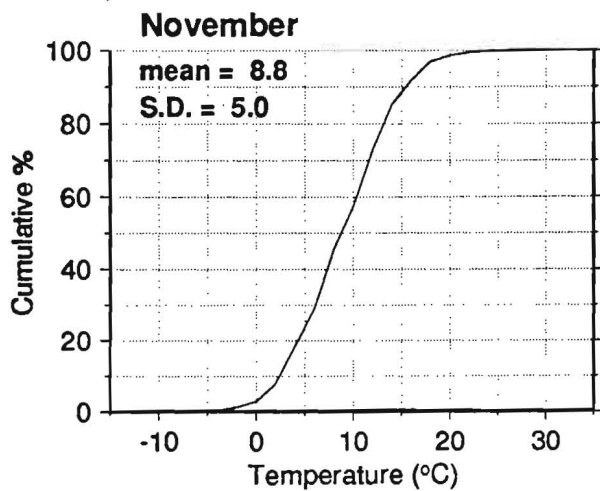
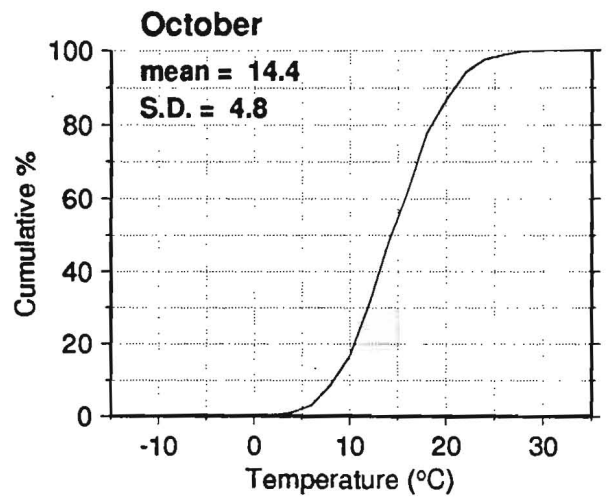
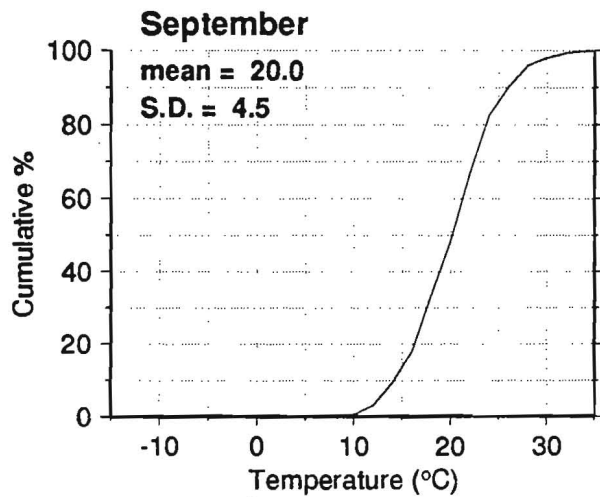
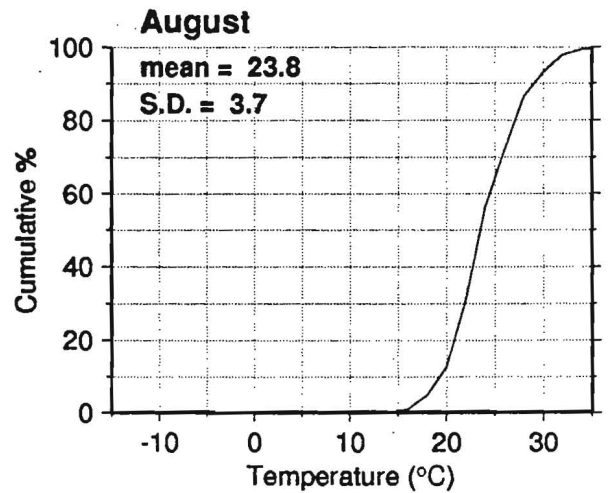
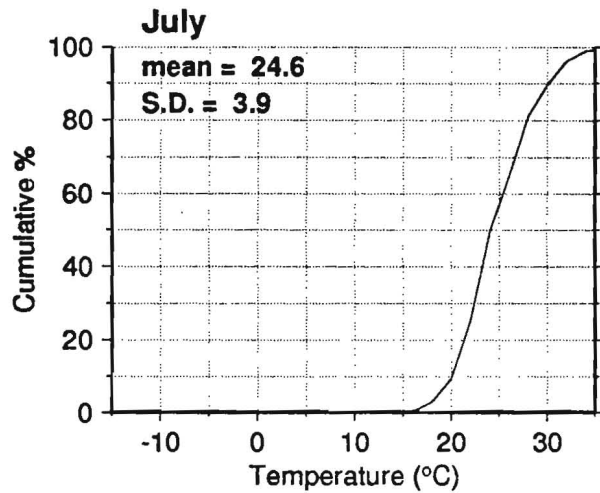
figure 18





Temperature, Cumulative Frequency 7/48-12/92 LaGuardia

figure 18

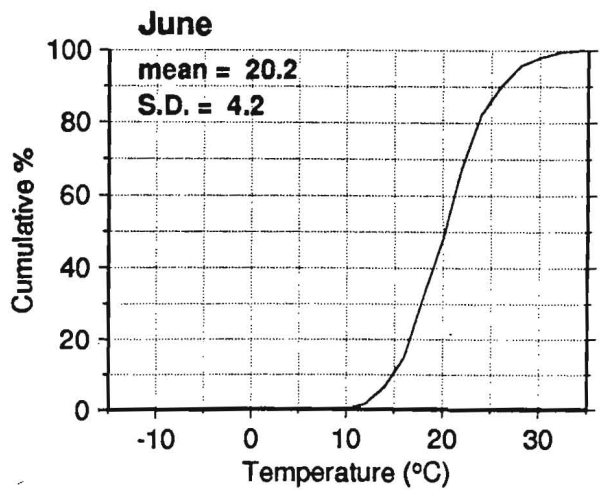
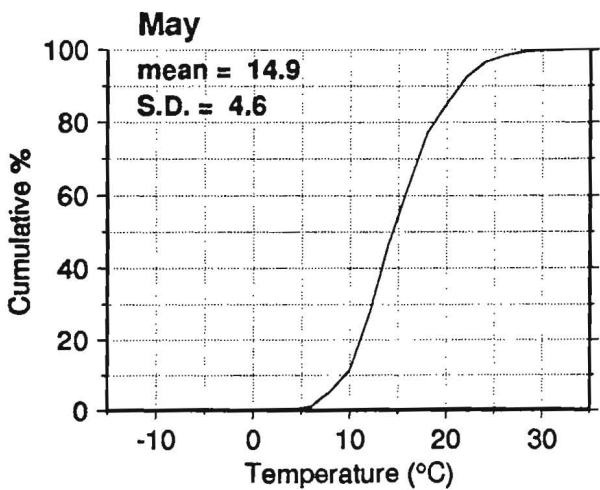
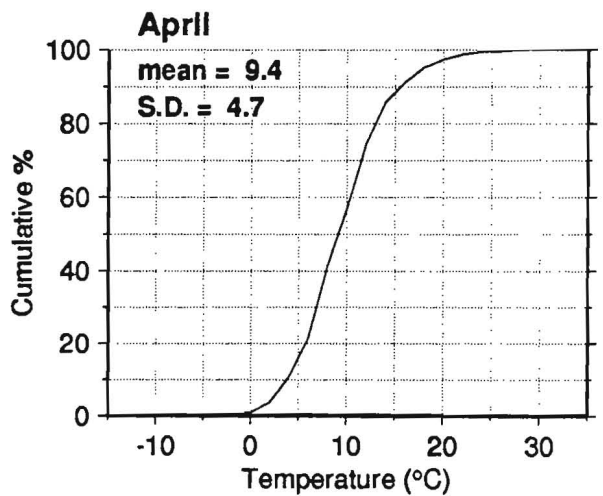
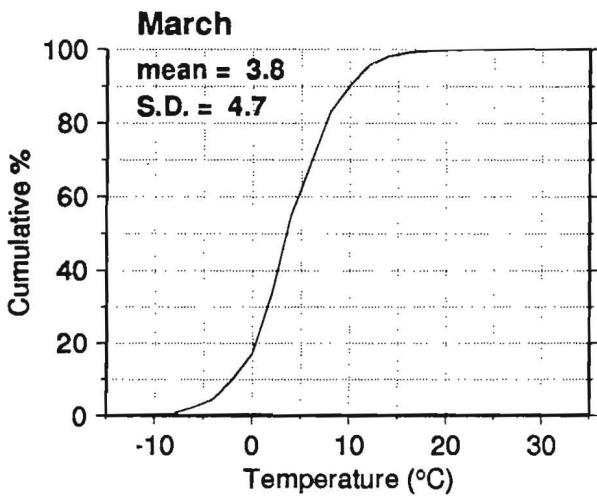
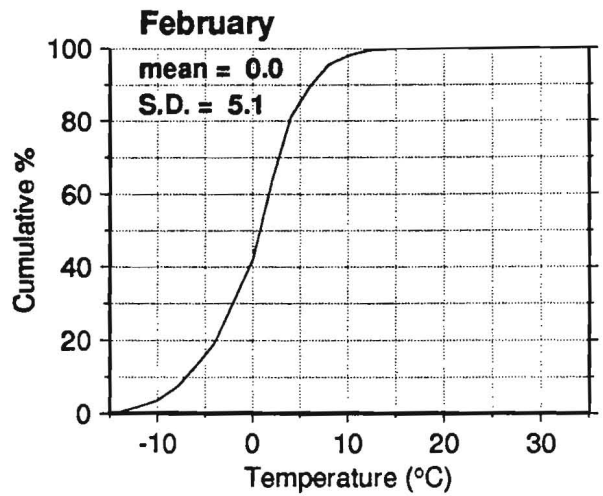
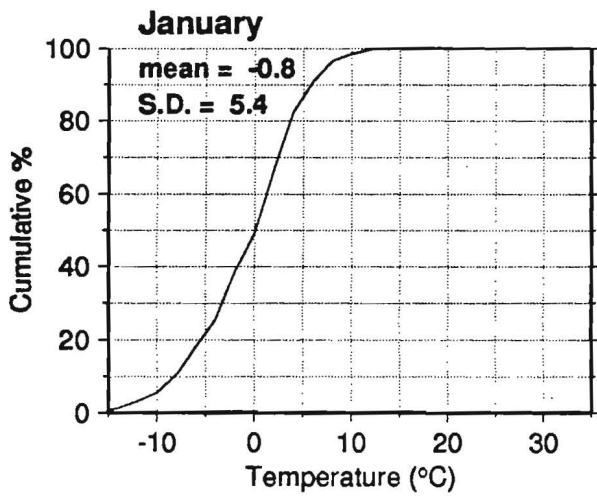




Temperature, Cumulative Frequency

7/48-12/92 Bridgeport

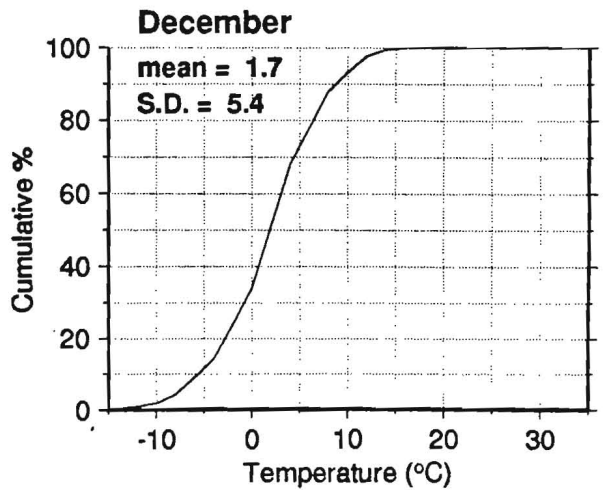
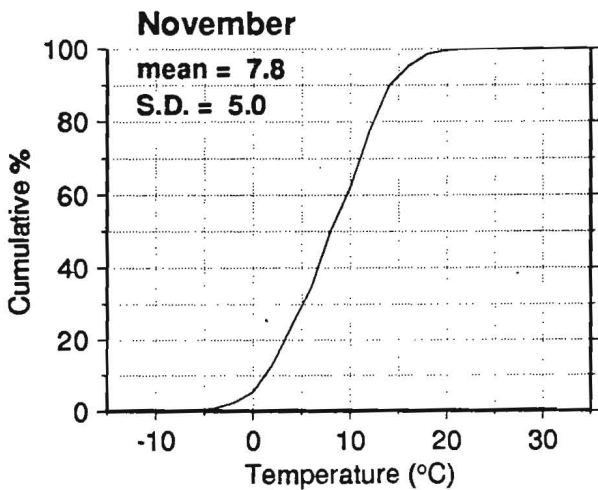
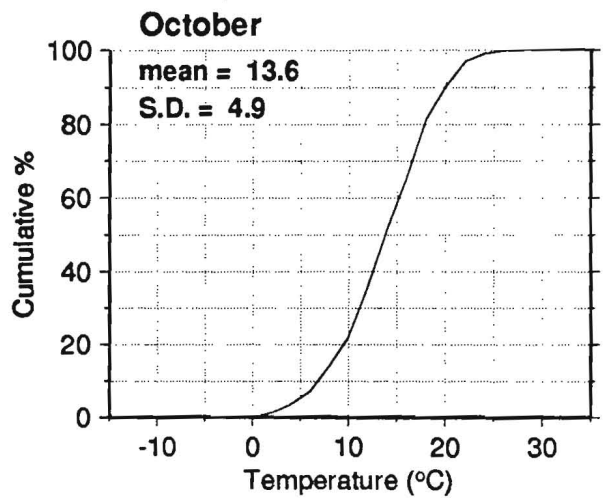
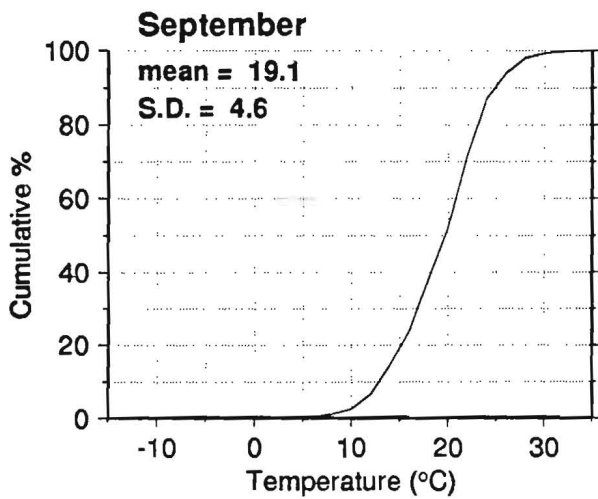
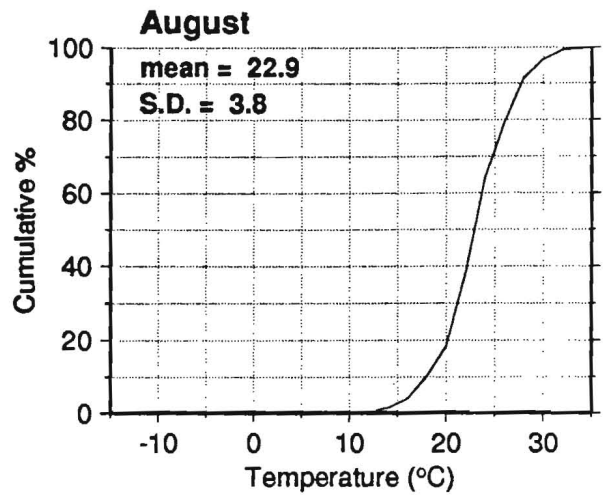
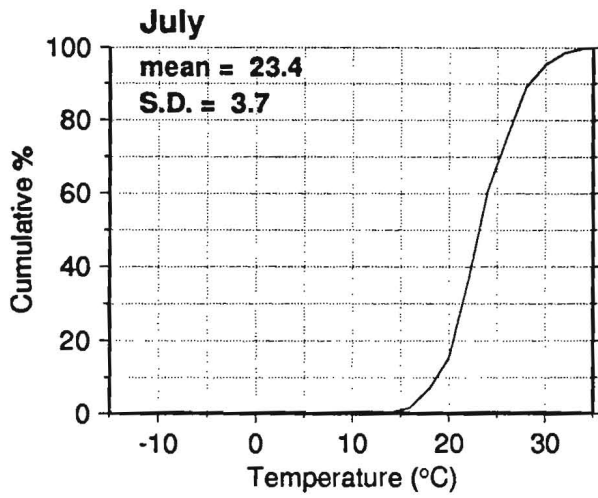
figure 19





Temperature, Cumulative Frequency 7/48-12/92 Bridgeport

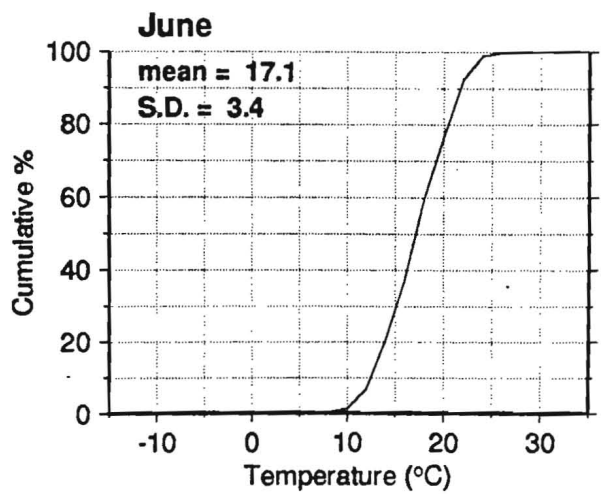
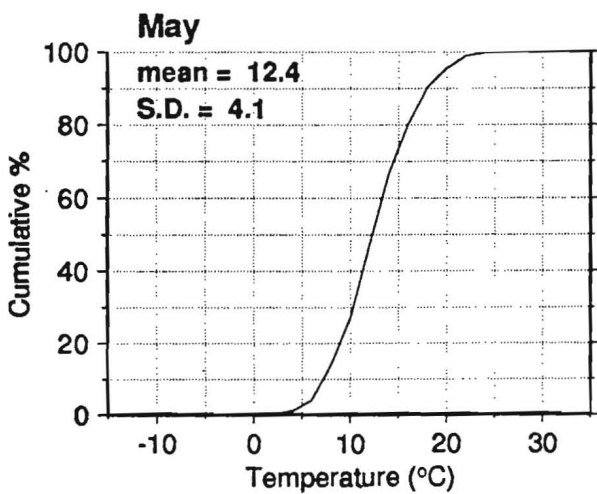
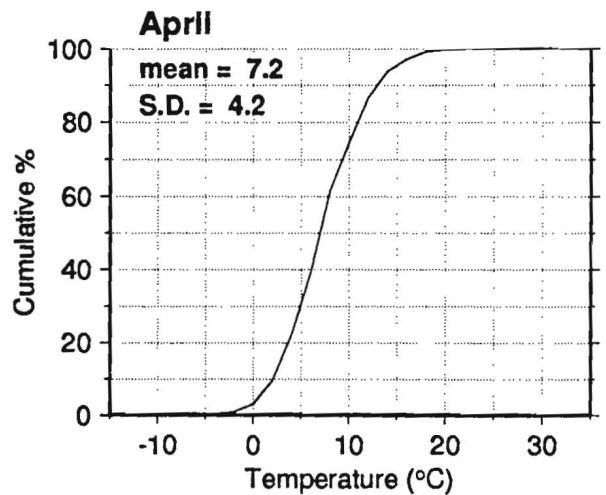
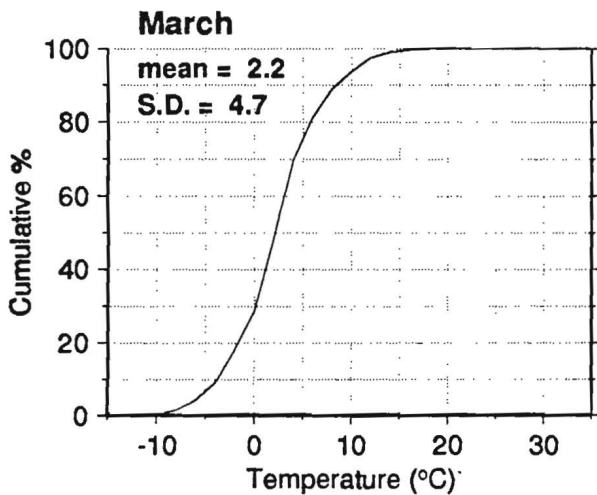
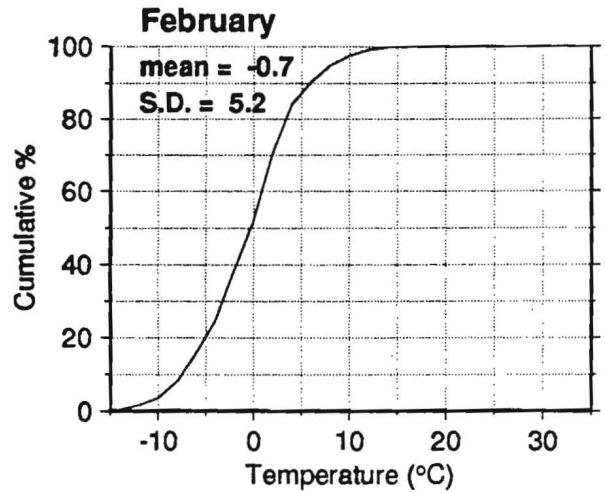
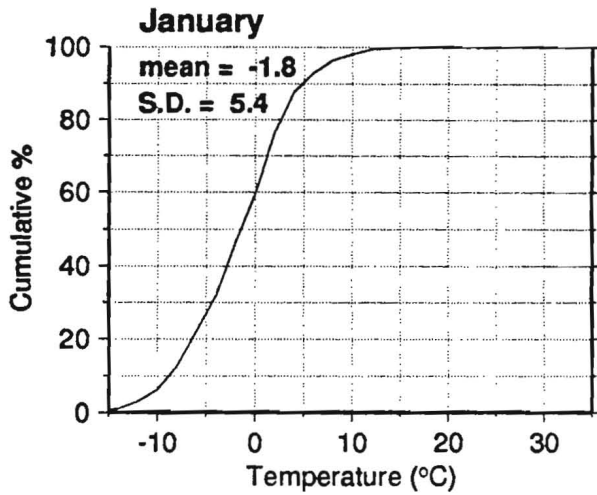
figure 19





Wet Bulb Temperature, Cumulative Frequency figure 20

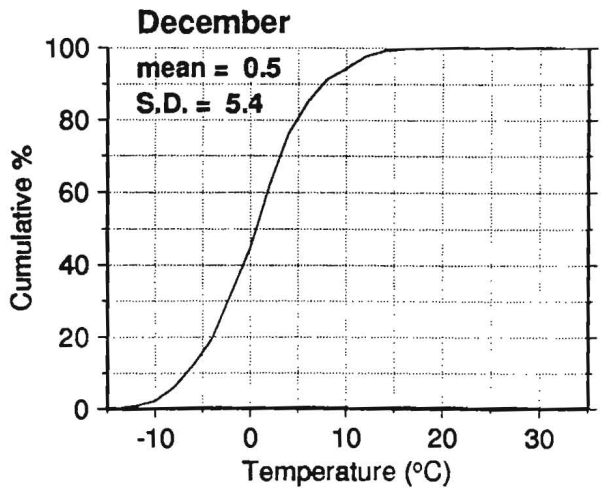
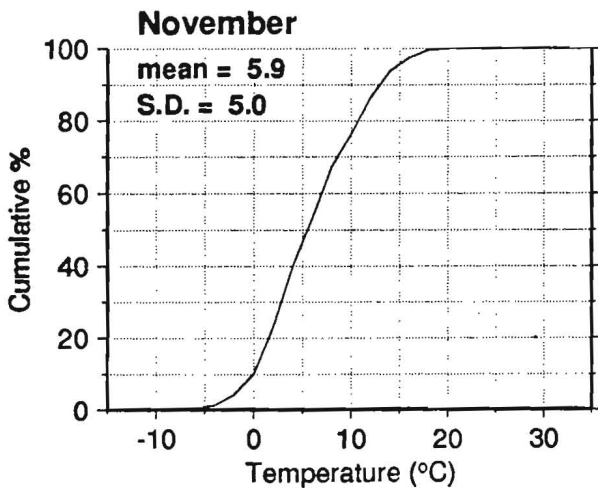
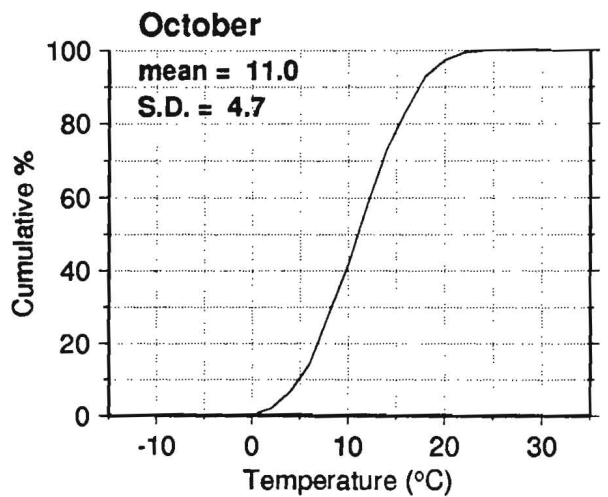
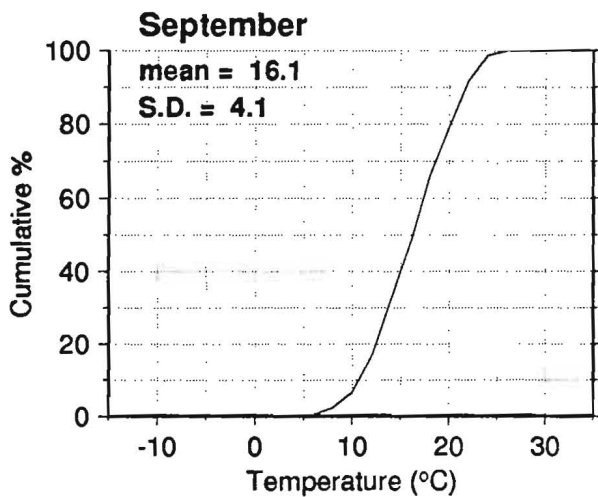
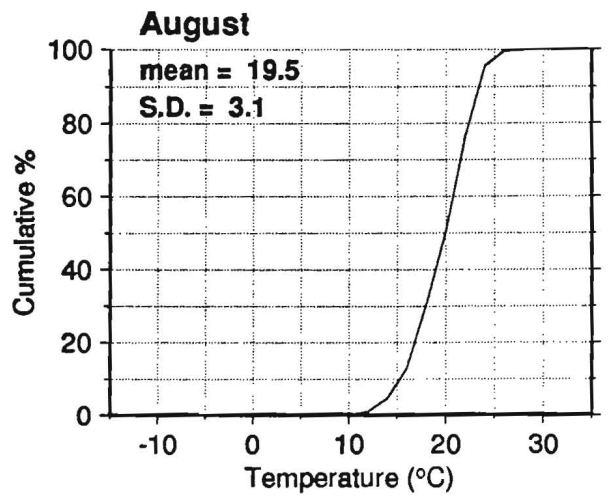
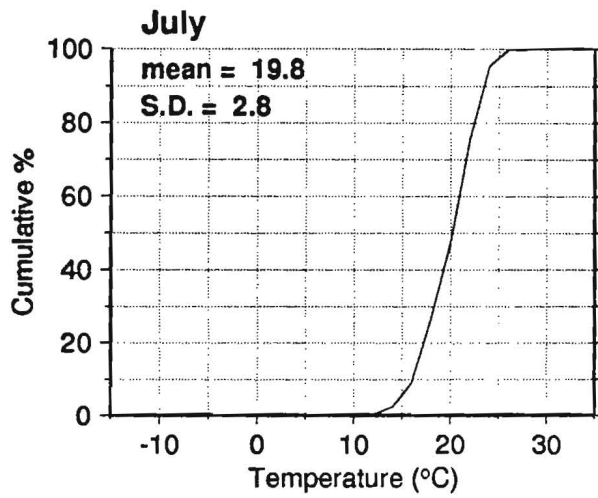
7/48-12/92 LaGuardia





Wet Bulb Temperature, Cumulative Frequency figure 20

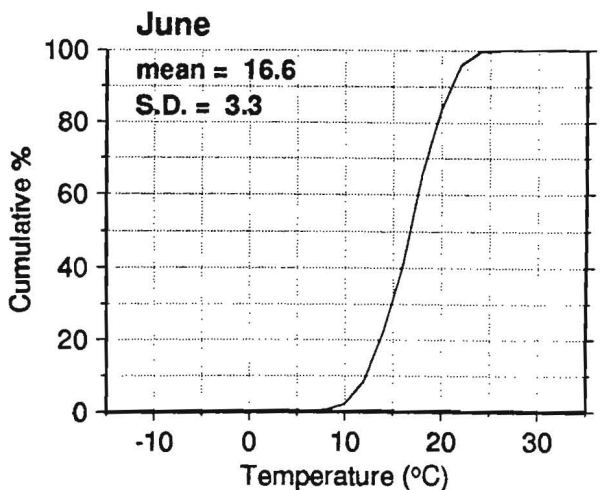
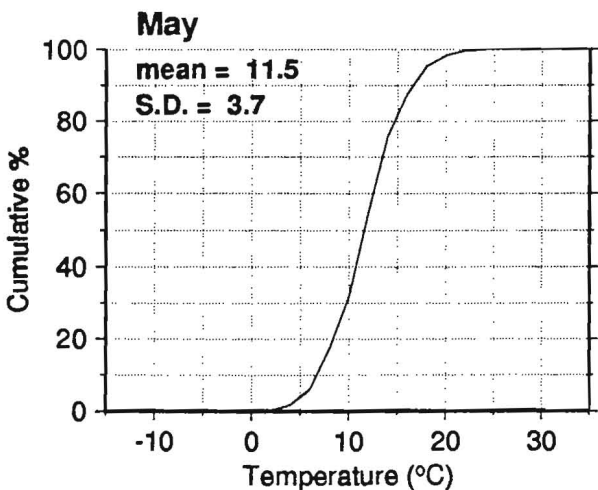
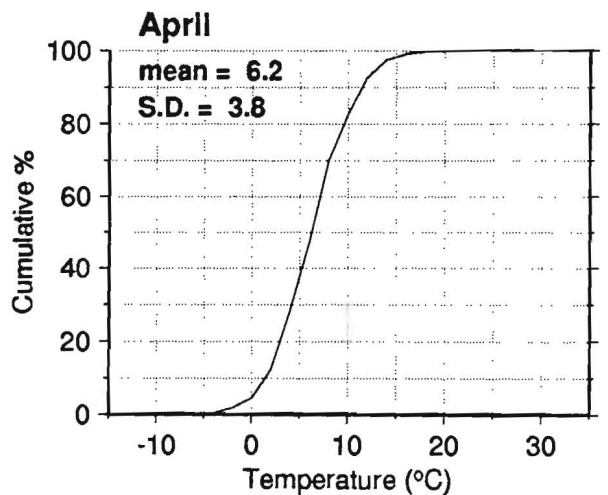
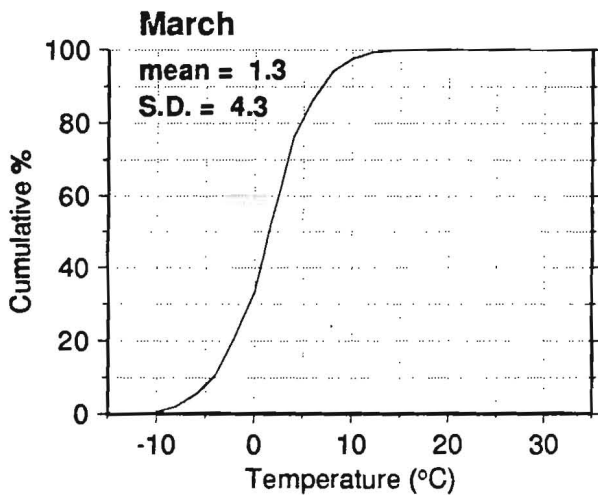
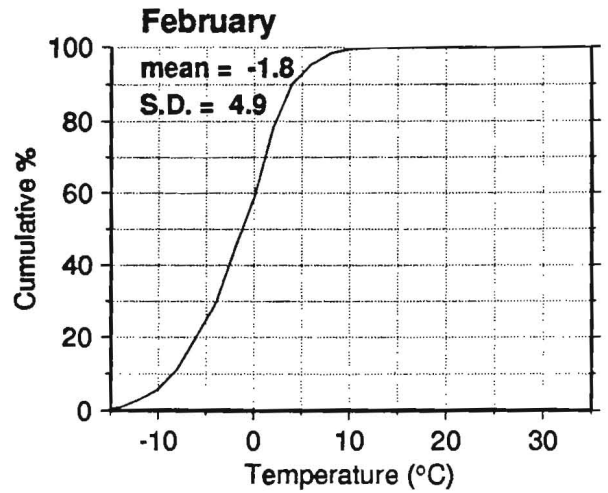
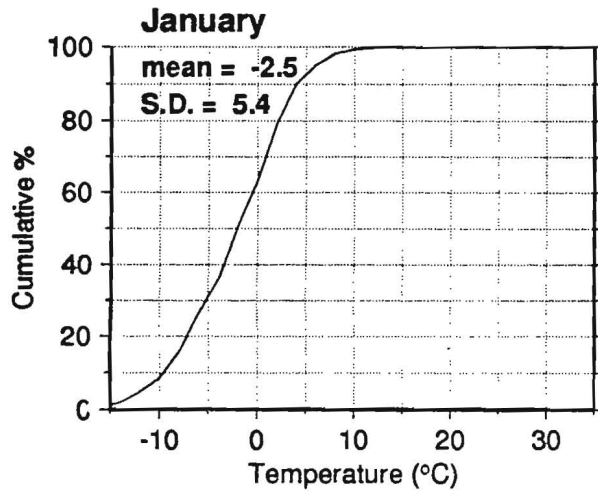
7/48-12/92 LaGuardia





Wet Bulb Temperature, Cumulative Frequency figure 21

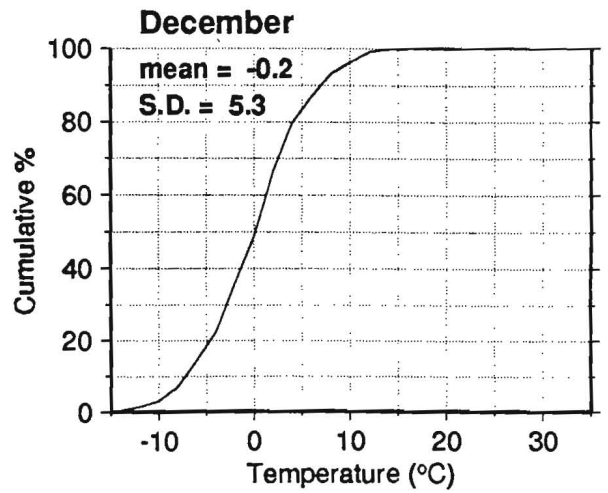
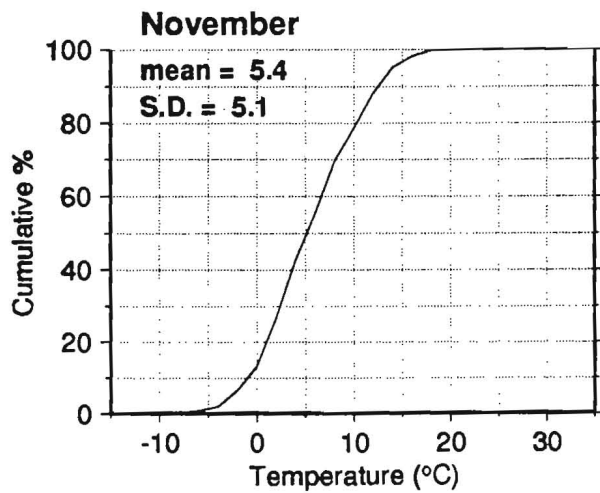
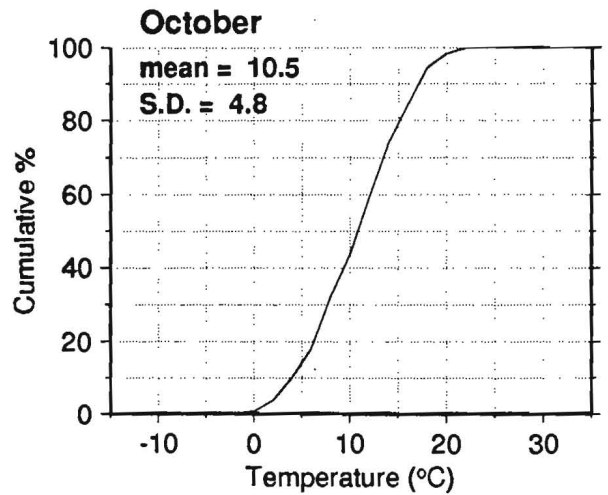
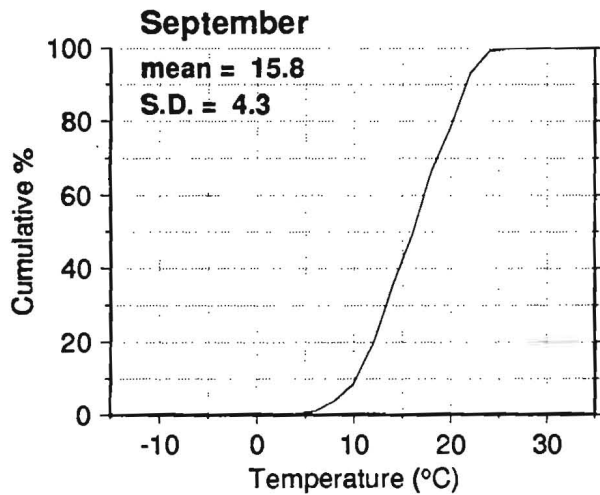
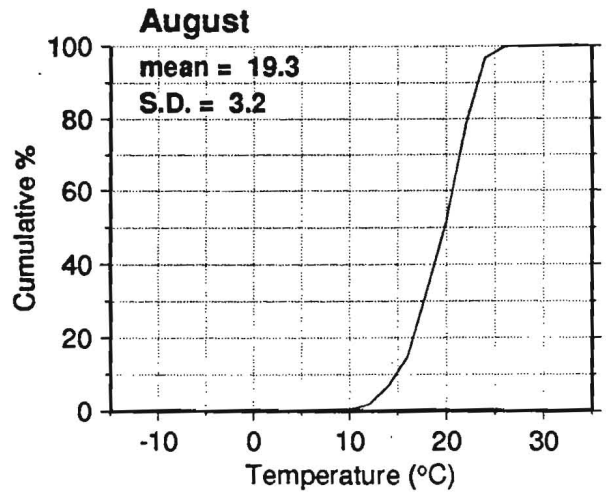
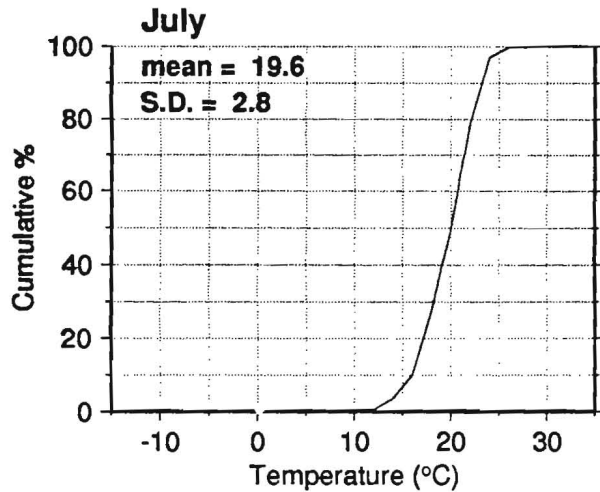
7/48-12/92 Bridgeport





Wet Bulb Temperature, Cumulative Frequency figure 21

7/48-12/92 Bridgeport

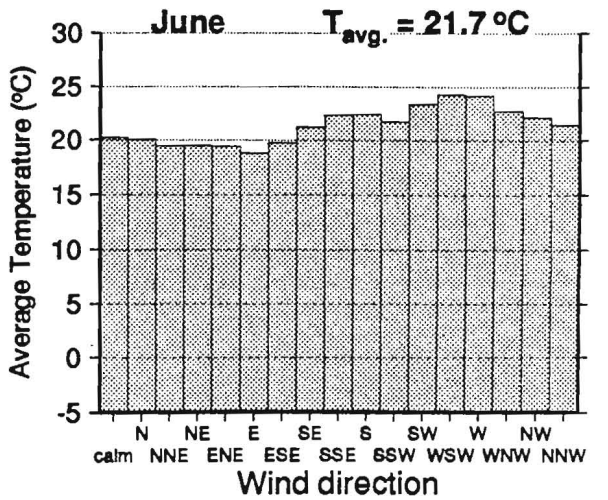
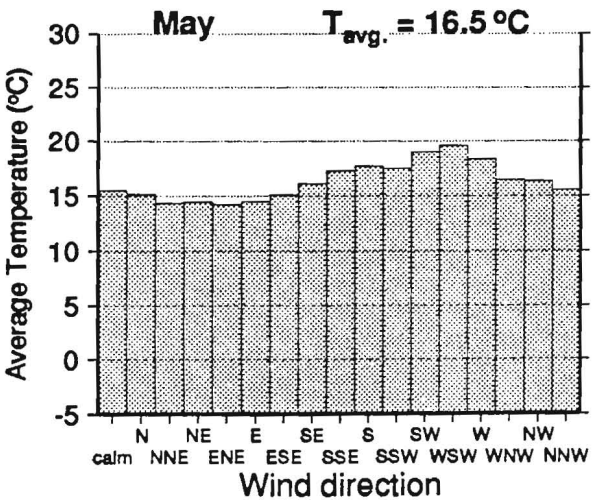
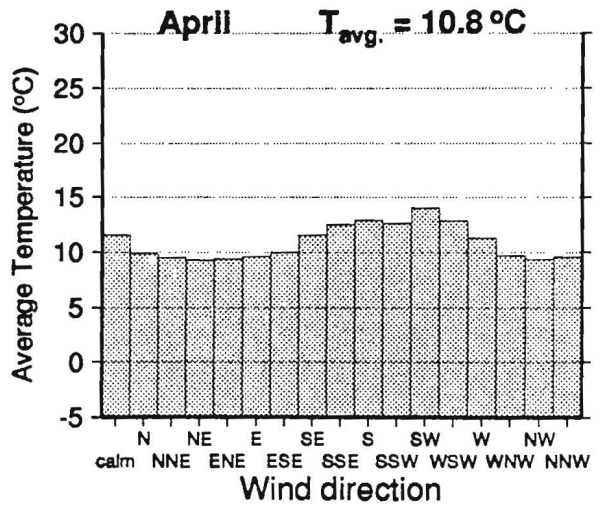
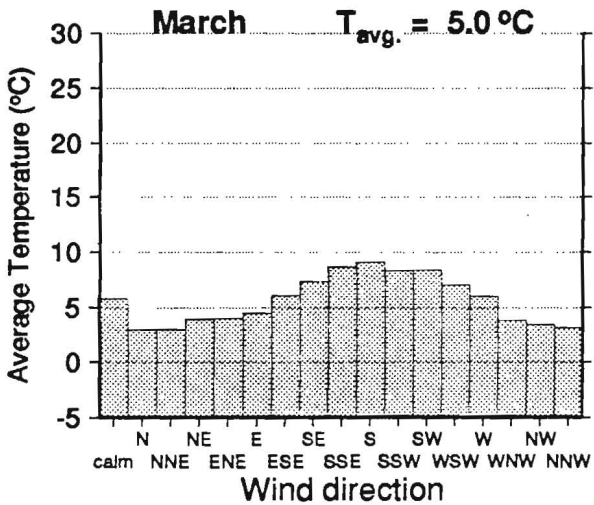
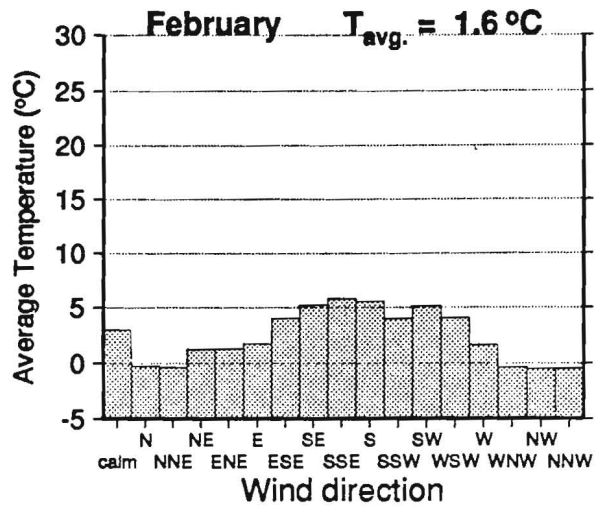
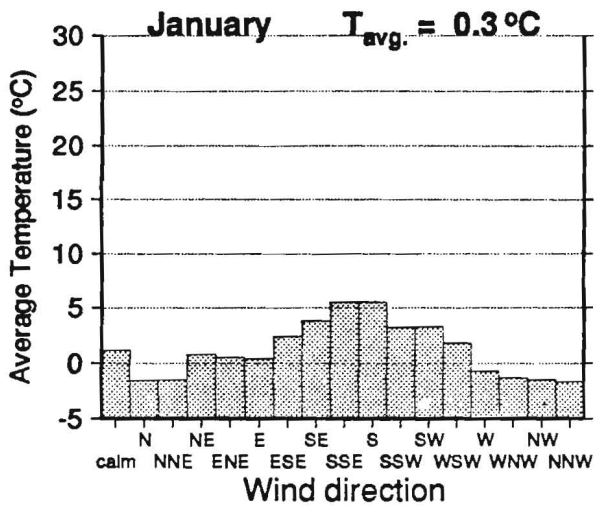




Temperature vs. Wind Direction

7/48-12/92 LaGuardia

figure 22

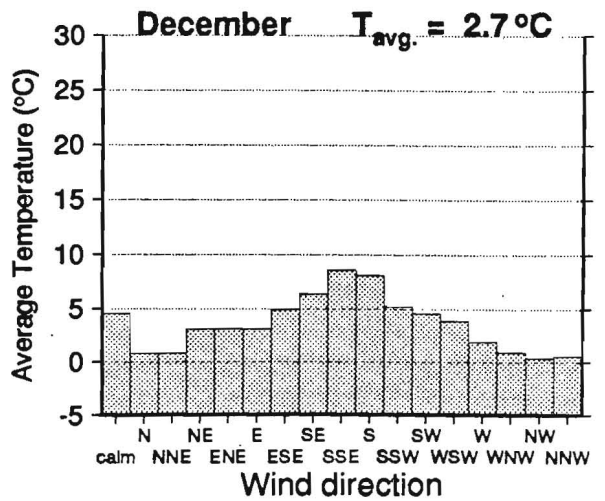
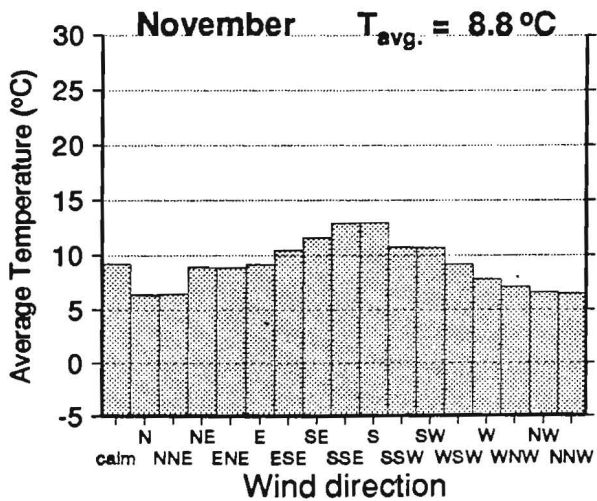
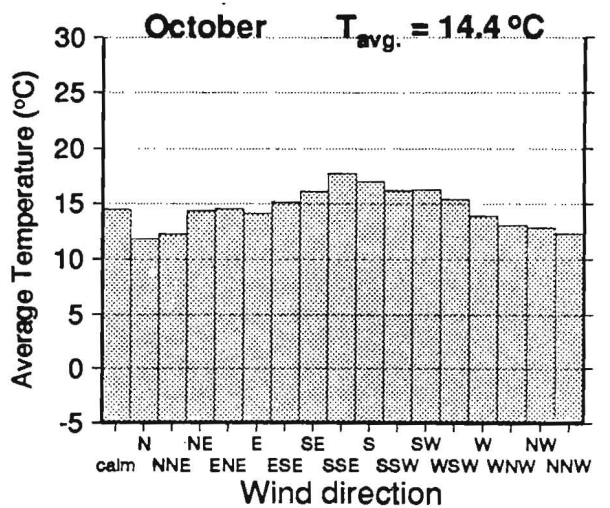
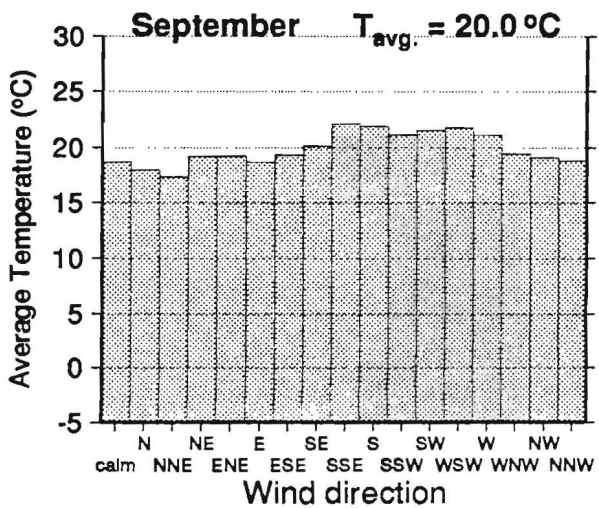
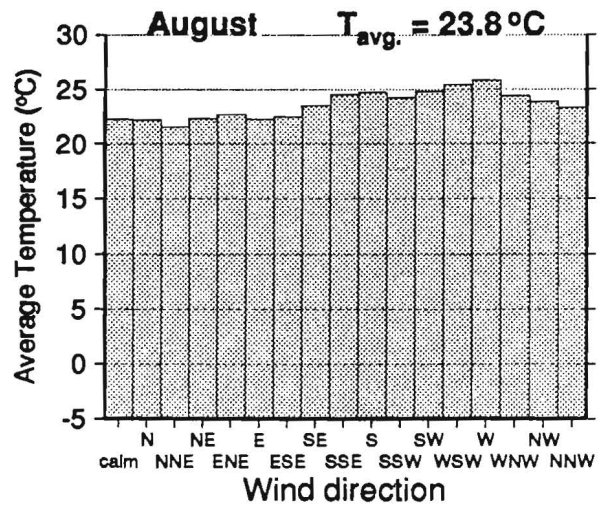
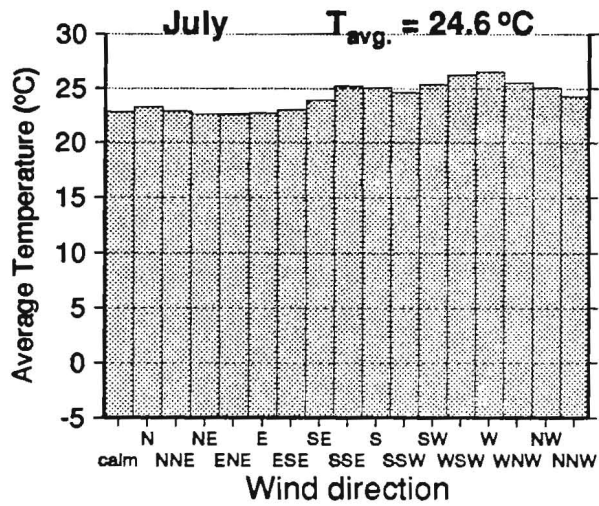




Temperature vs. Wind Direction

7/48-12/92 LaGuardia

figure 22

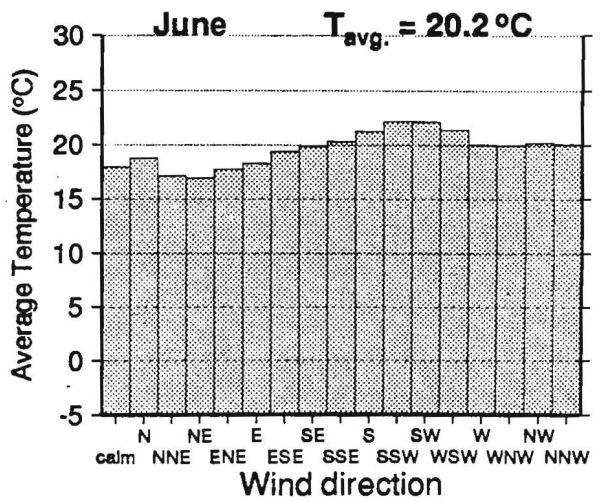
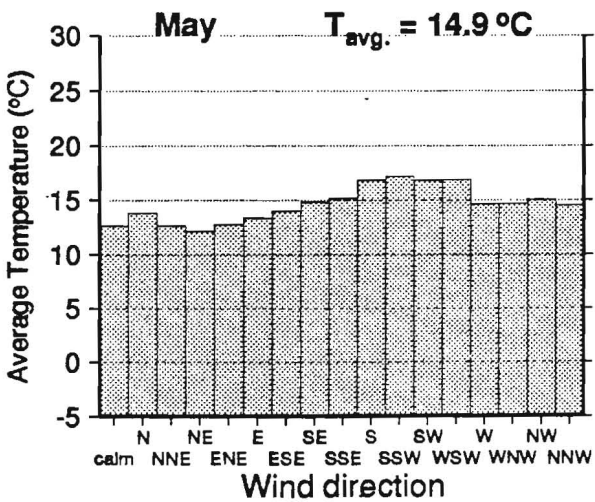
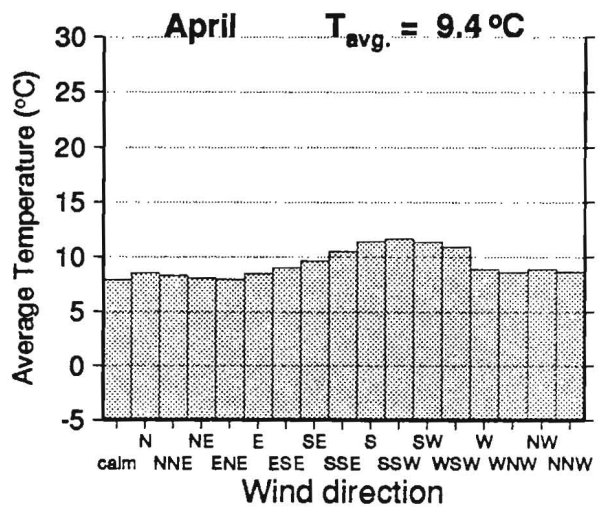
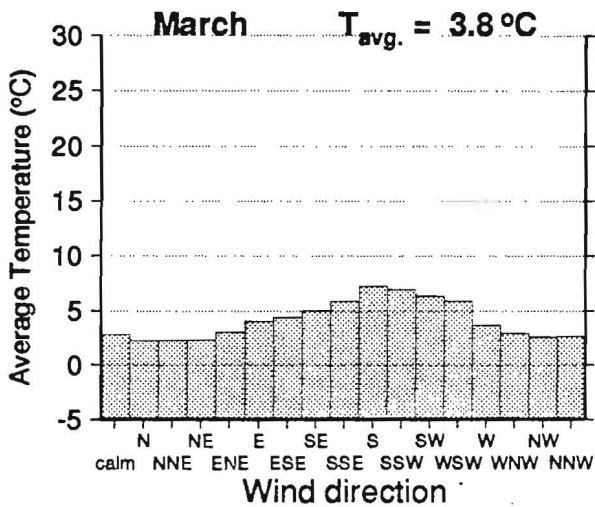
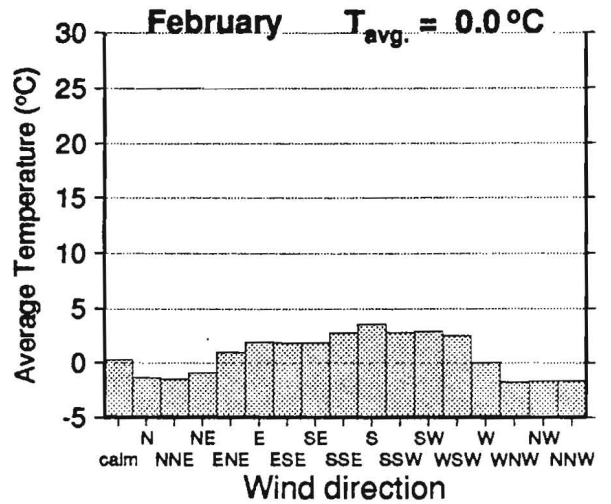
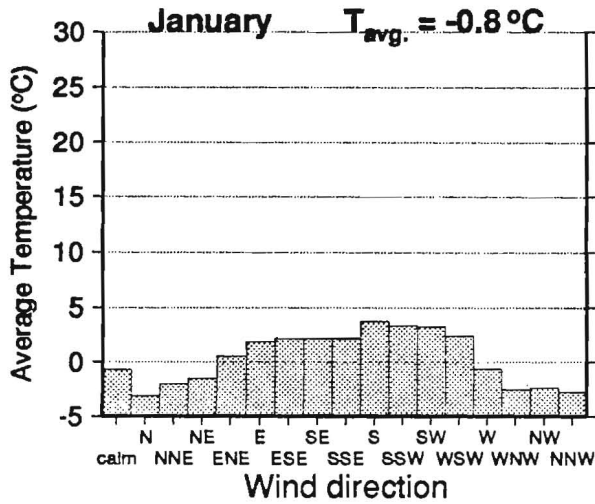


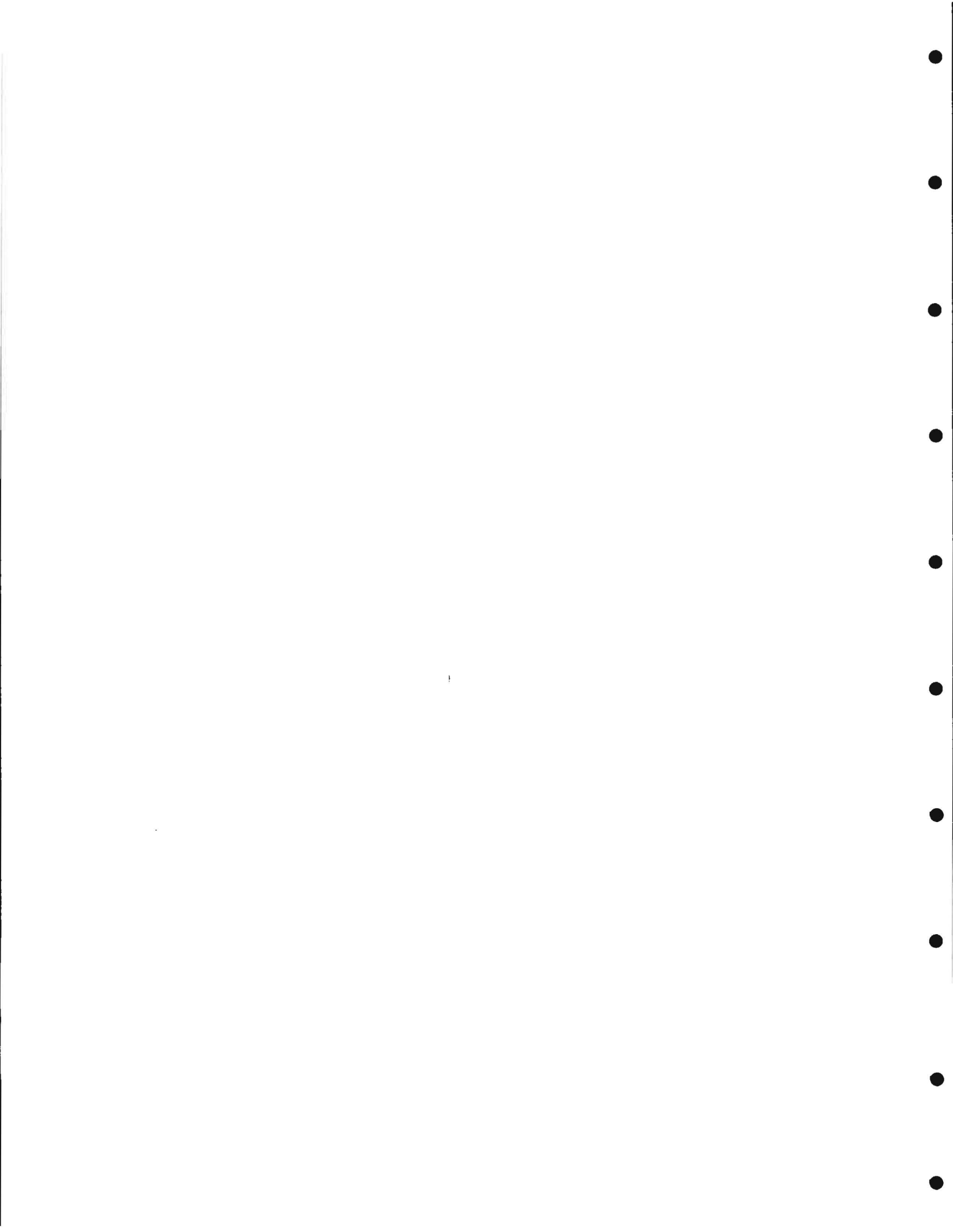


Temperature vs. Wind Direction

7/48-12/92 Bridgeport

figure 23

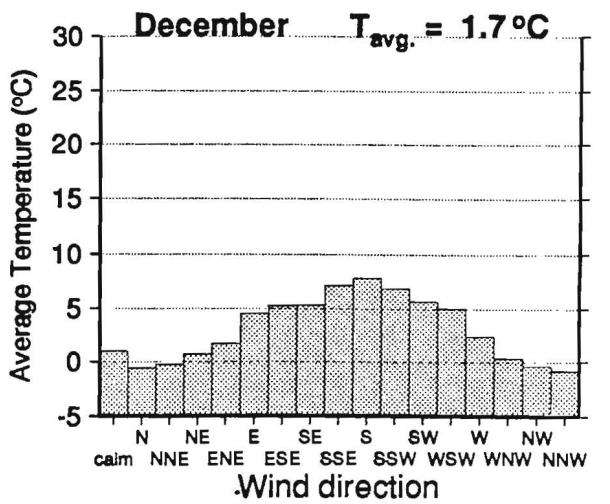
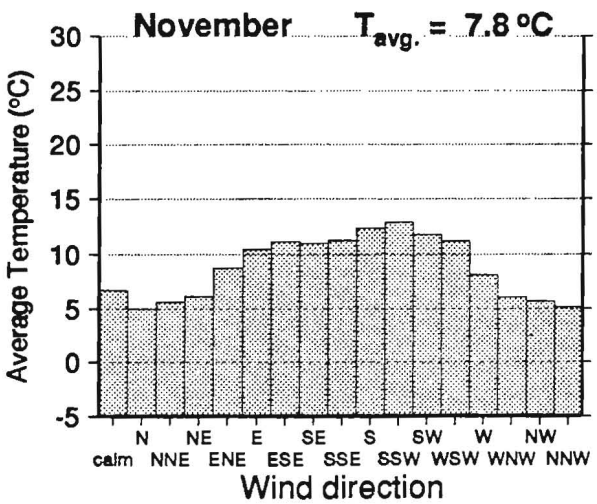
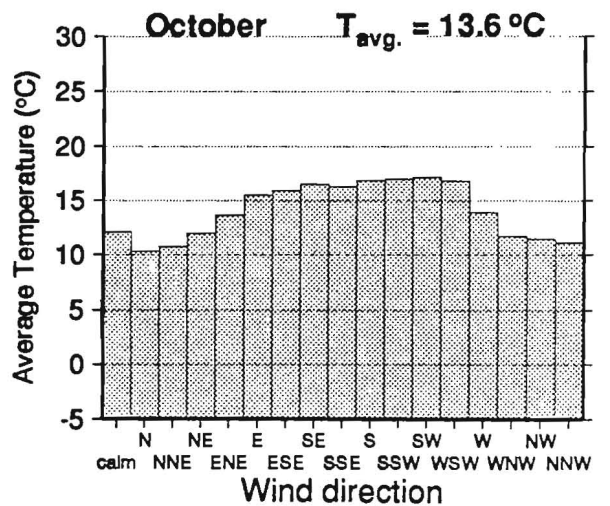
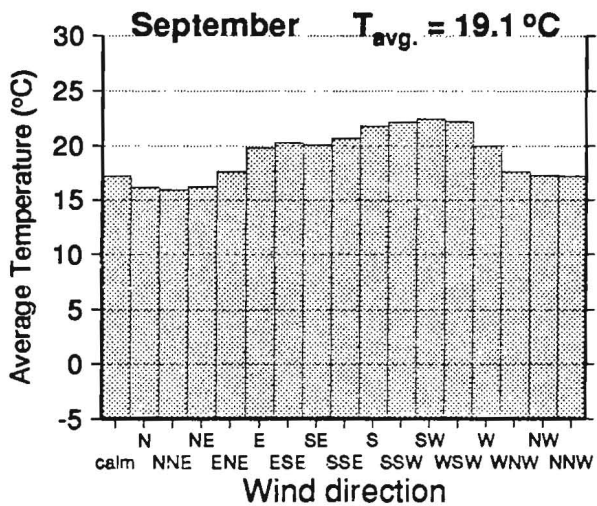
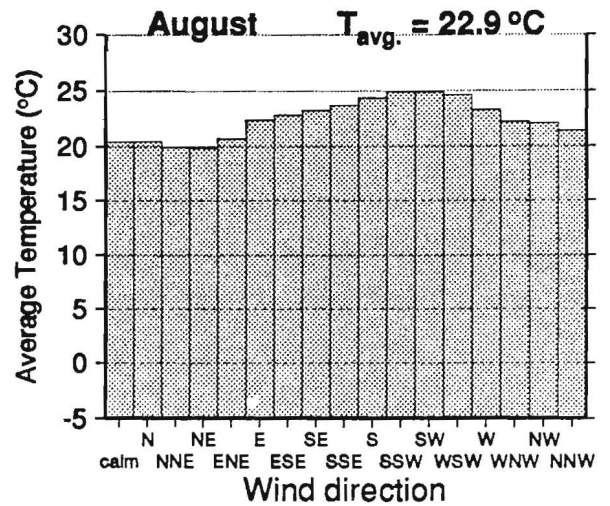
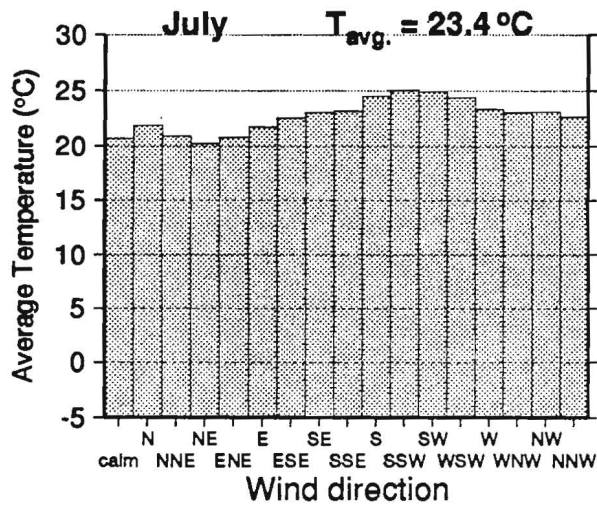




Temperature vs. Wind Direction

7/48-12/92 Bridgeport

figure 23

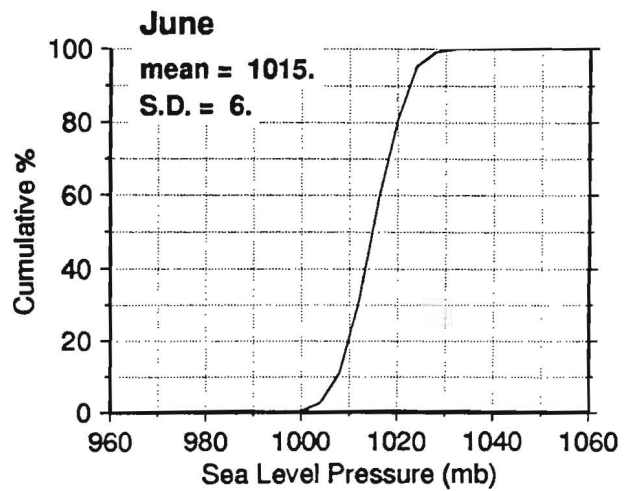
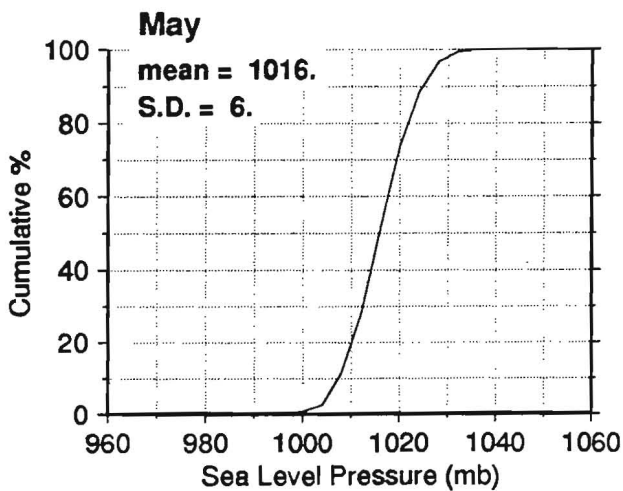
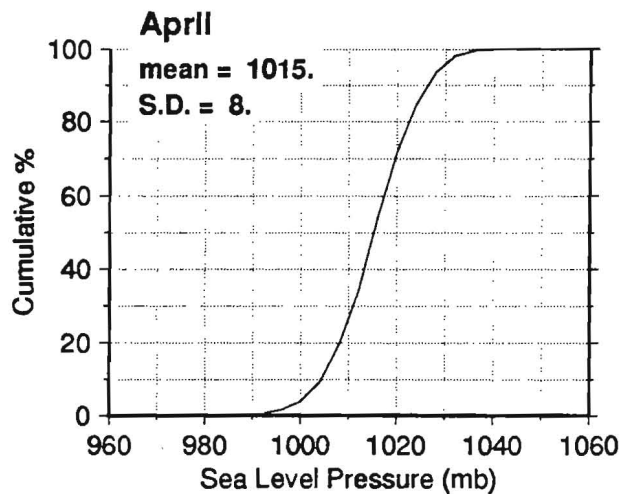
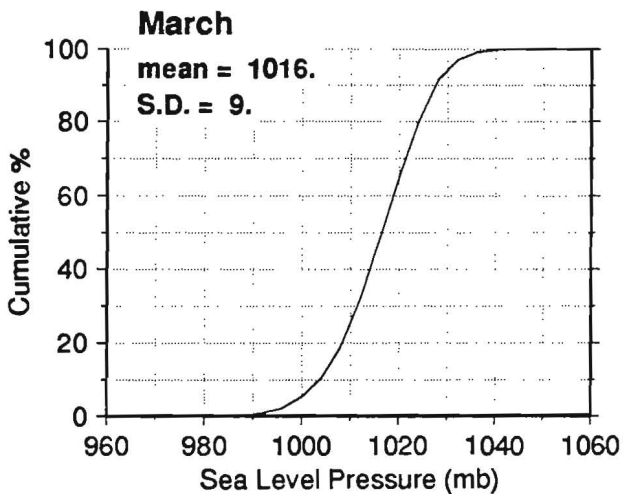
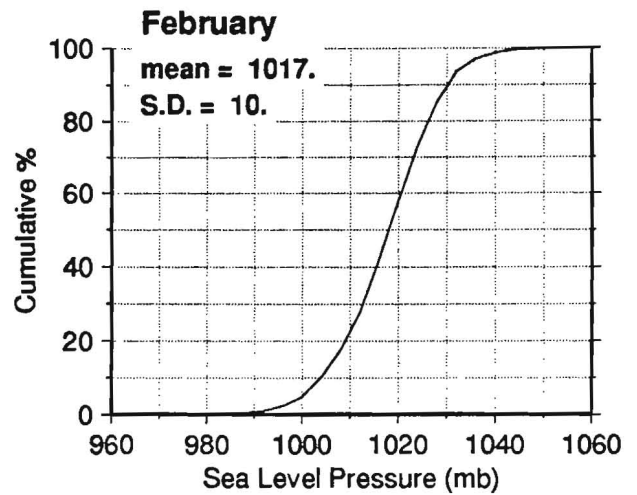
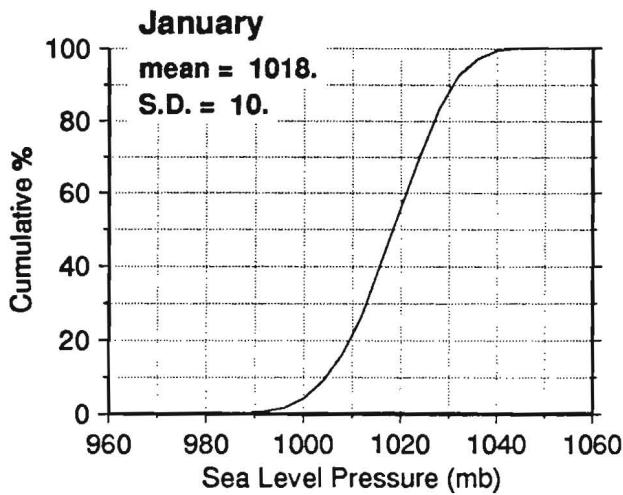




Sea Level Pressure, Cumulative Frequency

7/48-12/92 LaGuardia

figure 24



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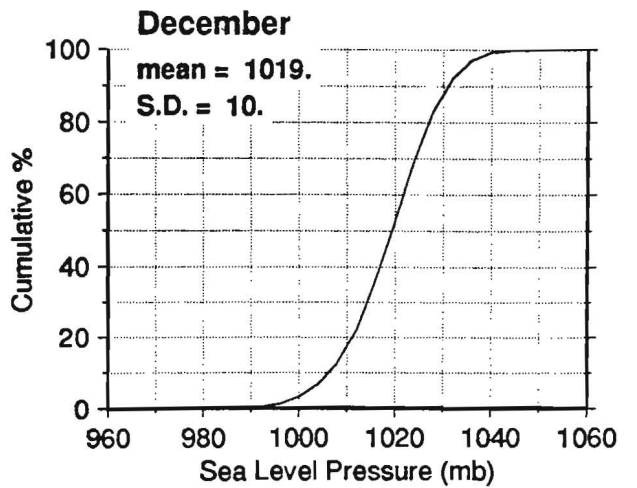
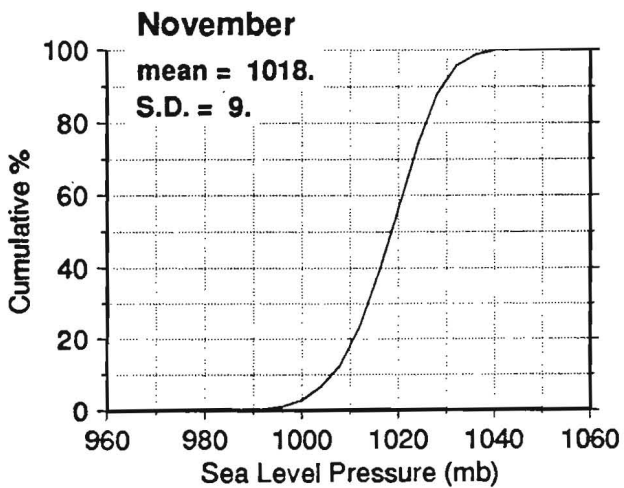
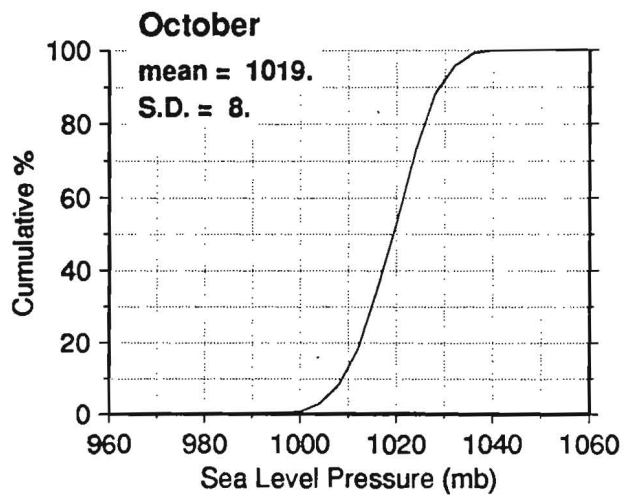
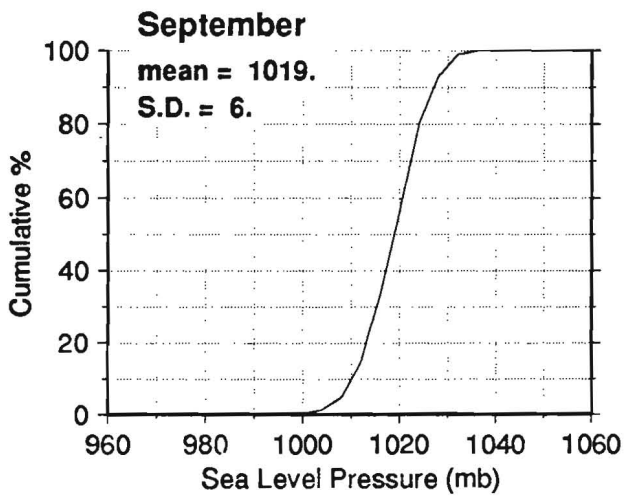
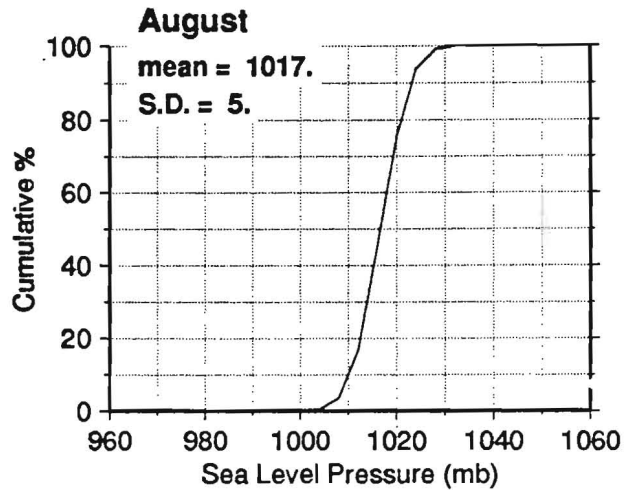
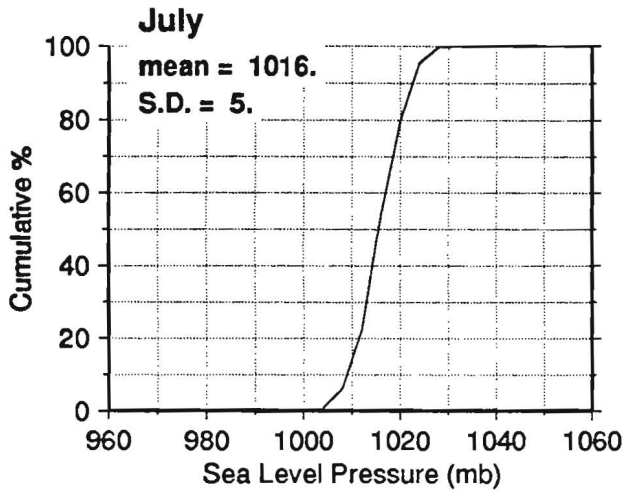
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Sea Level Pressure, Cumulative Frequency 7/48-12/92 LaGuardia

figure 24



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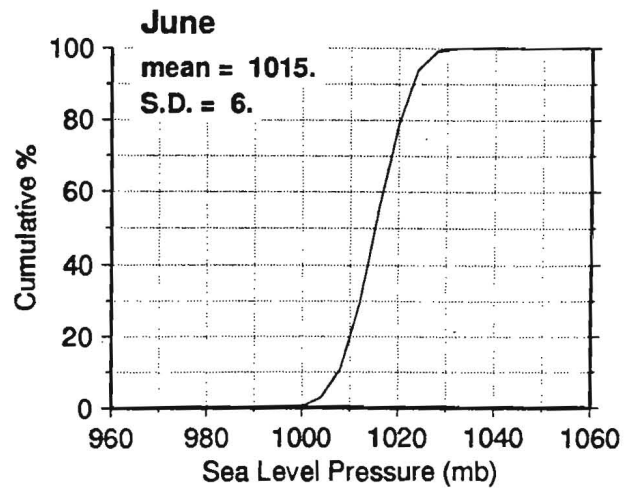
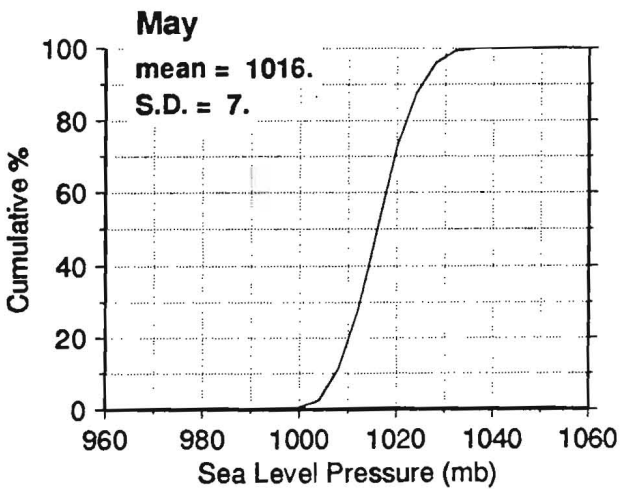
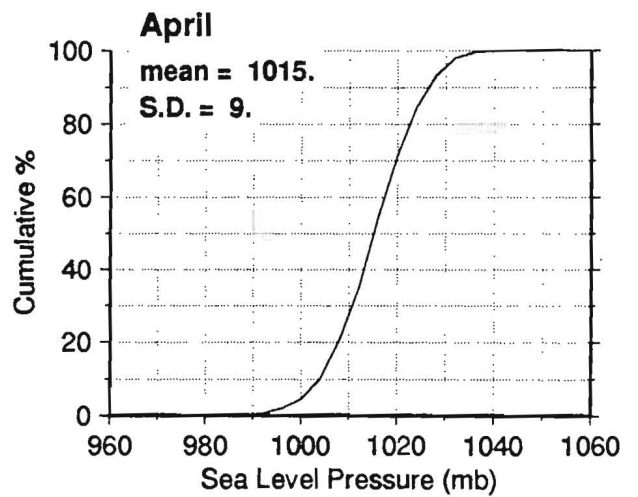
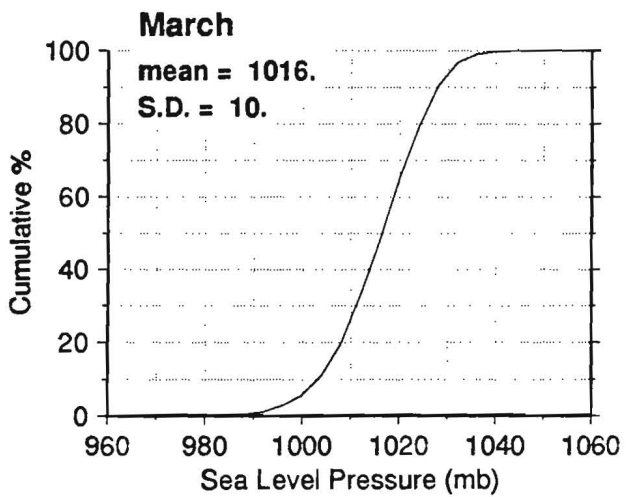
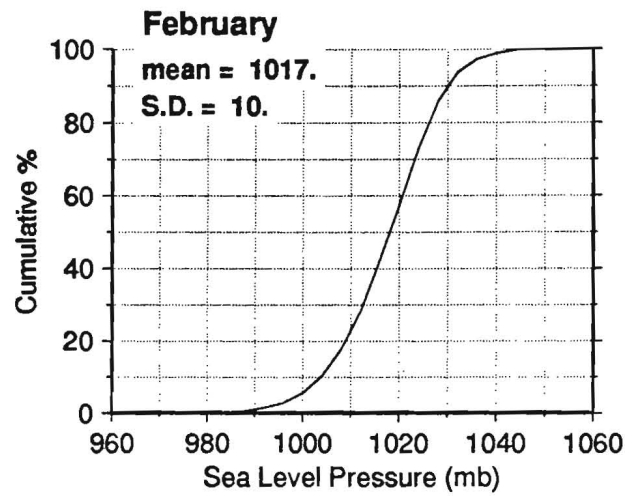
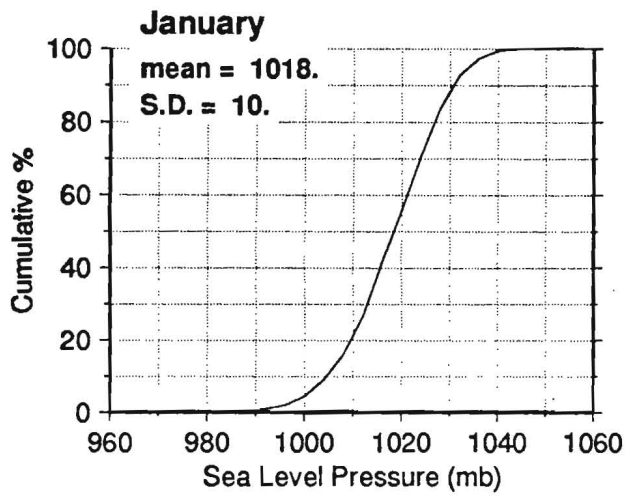
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Sea Level Pressure, Cumulative Frequency

7/48-12/92 Bridgeport

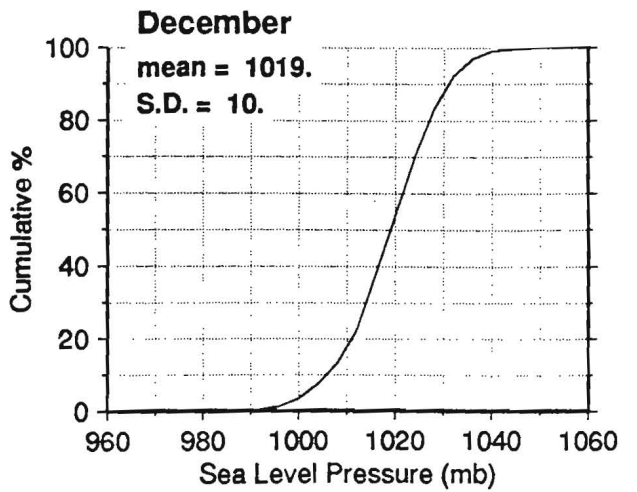
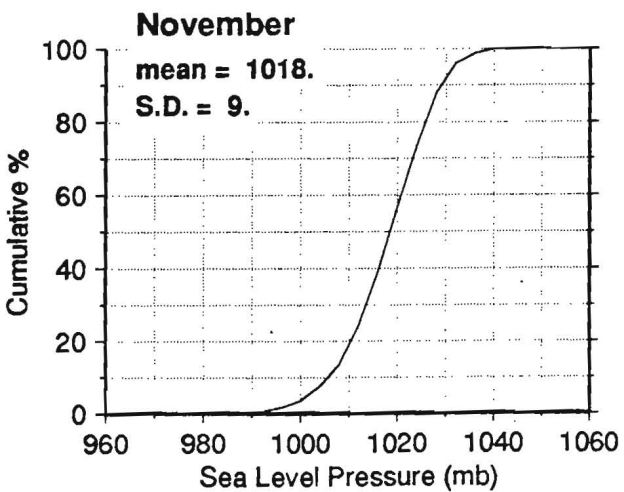
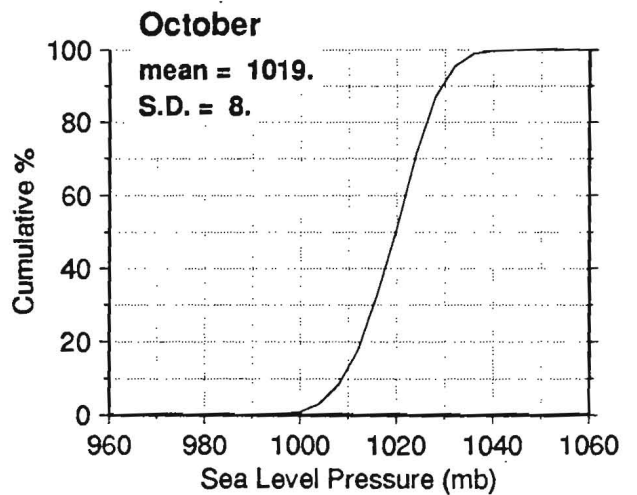
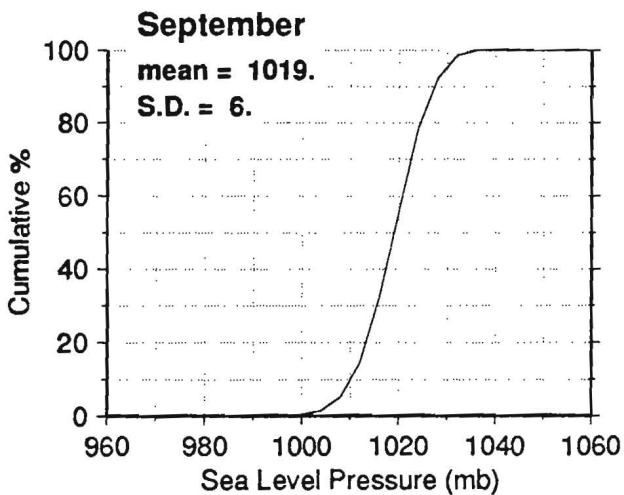
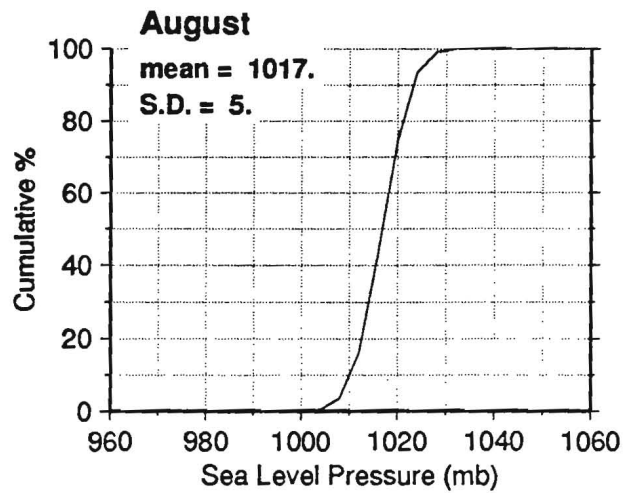
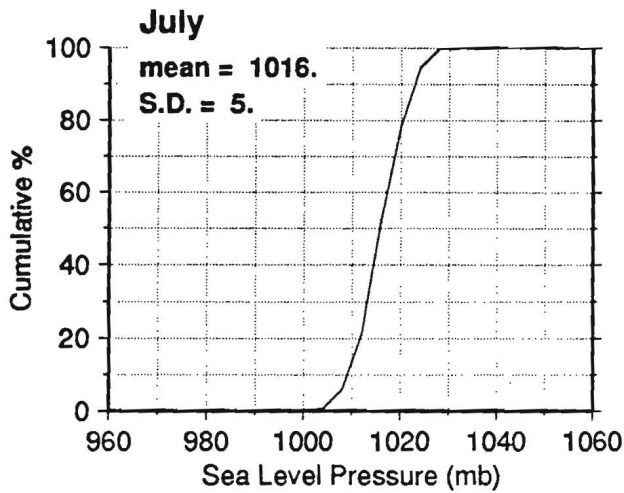
figure 25





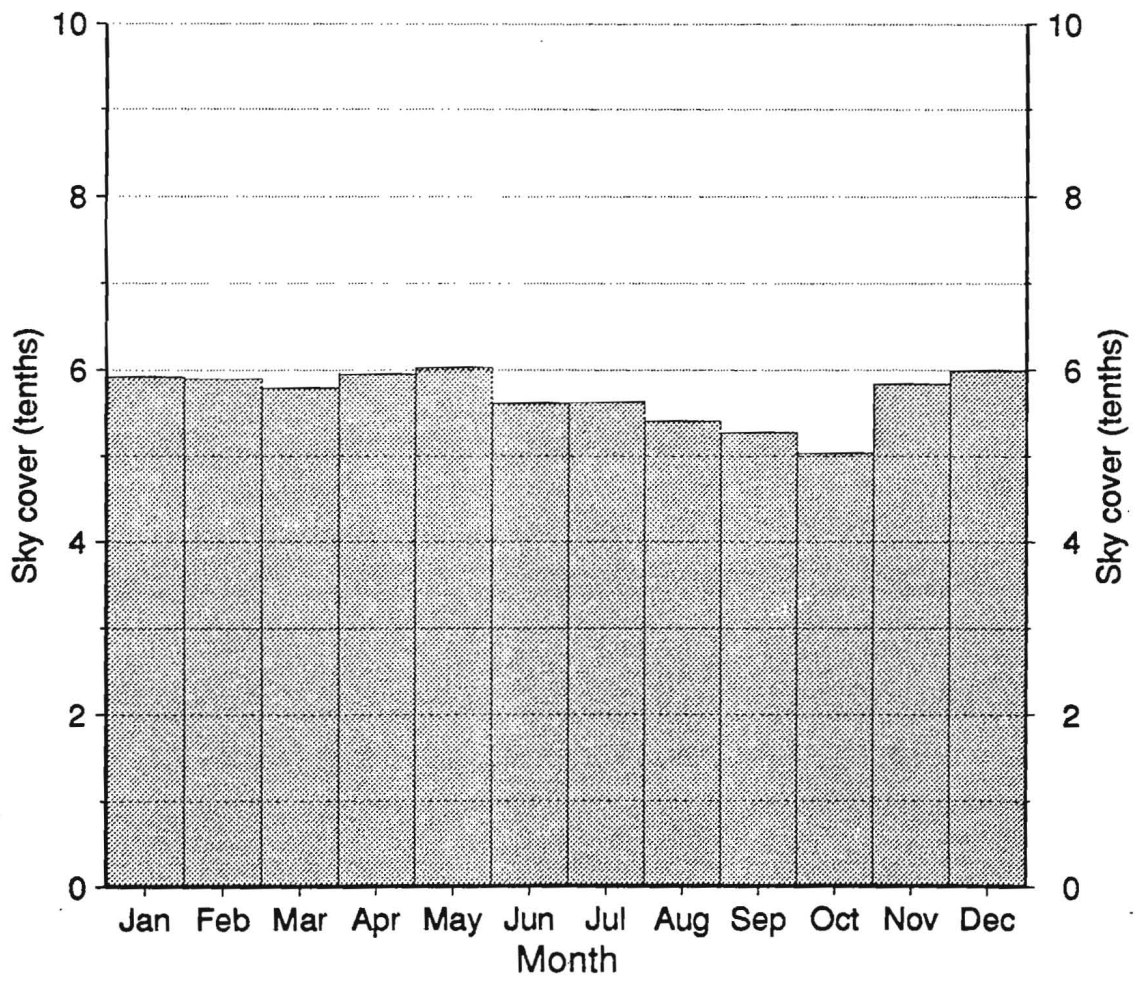
Sea Level Pressure, Cumulative Frequency 7/48-12/92 Bridgeport

figure 25



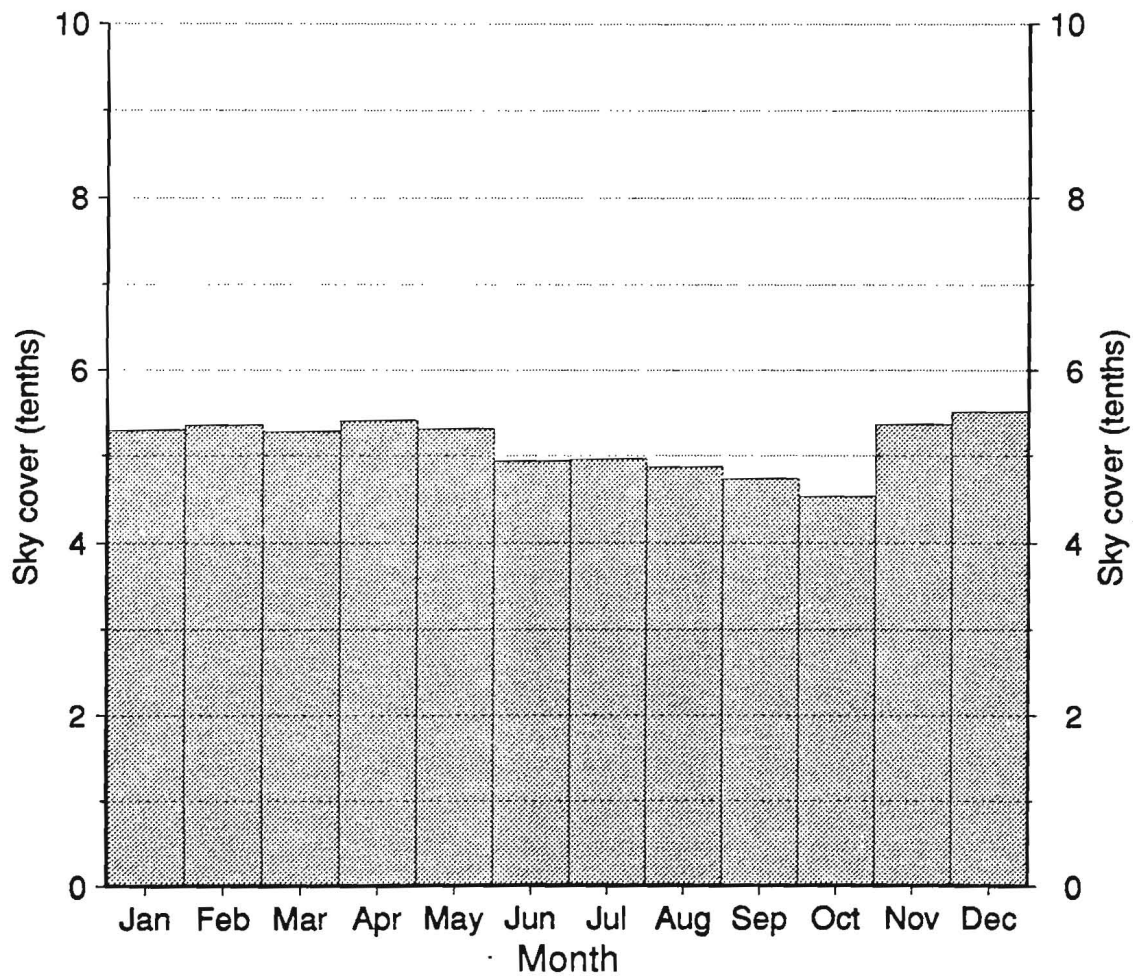


Total Sky Cover 7/48-12/92 LaGuardia



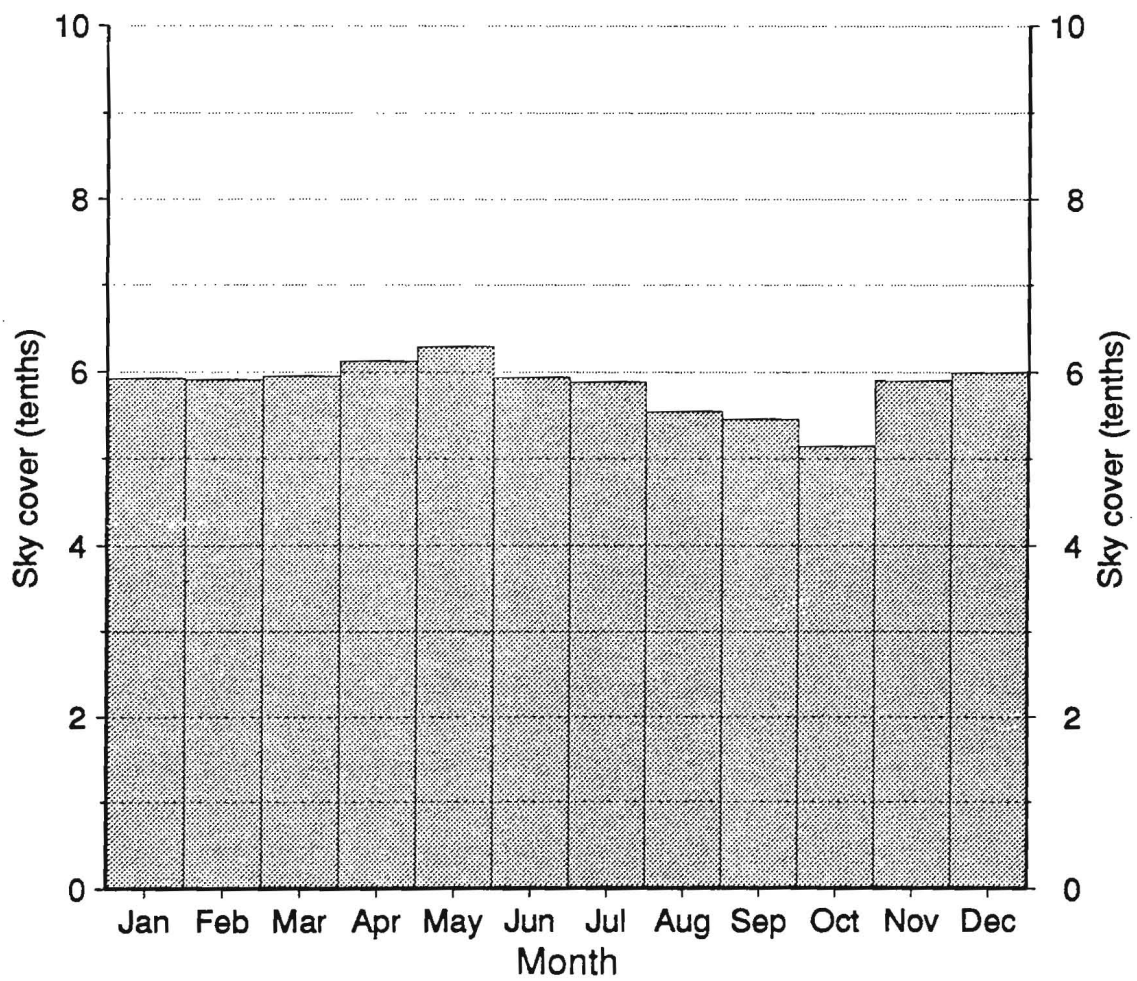


Opaque Sky Cover 7/48-12/92 LaGuardia



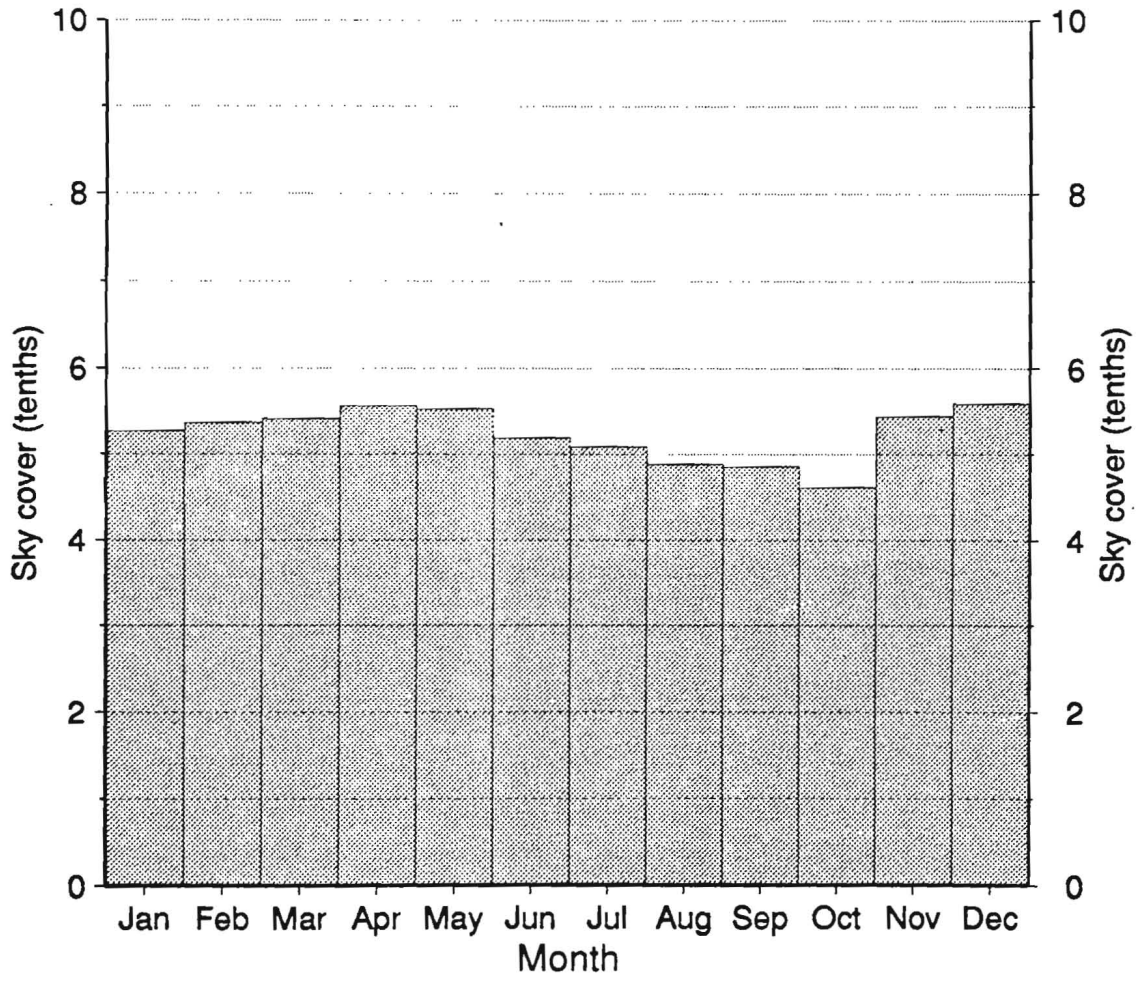


Total Sky Cover 7/48-12/92 Bridgeport



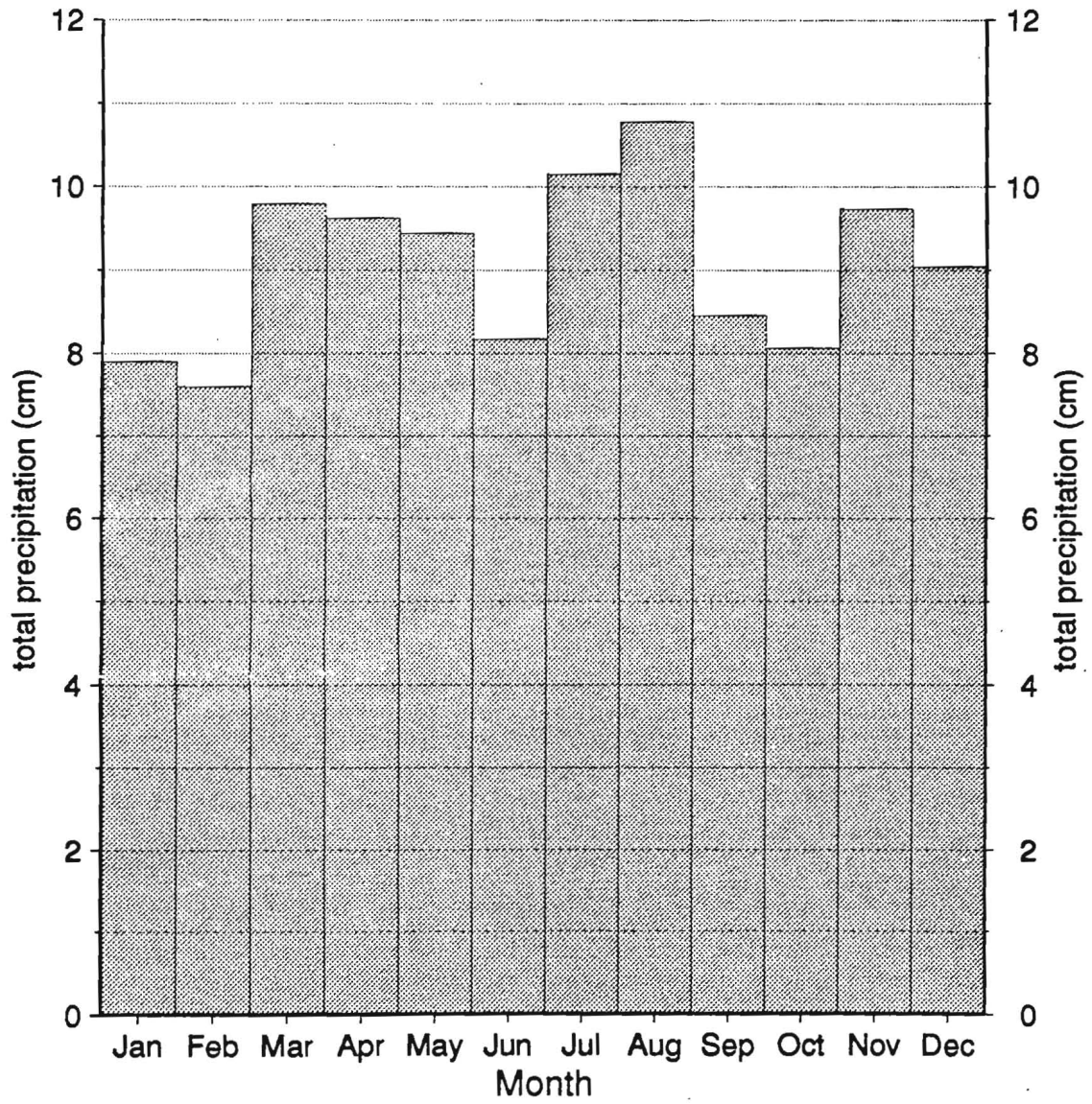


Opaque Sky Cover 7/48-12/92 Bridgeport



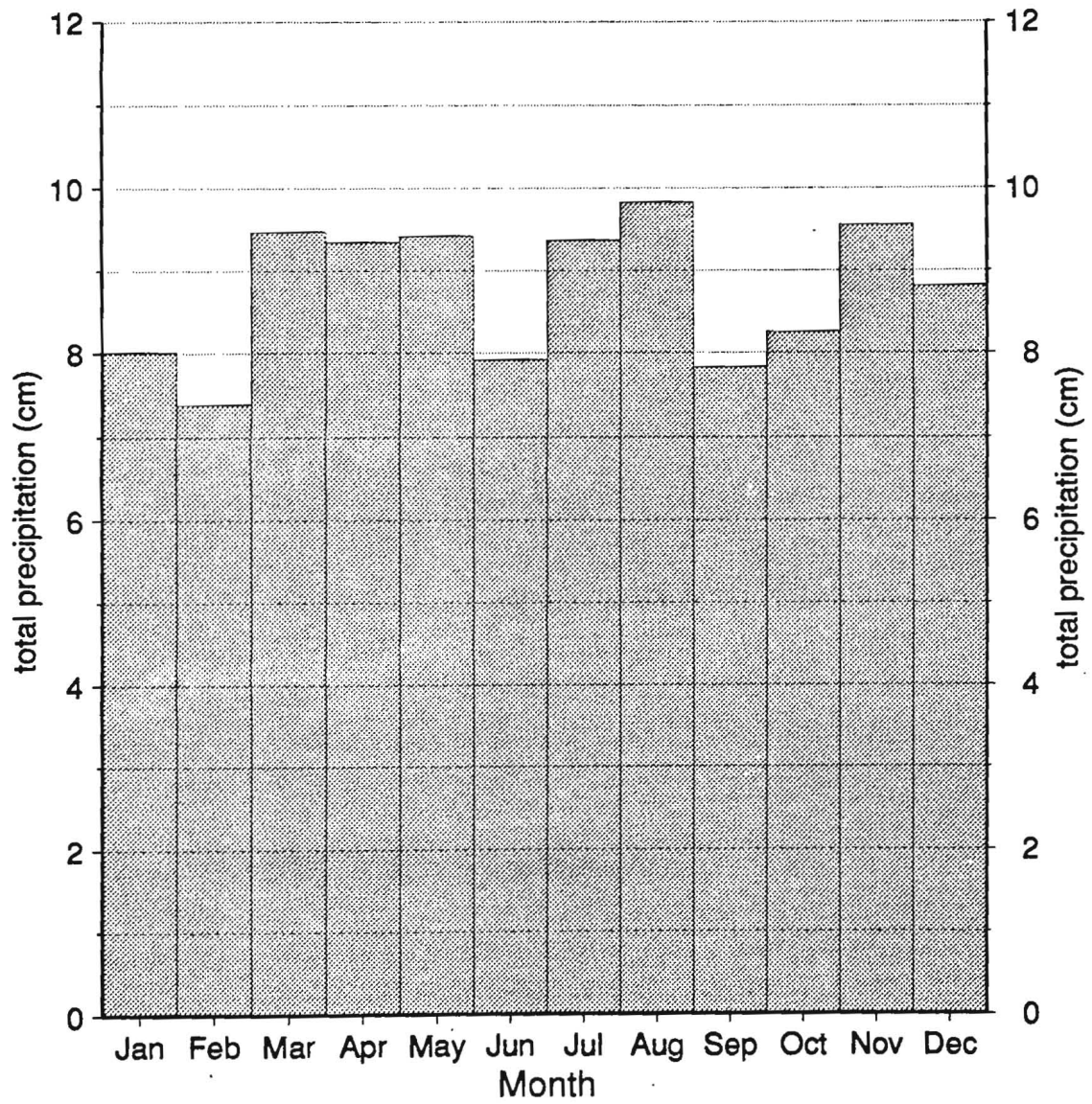


Monthly precipitation 1/49-12/92 LaGuardia





Monthly precipitation 1/49-12/92 Bridgeport

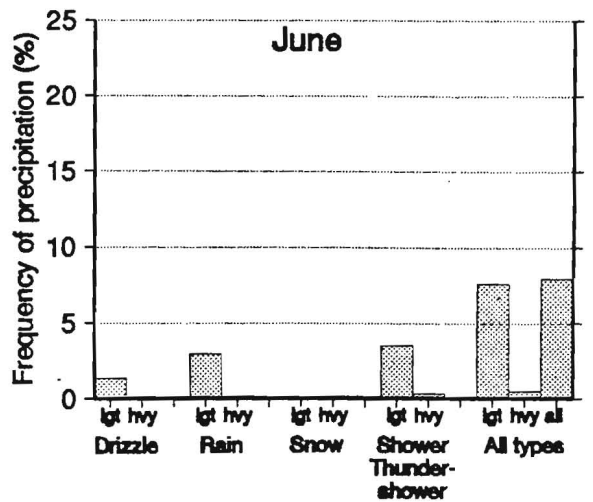
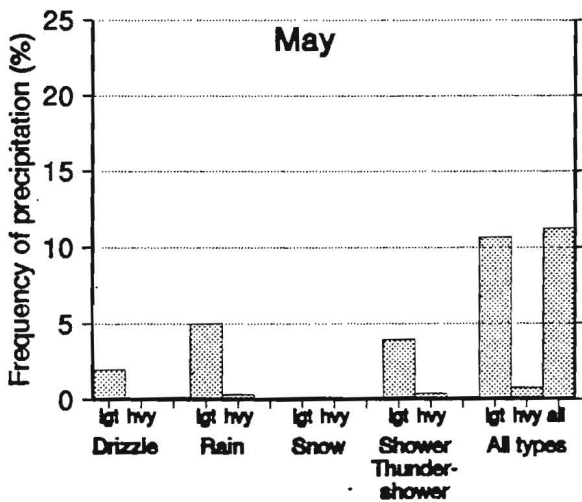
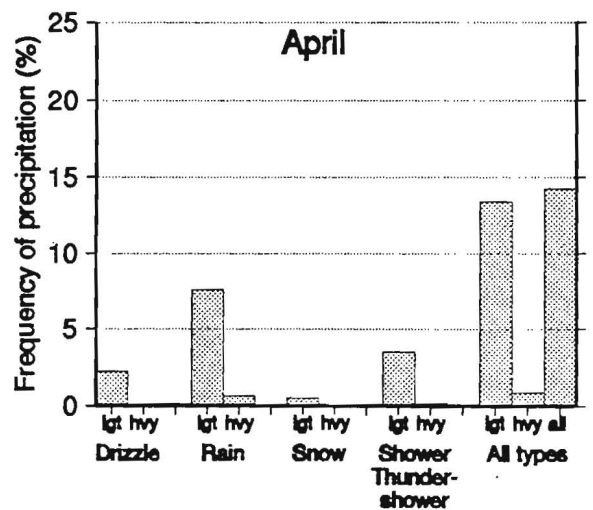
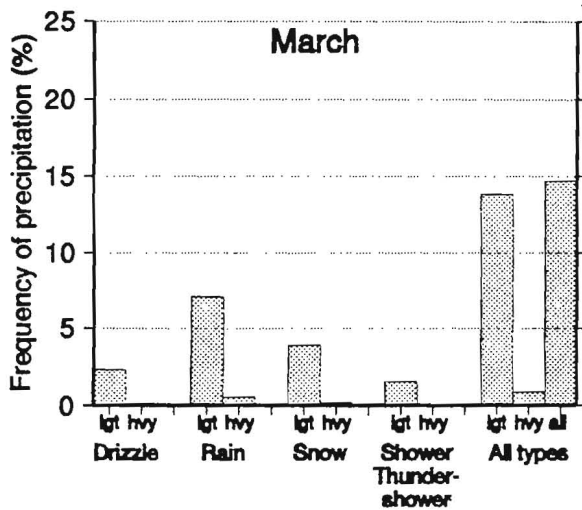
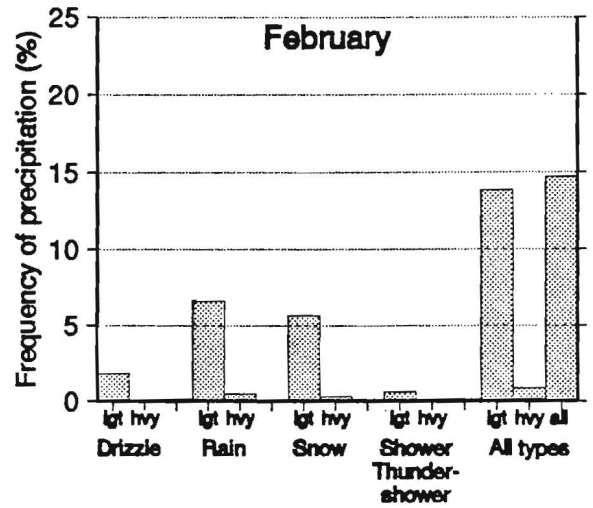
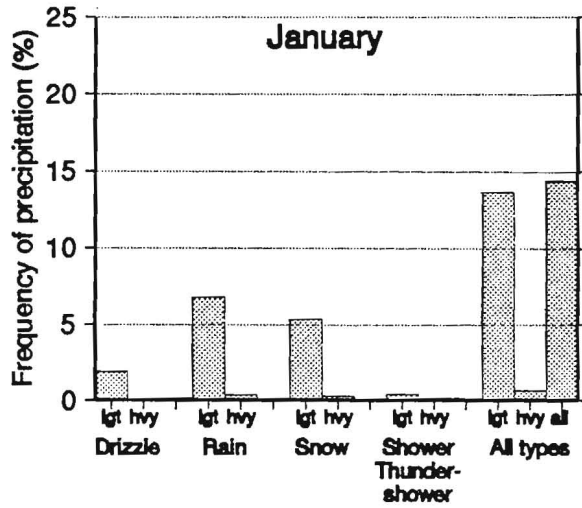


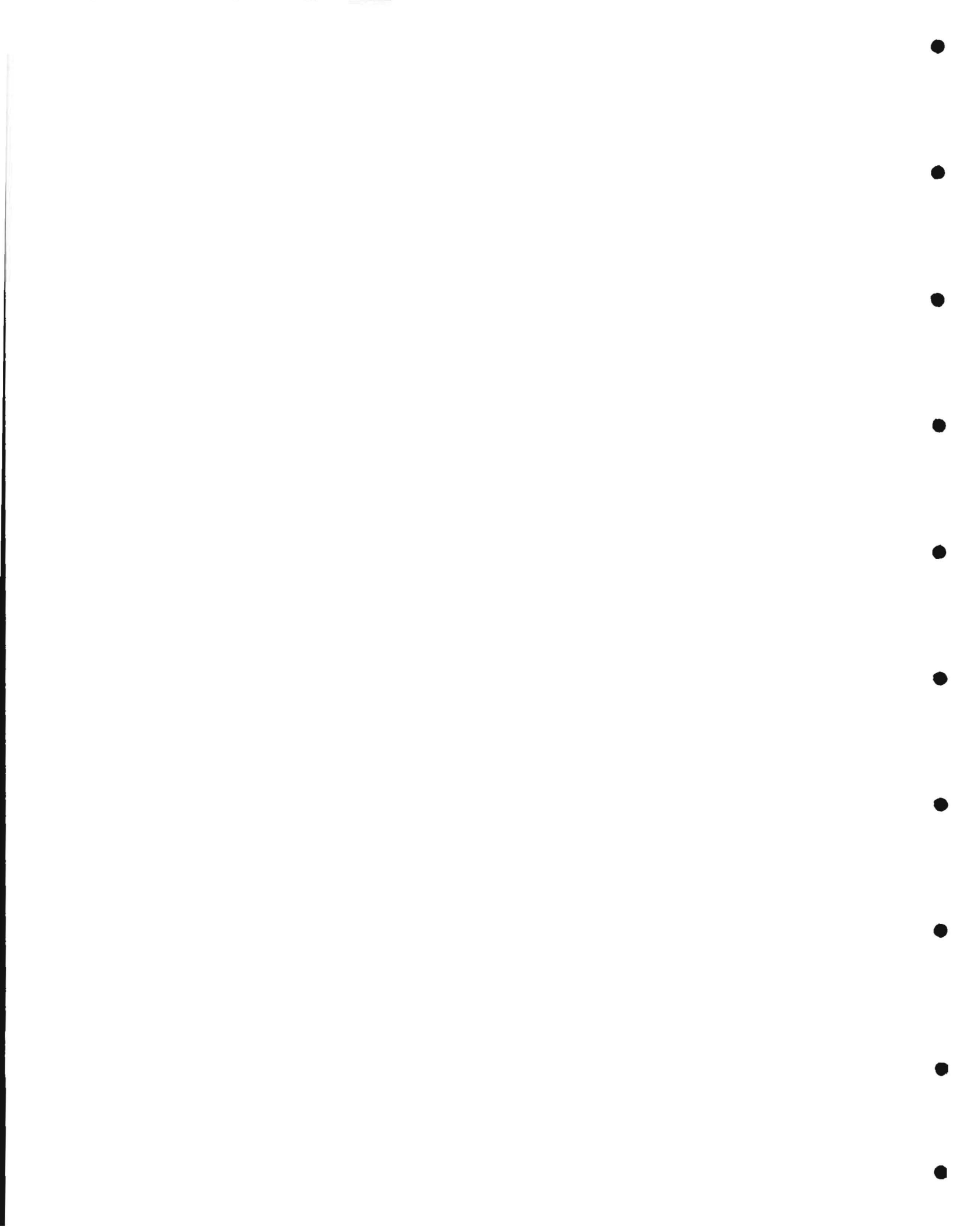


Precipitation Types

7/48-12/92 LaGuardia

figure 32

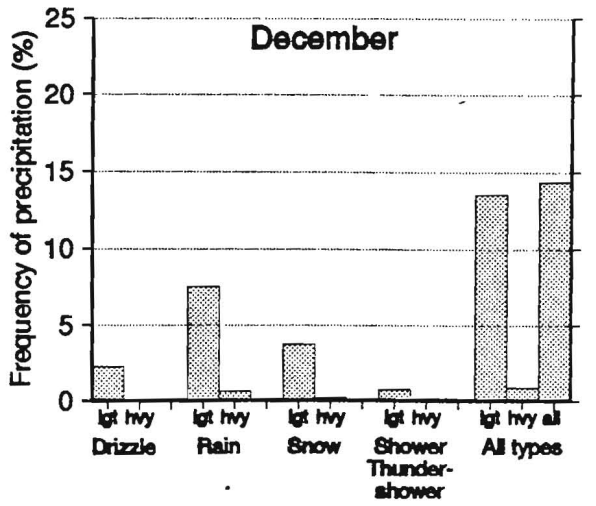
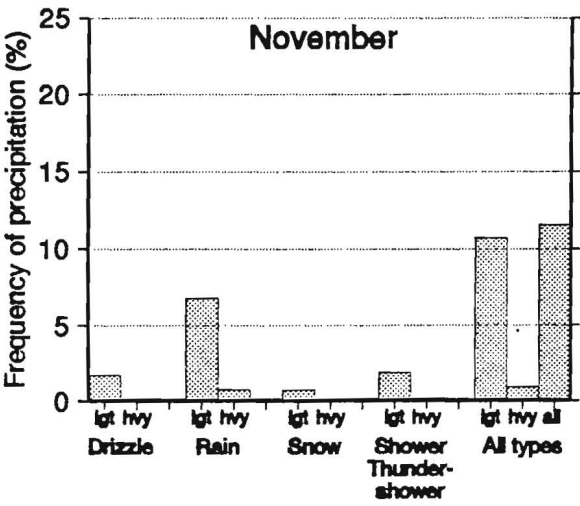
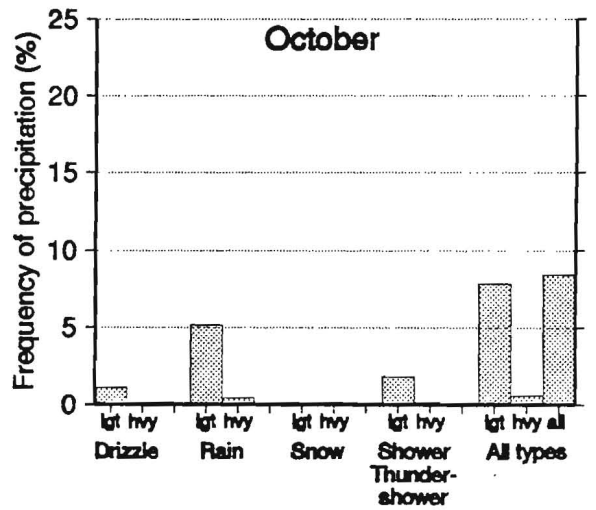
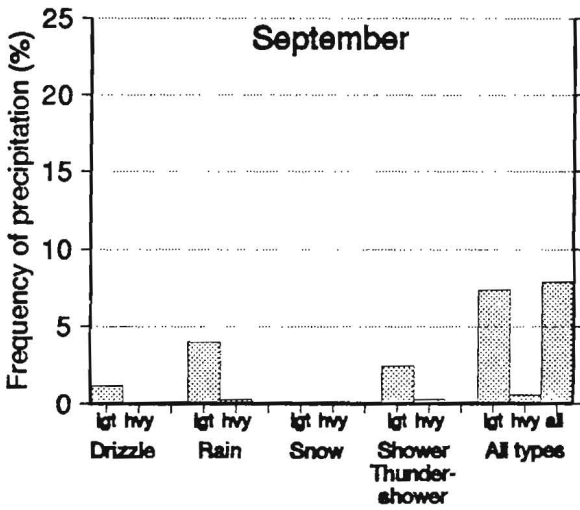
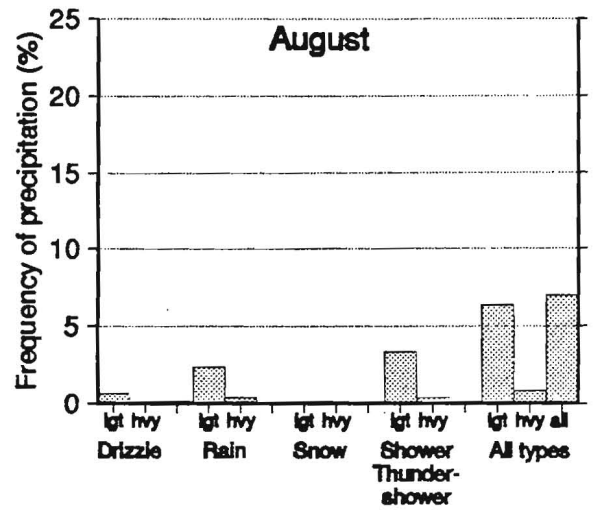
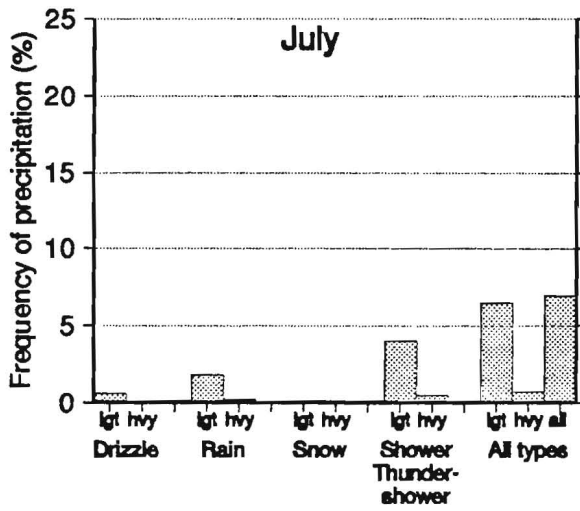




Precipitation Types

7/48-12/92 LaGuardia

figure 32

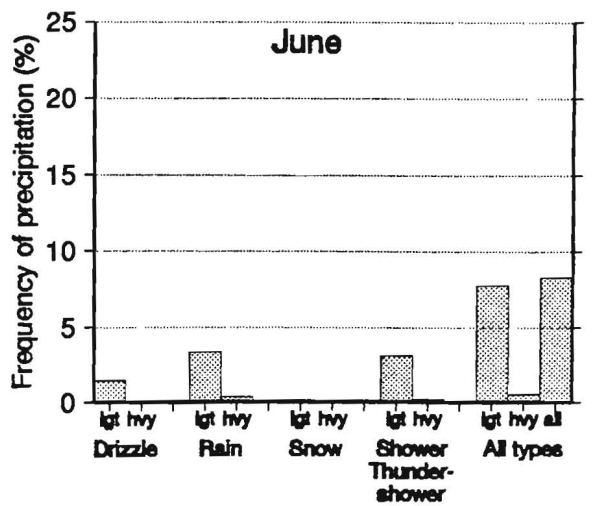
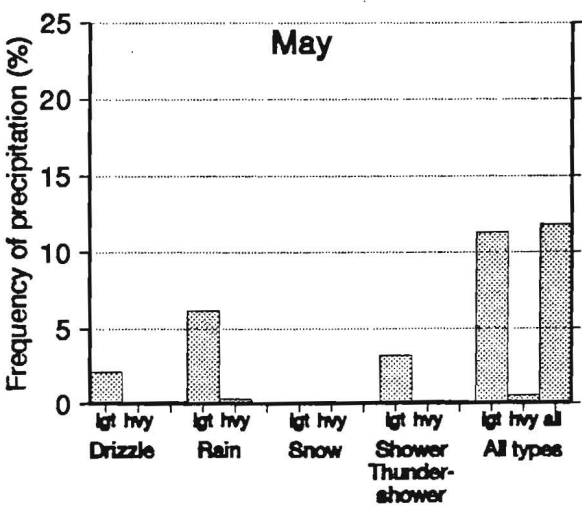
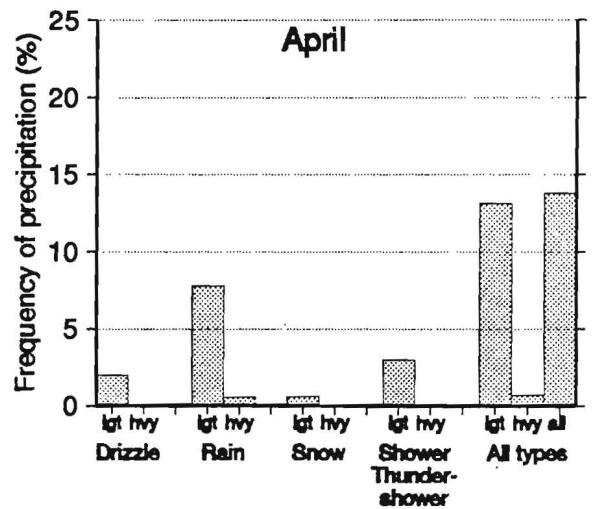
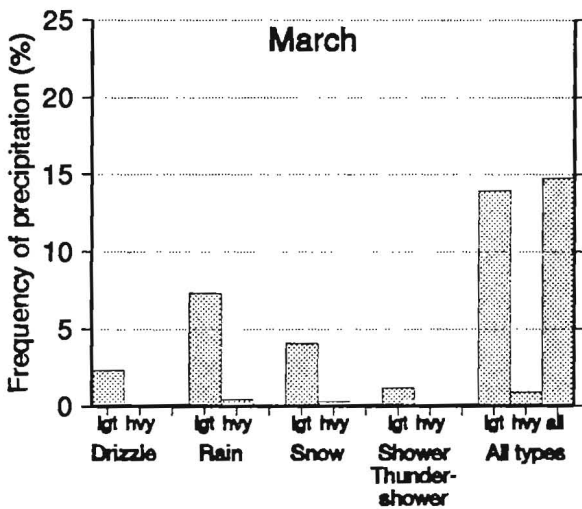
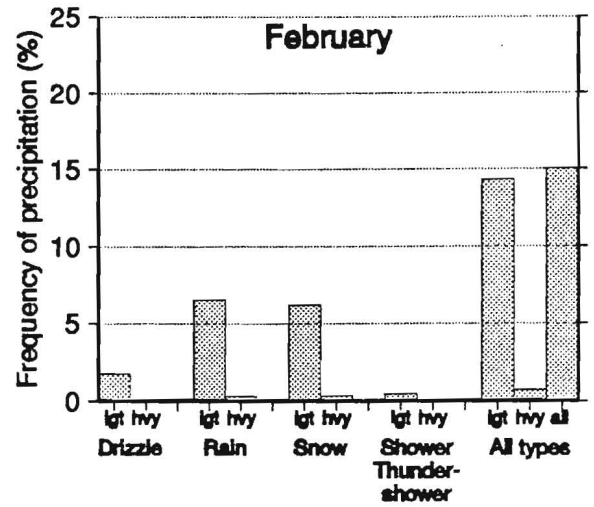
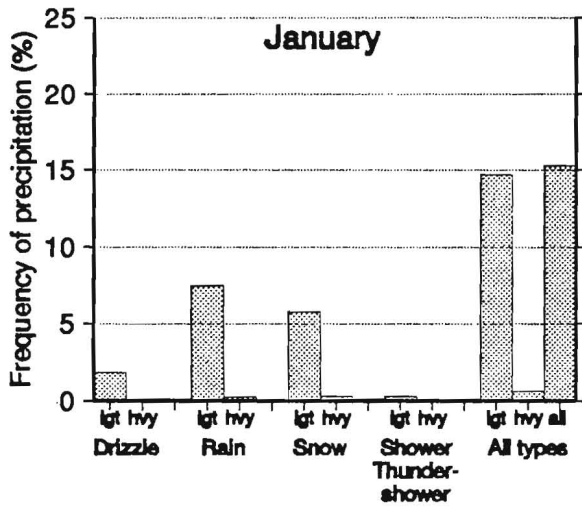


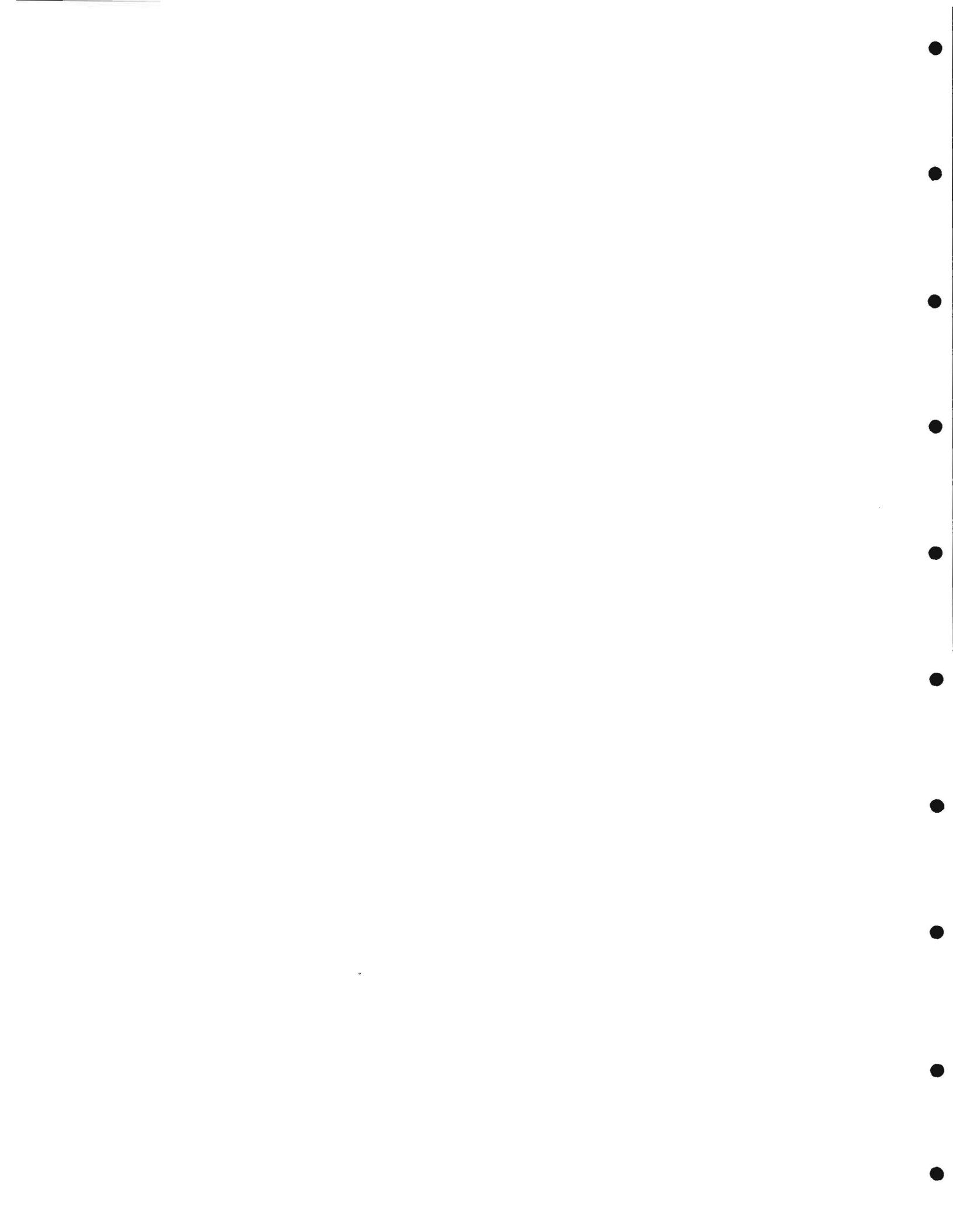


Precipitation Types

7/48-12/92 Bridgeport

figure 33

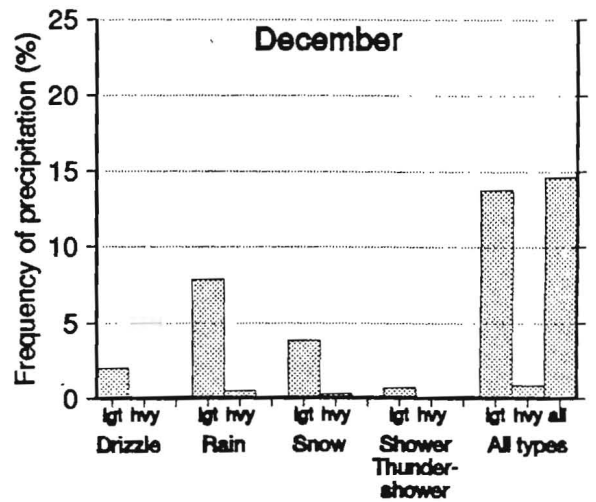
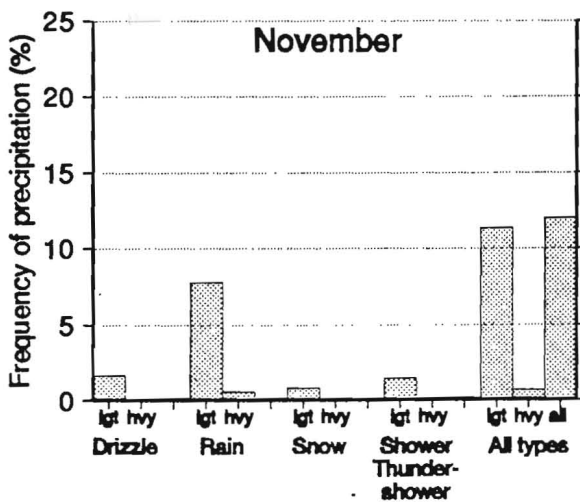
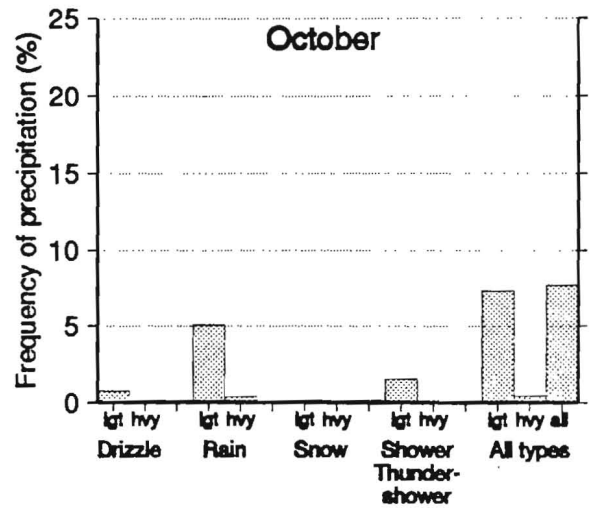
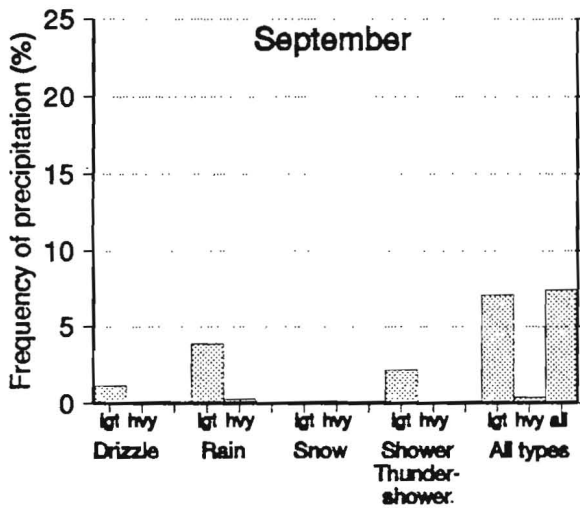
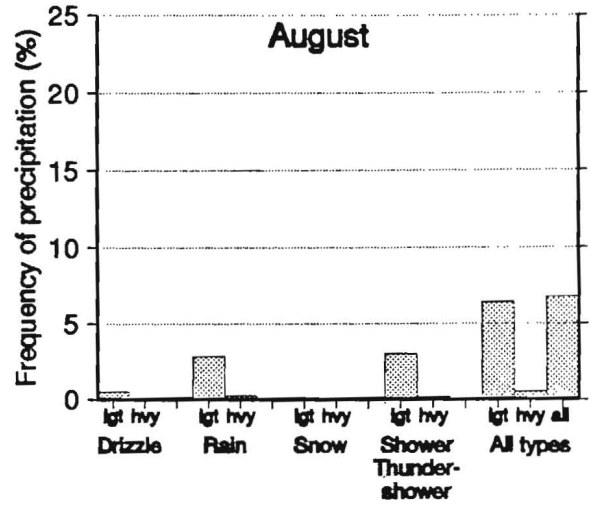
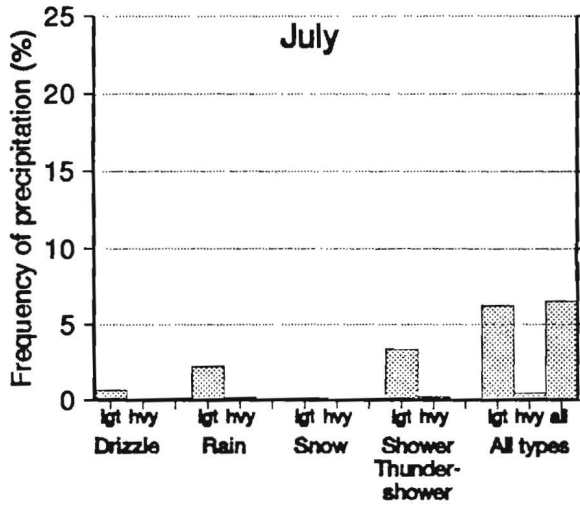




Precipitation Types

7/48-12/92 Bridgeport

figure 33

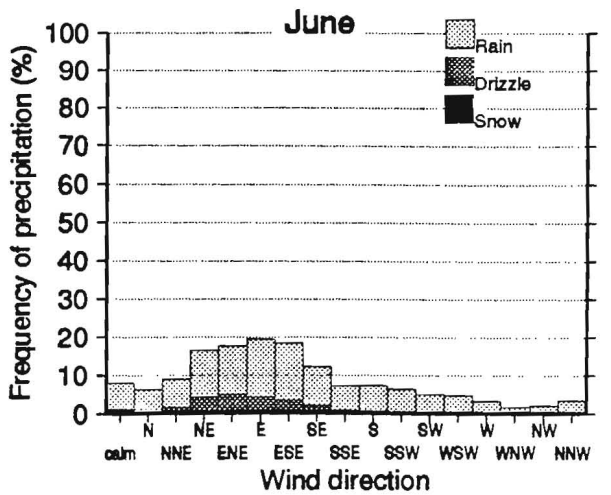
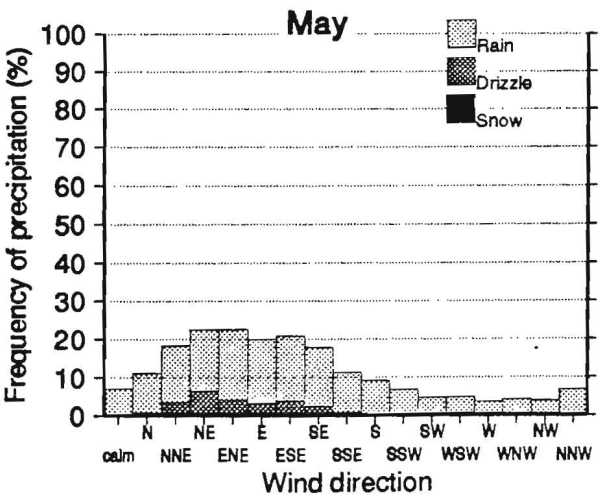
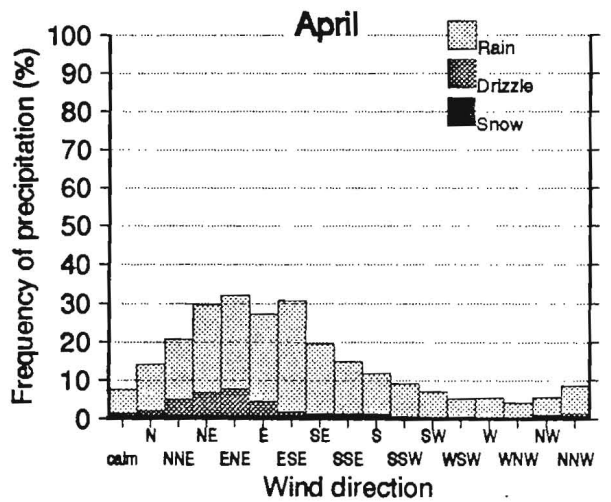
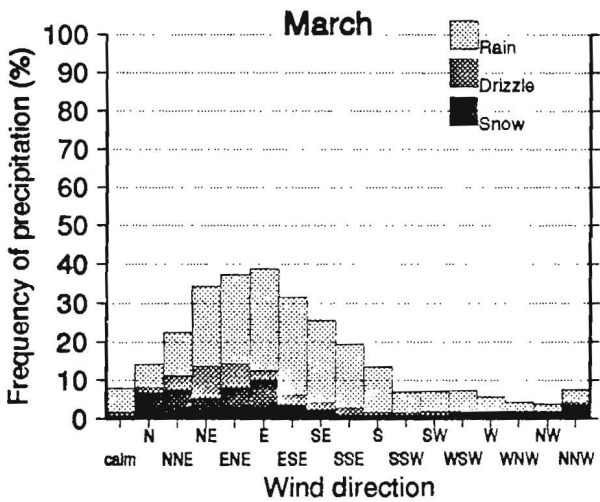
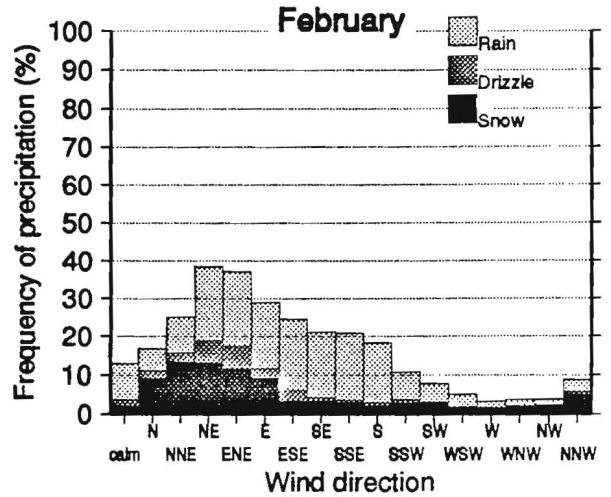
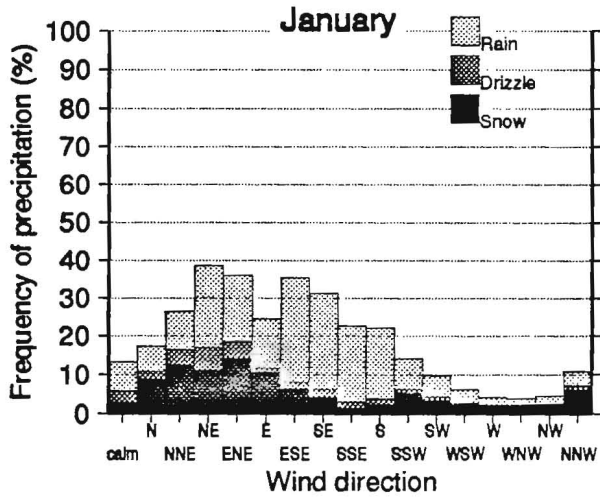




Precipitation vs. Wind Direction

7/48-12/92 LaGuardia

figure 34

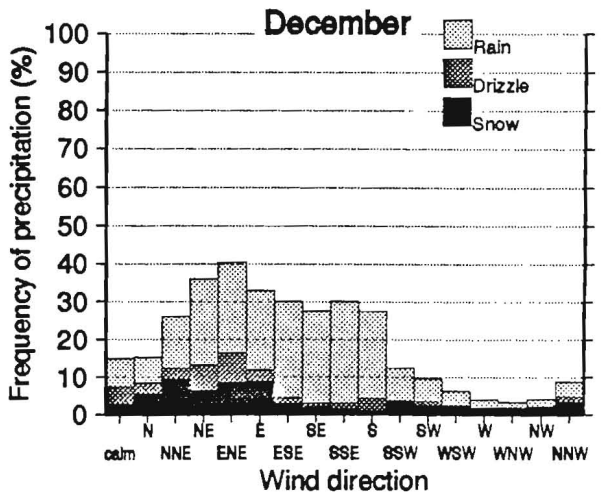
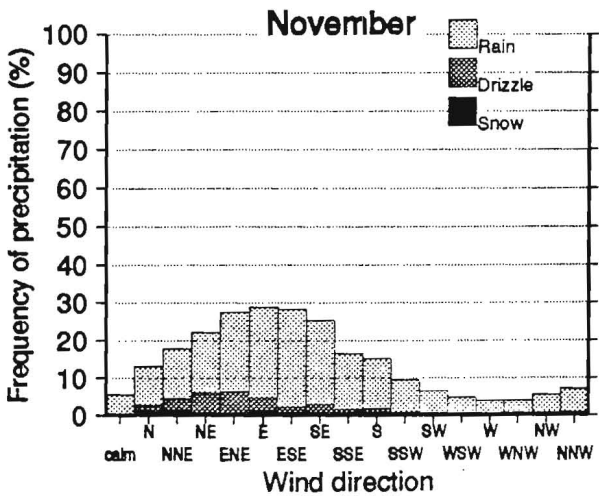
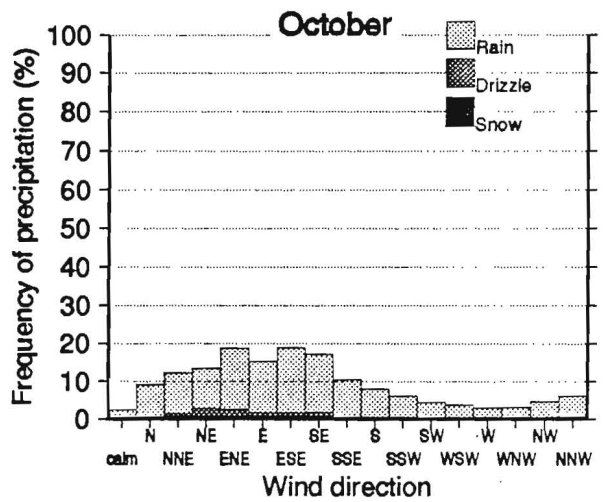
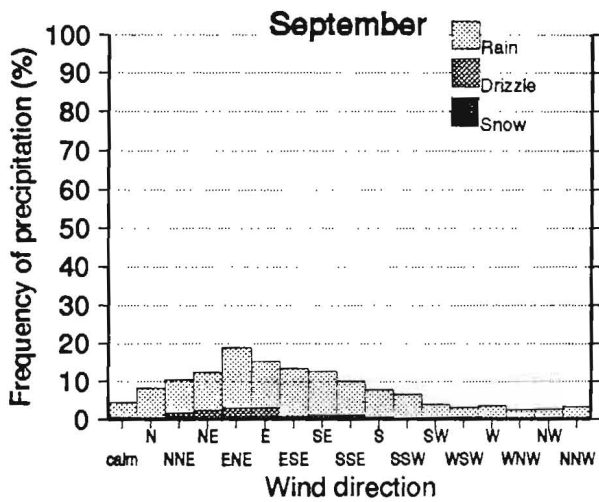
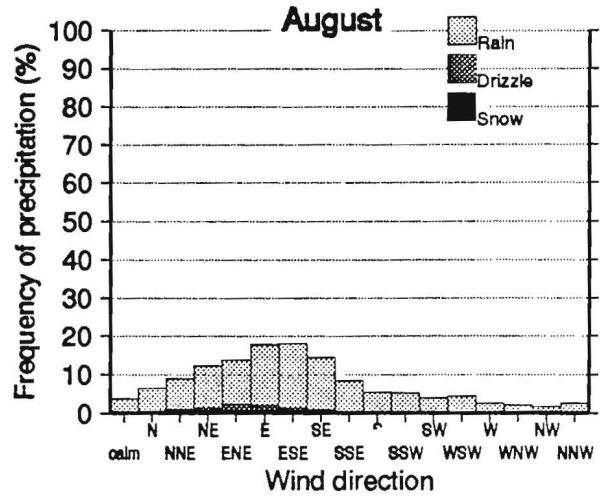
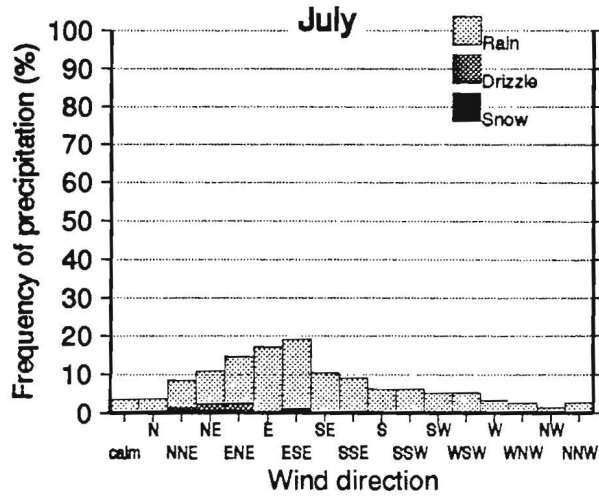




Precipitation vs. Wind Direction

7/48-12/92 LaGuardia

figure 34

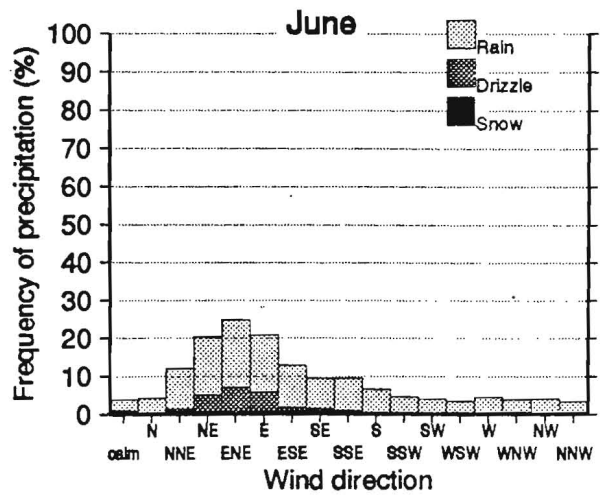
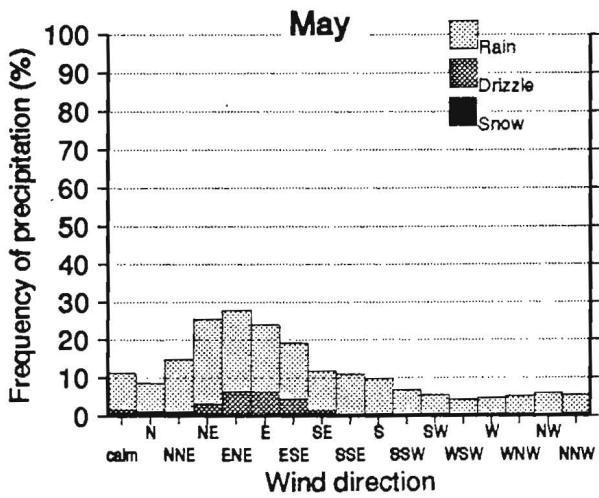
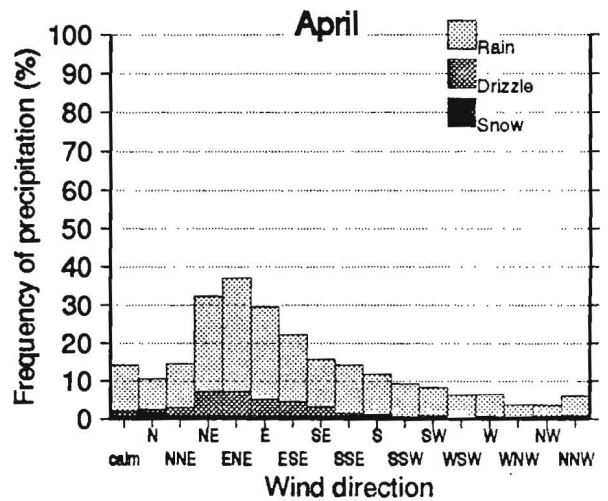
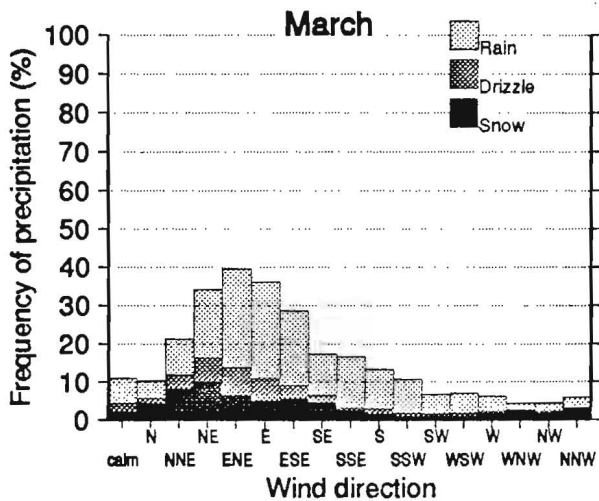
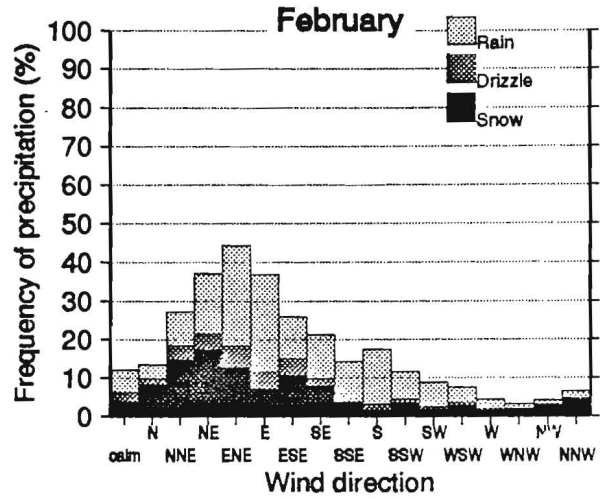
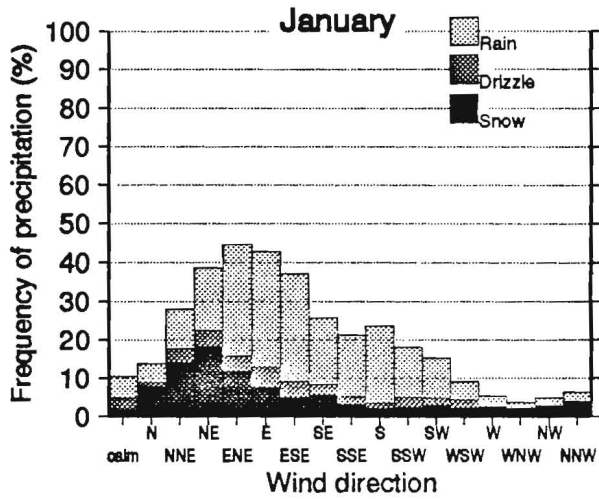




Precipitation vs. Wind Direction

7/48-12/92 Bridgeport

figure 35





Precipitation vs. Wind Direction

7/48-12/92 Bridgeport

figure 35

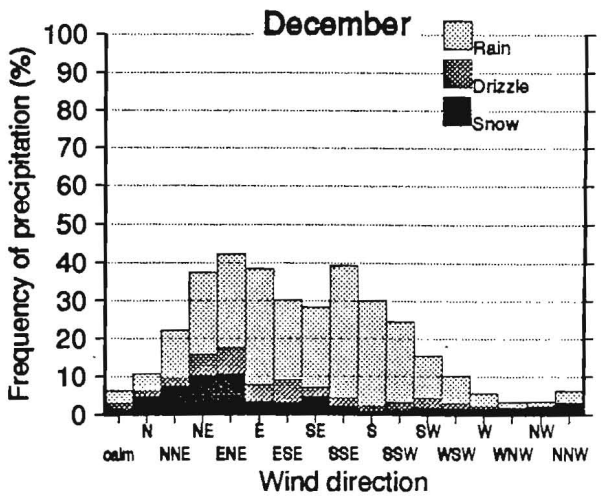
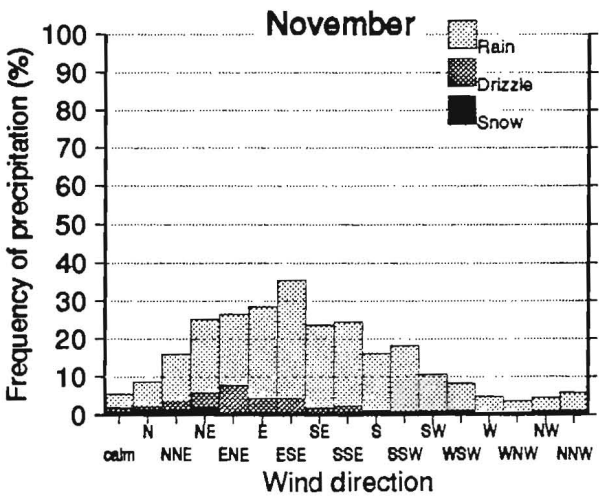
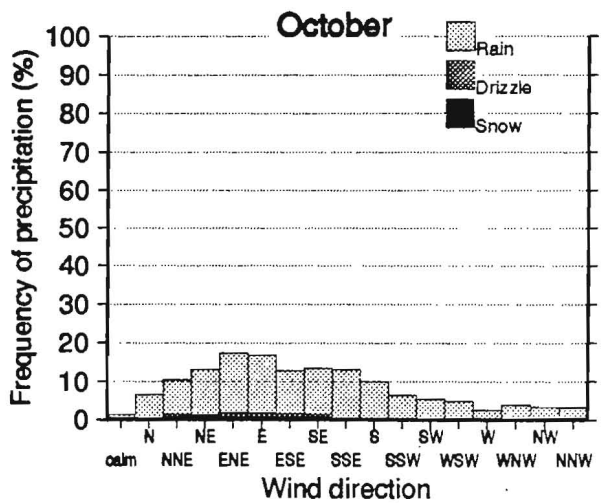
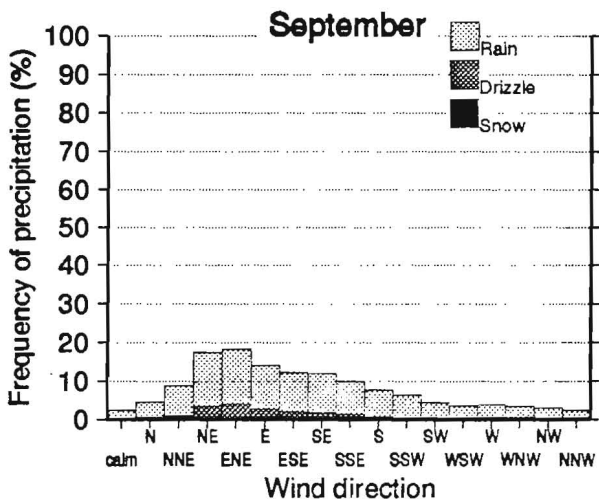
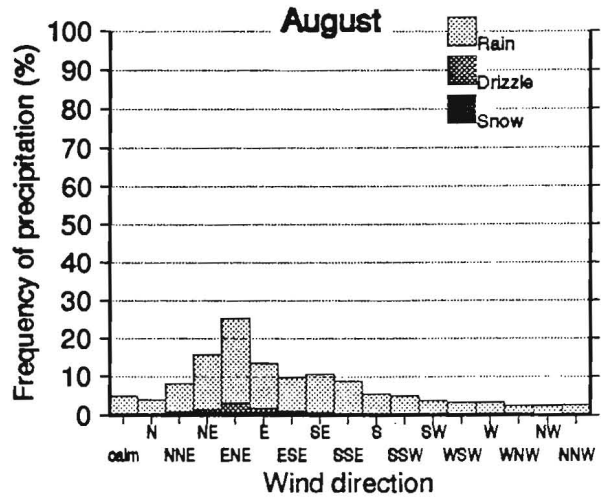
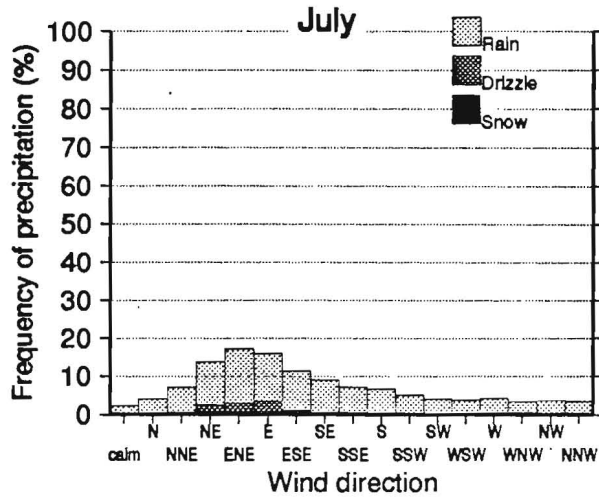












figure 40

Monthly Averaged Wind Persistence (%) 1/49-12/92 LaGuardia

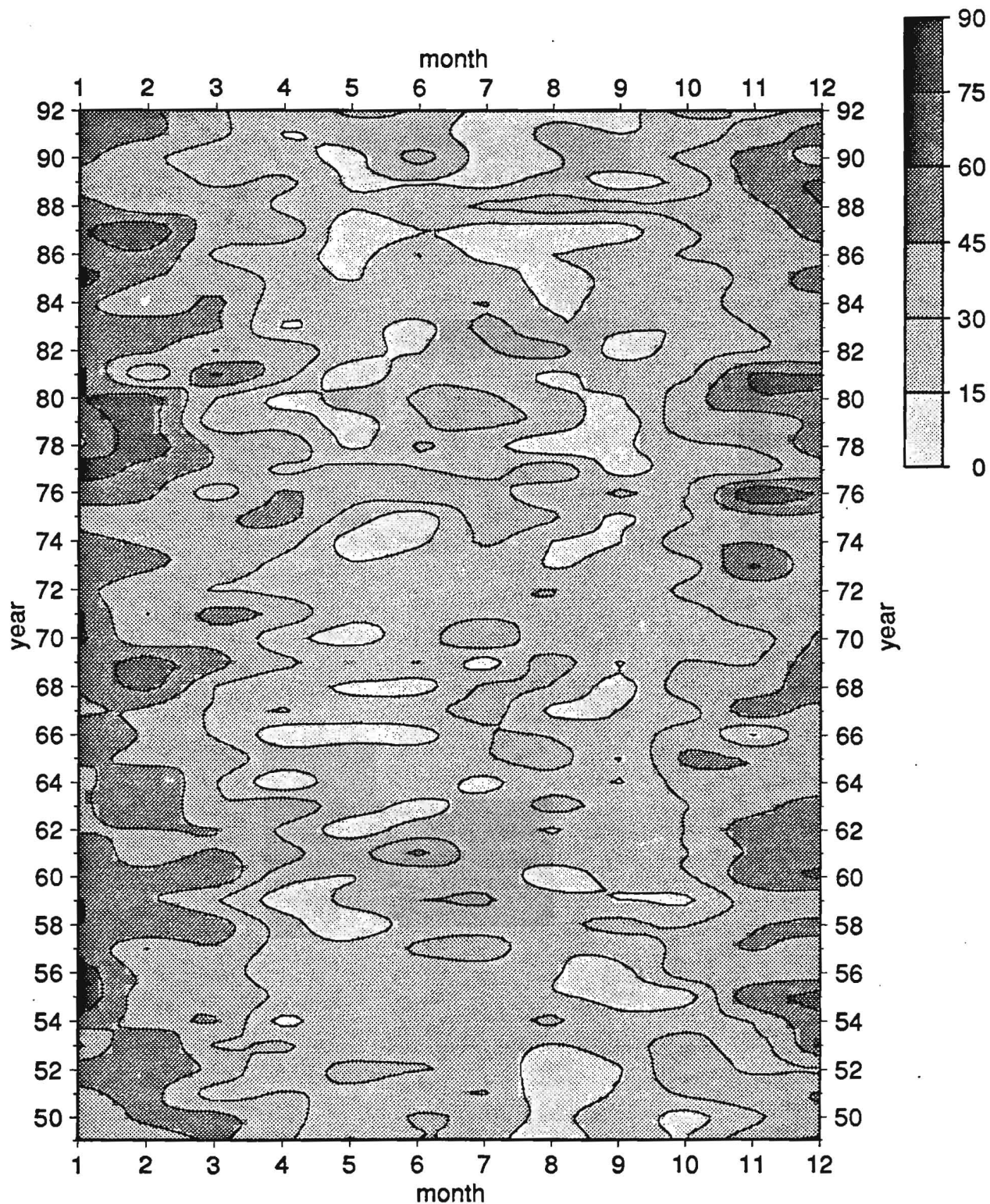




figure 41

Monthly Averaged Wind Persistence Anomaly (%) 1/49-12/92 LaGuardia

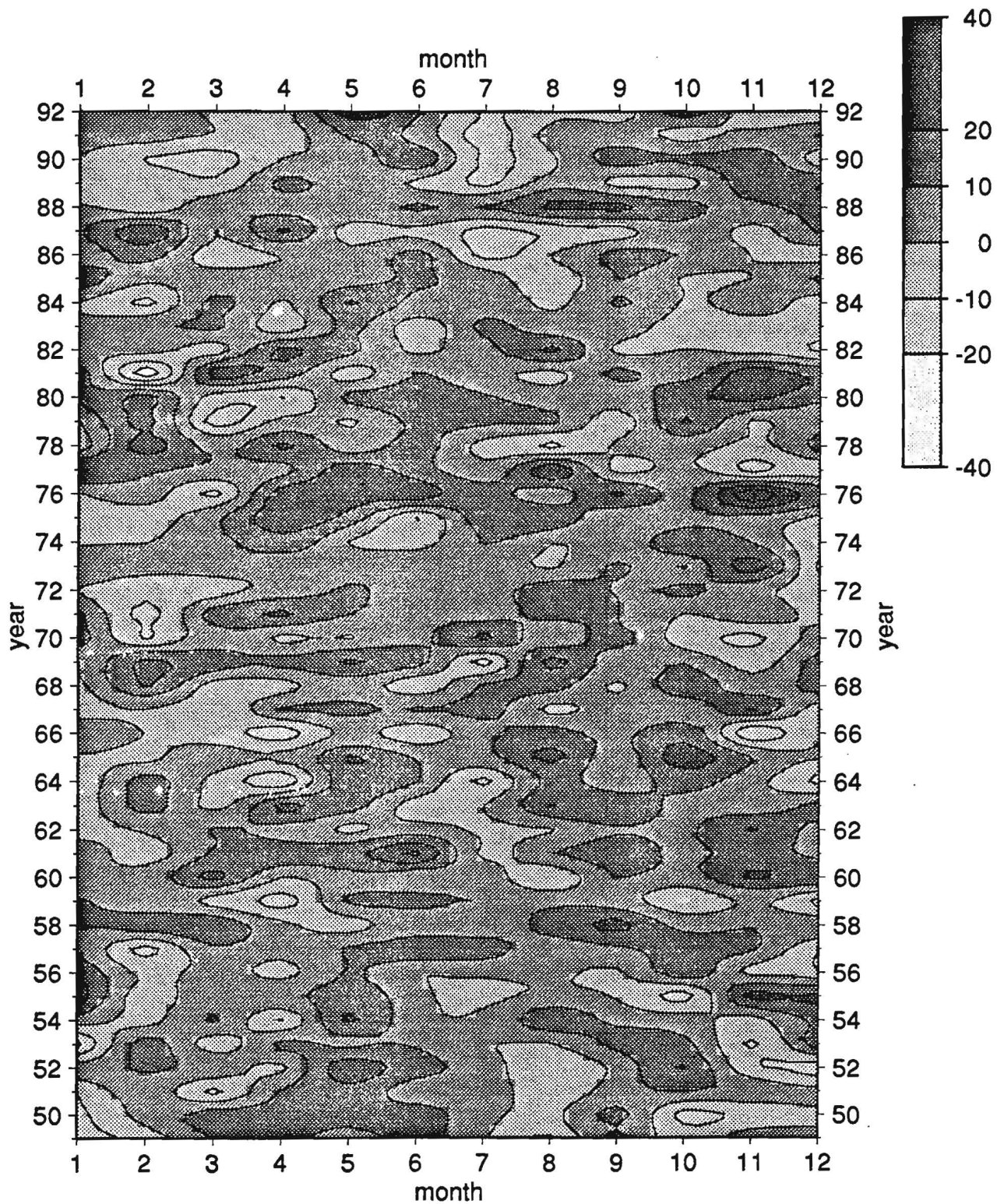
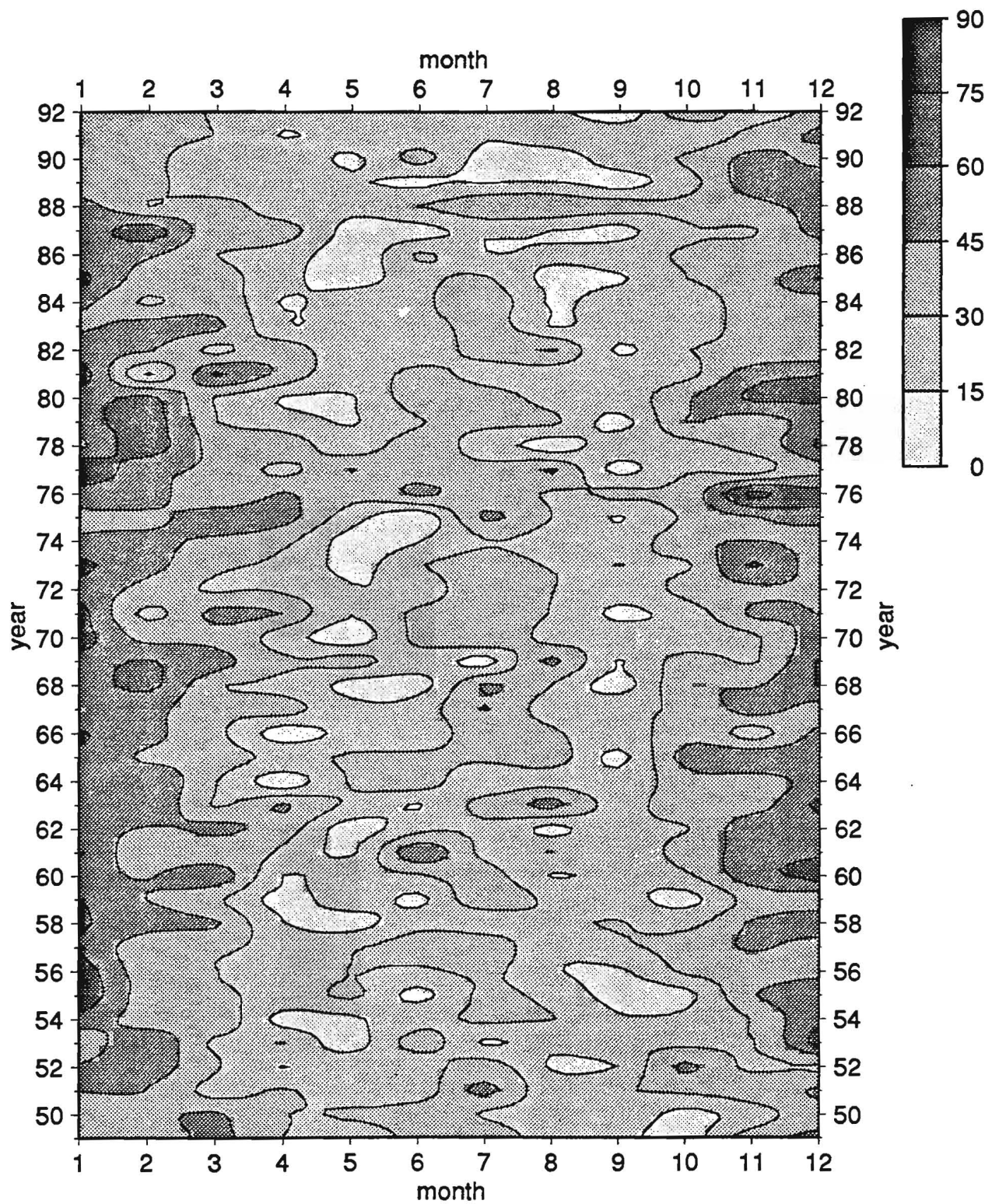




figure 42

Monthly Averaged Wind Persistence (%) 1/49-12/92 Bridgeport



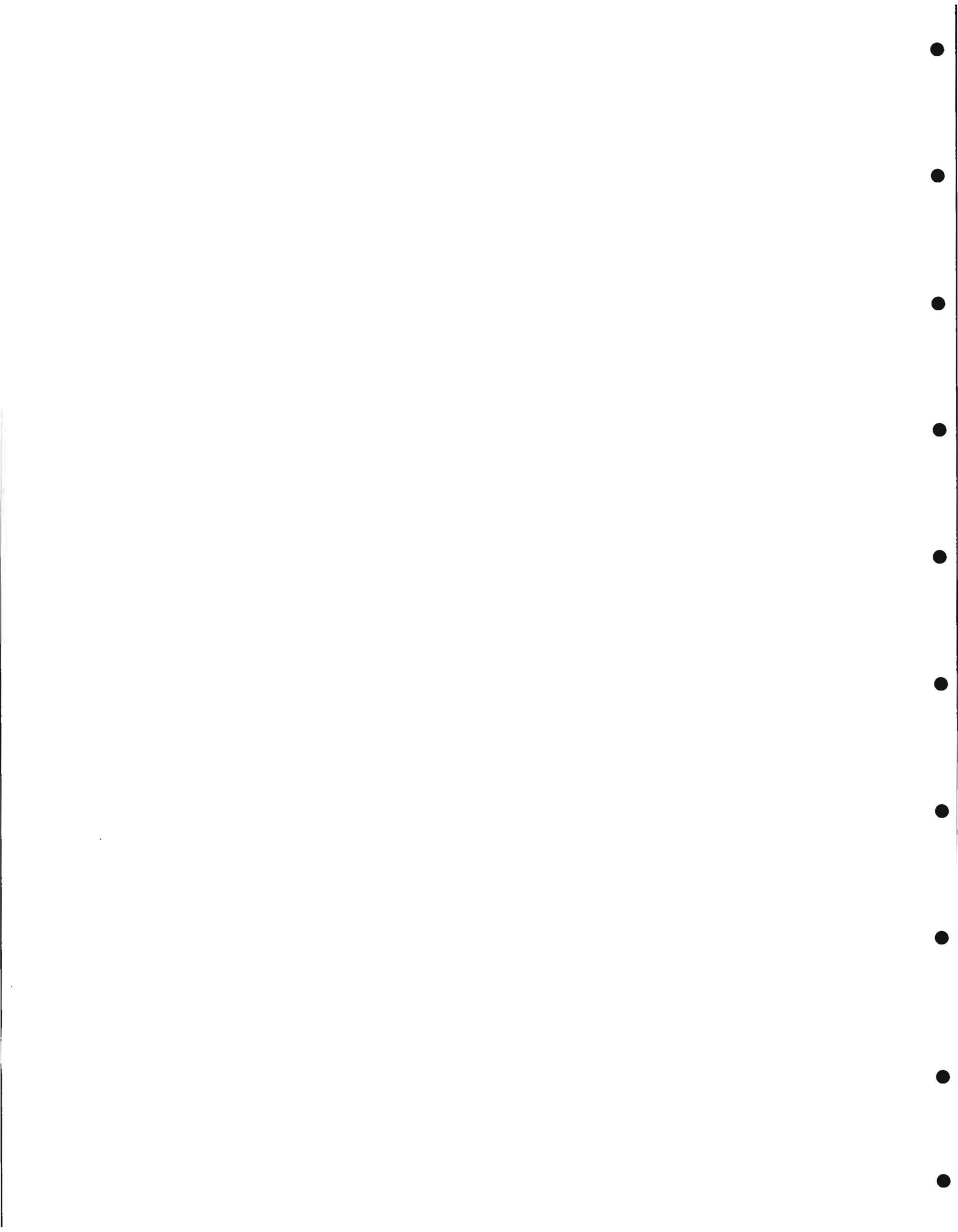
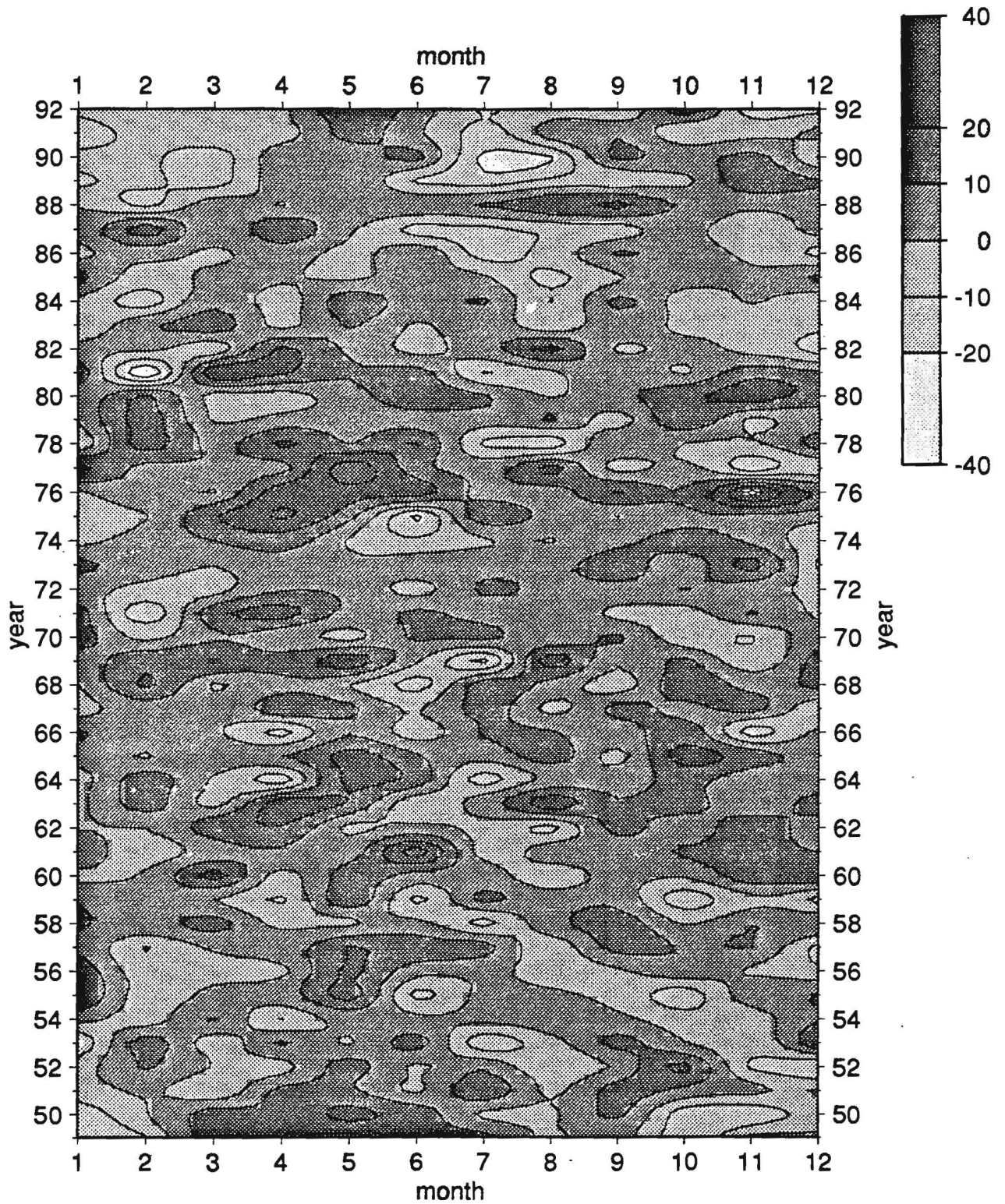


figure 43

Monthly Averaged Wind Persistence Anomaly (%) 1/49-12/92 Bridgeport



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figure 44

Monthly Averaged Temperature (°C) 1/49-12/92 LaGuardia

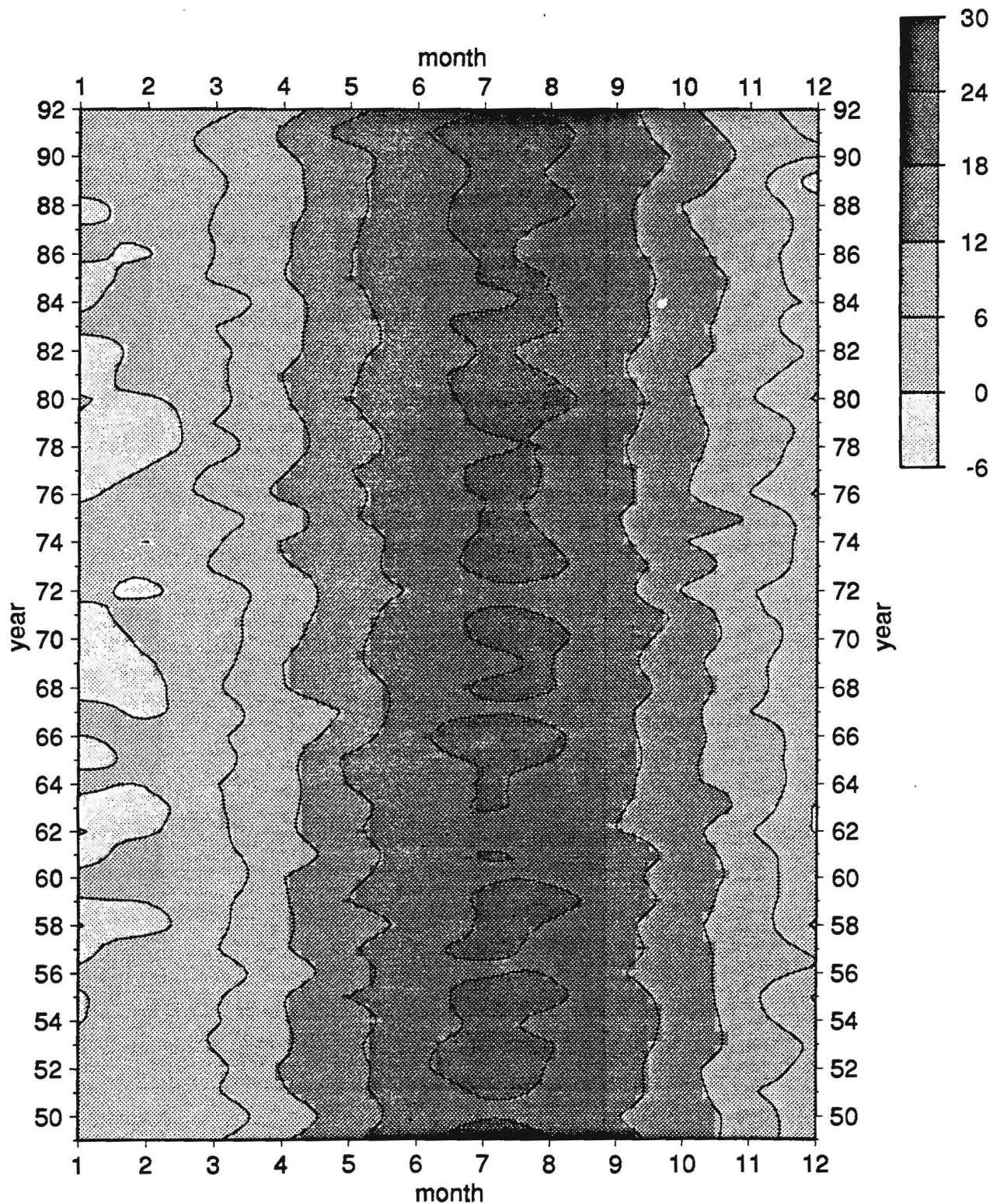




figure 45

Monthly Averaged Temperature Anomaly (°C) 1/49-12/92 LaGuardia

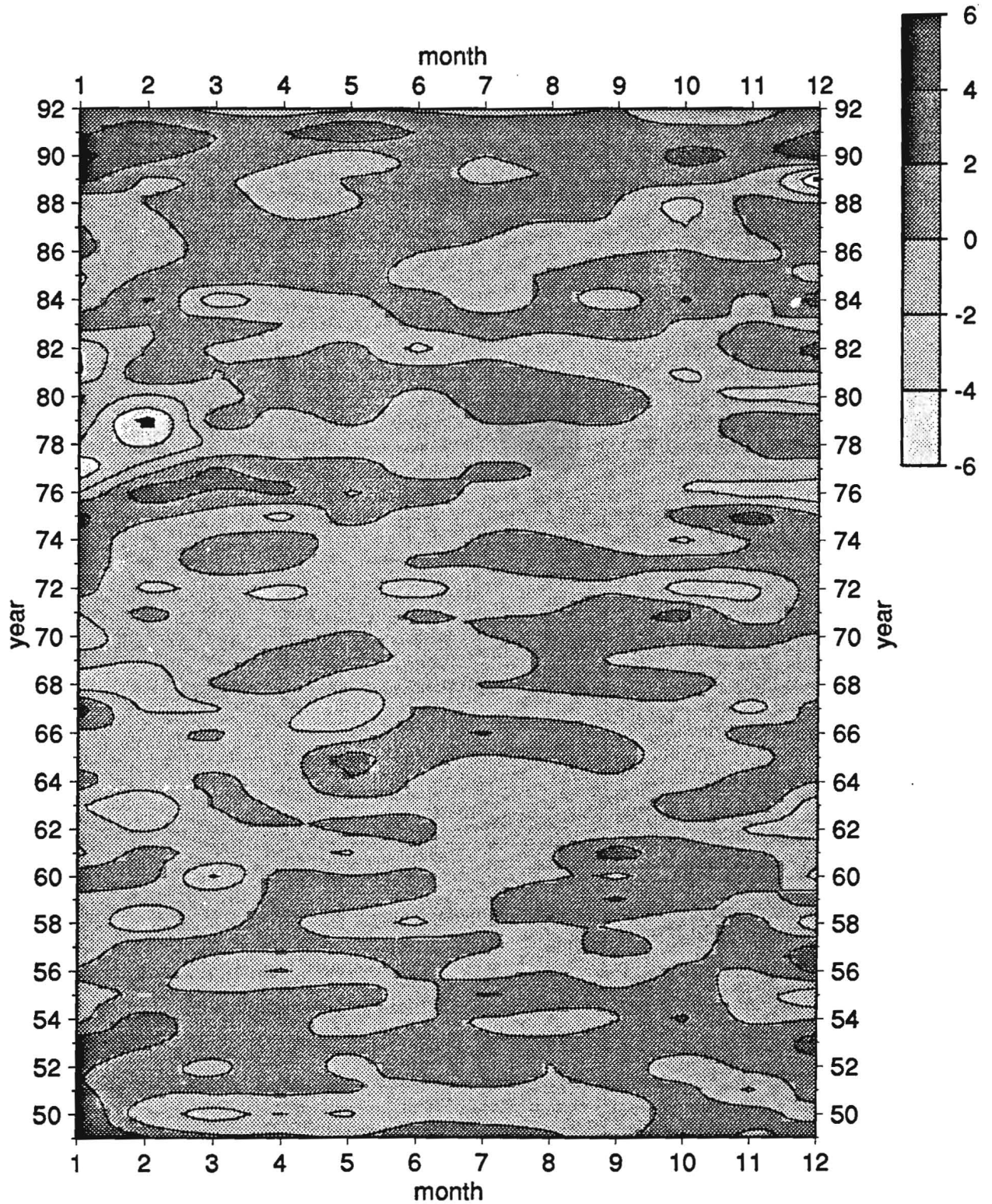
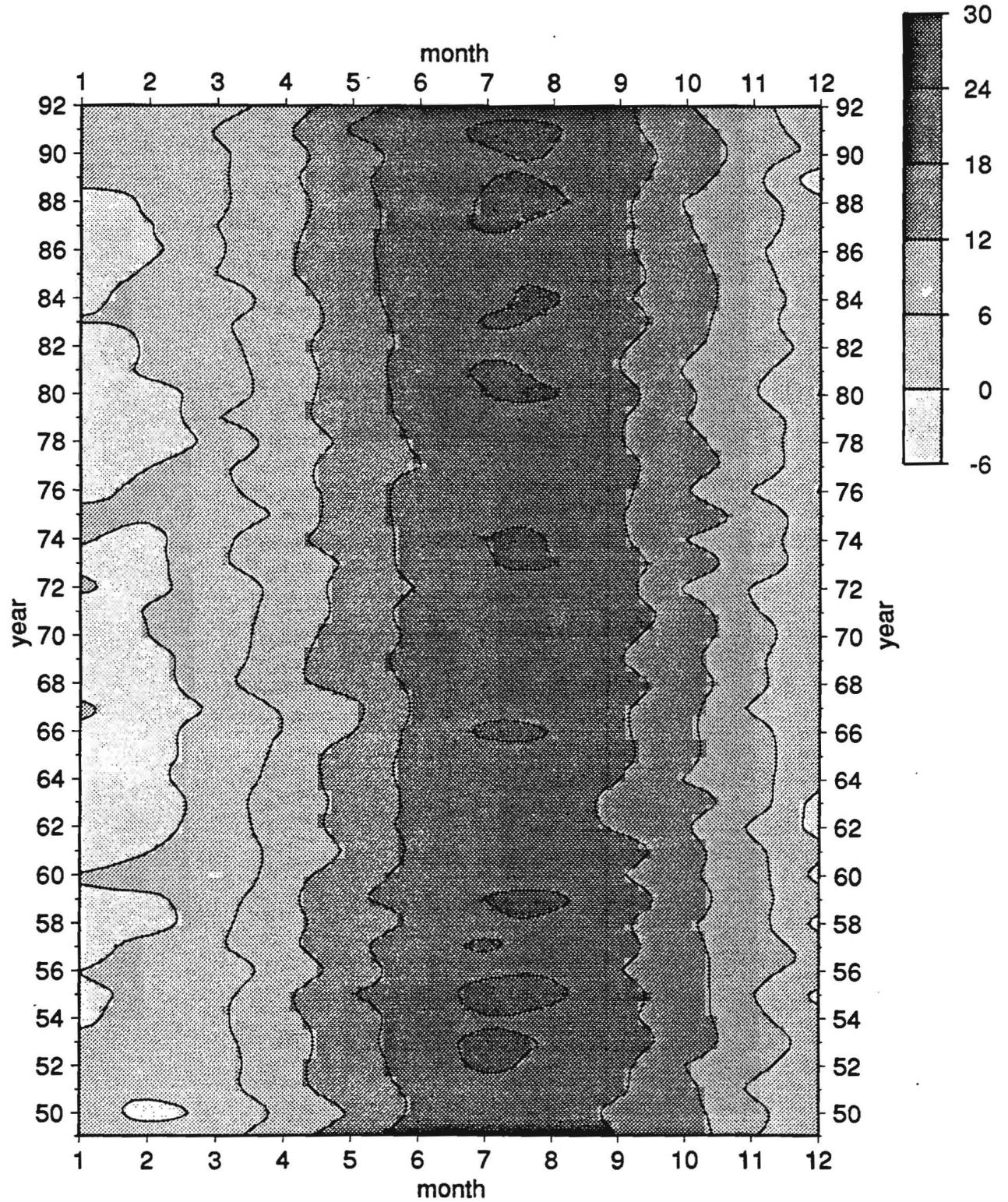




figure 46

Monthly Averaged Temperature (°C) 1/49-12/92 Bridgeport





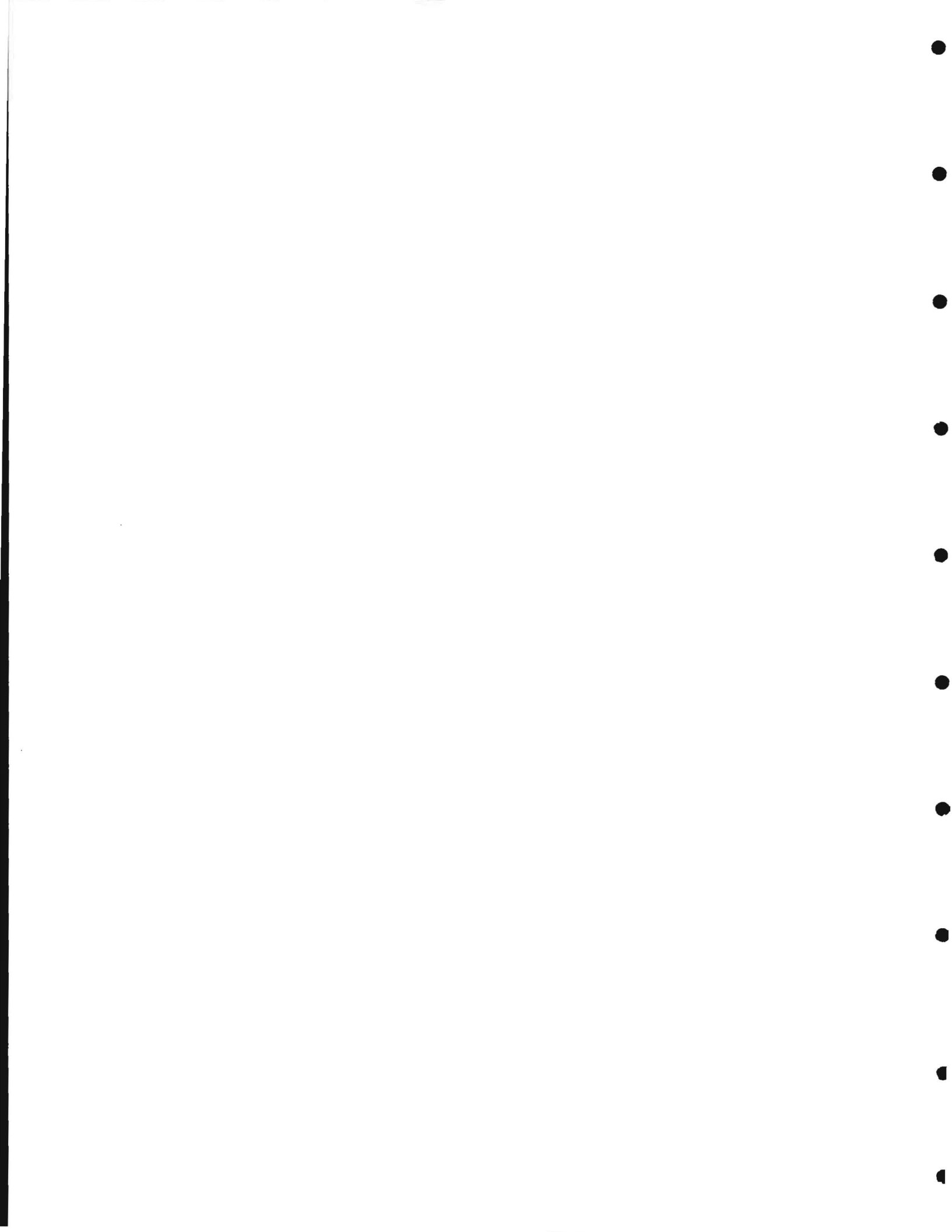
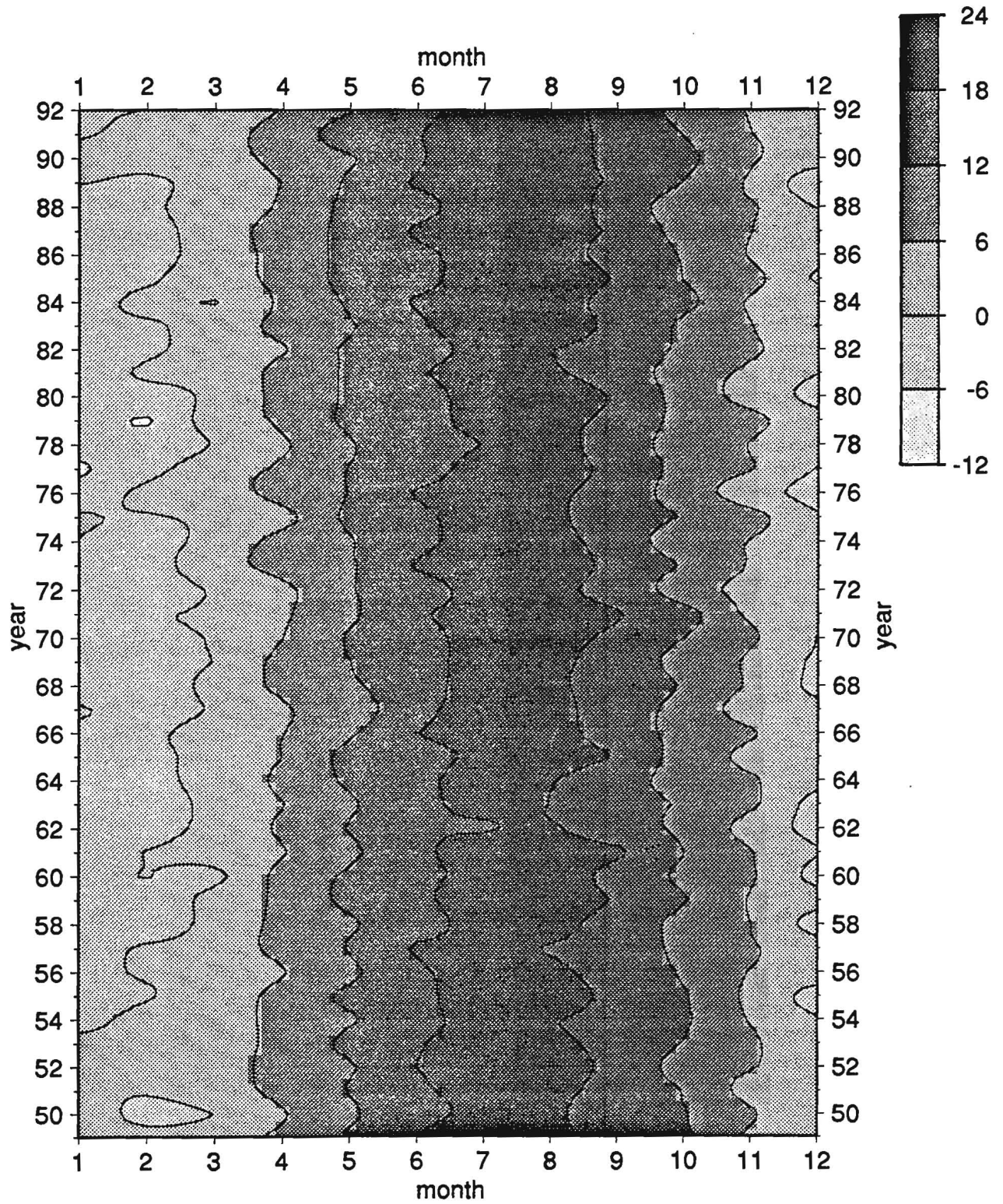


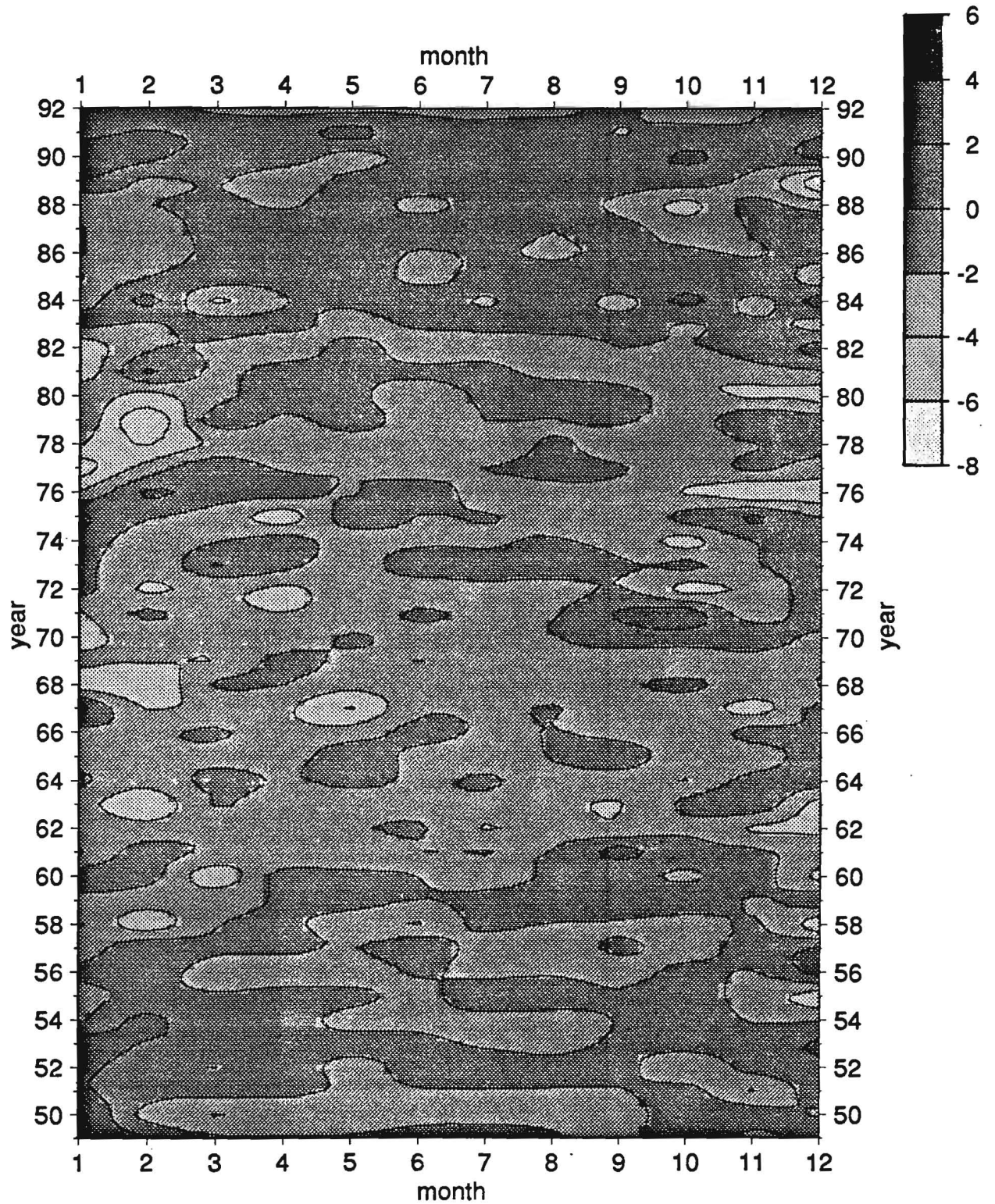
figure 48

Monthly Averaged Wet Bulb Temp. (°C) 1/49-12/92 LaGuardia





Monthly Averaged Wet Bulb Temp. Anomaly ($^{\circ}\text{C}$)
1/49-12/92 LaGuardia figure 49





Monthly Averaged Wet Bulb Temp. (°C)
1/49-12/92 Bridgeport

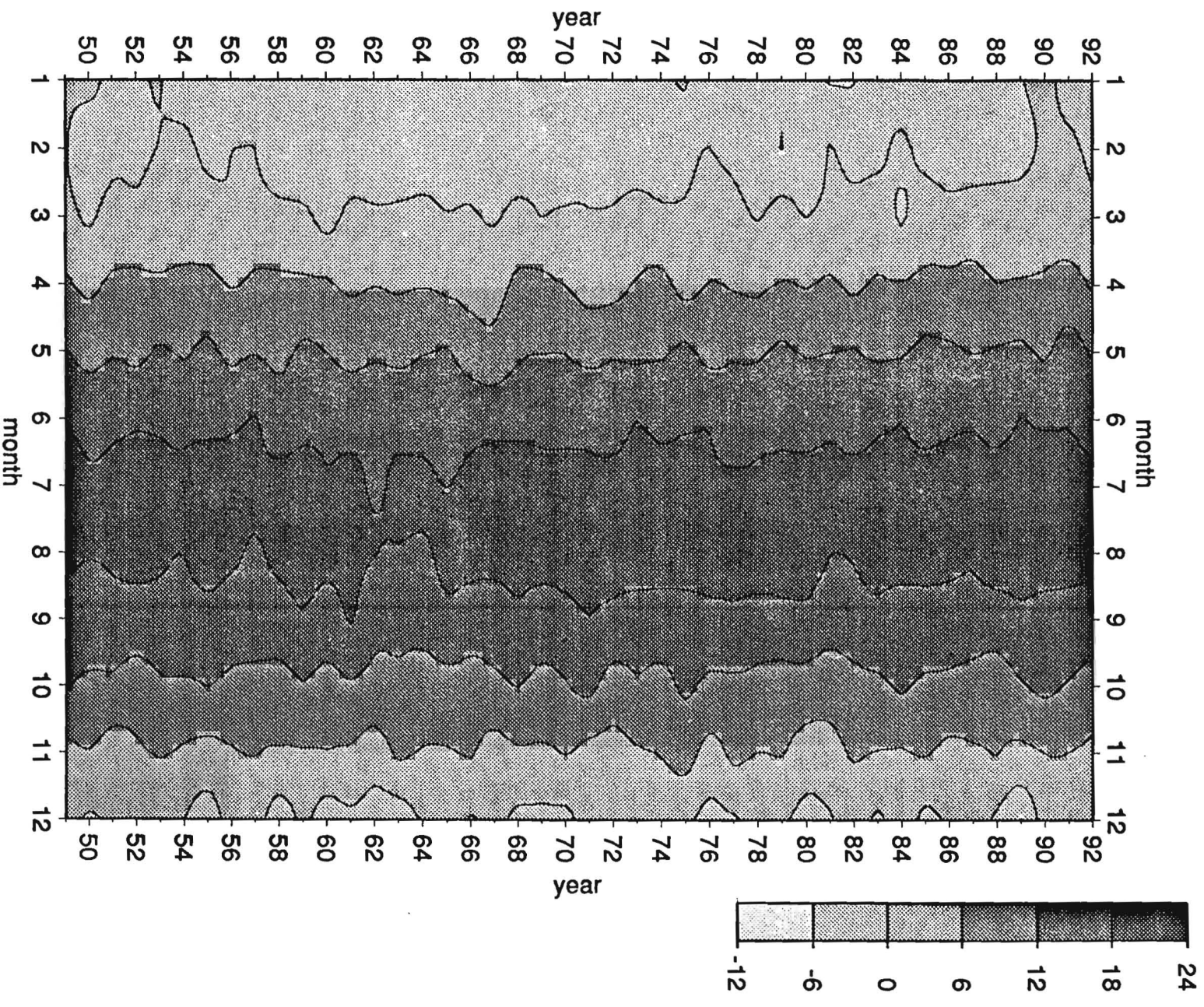


figure 50





figure 52

Monthly Averaged Sea Level Pressure (mb) 1/49-12/92 LaGuardia

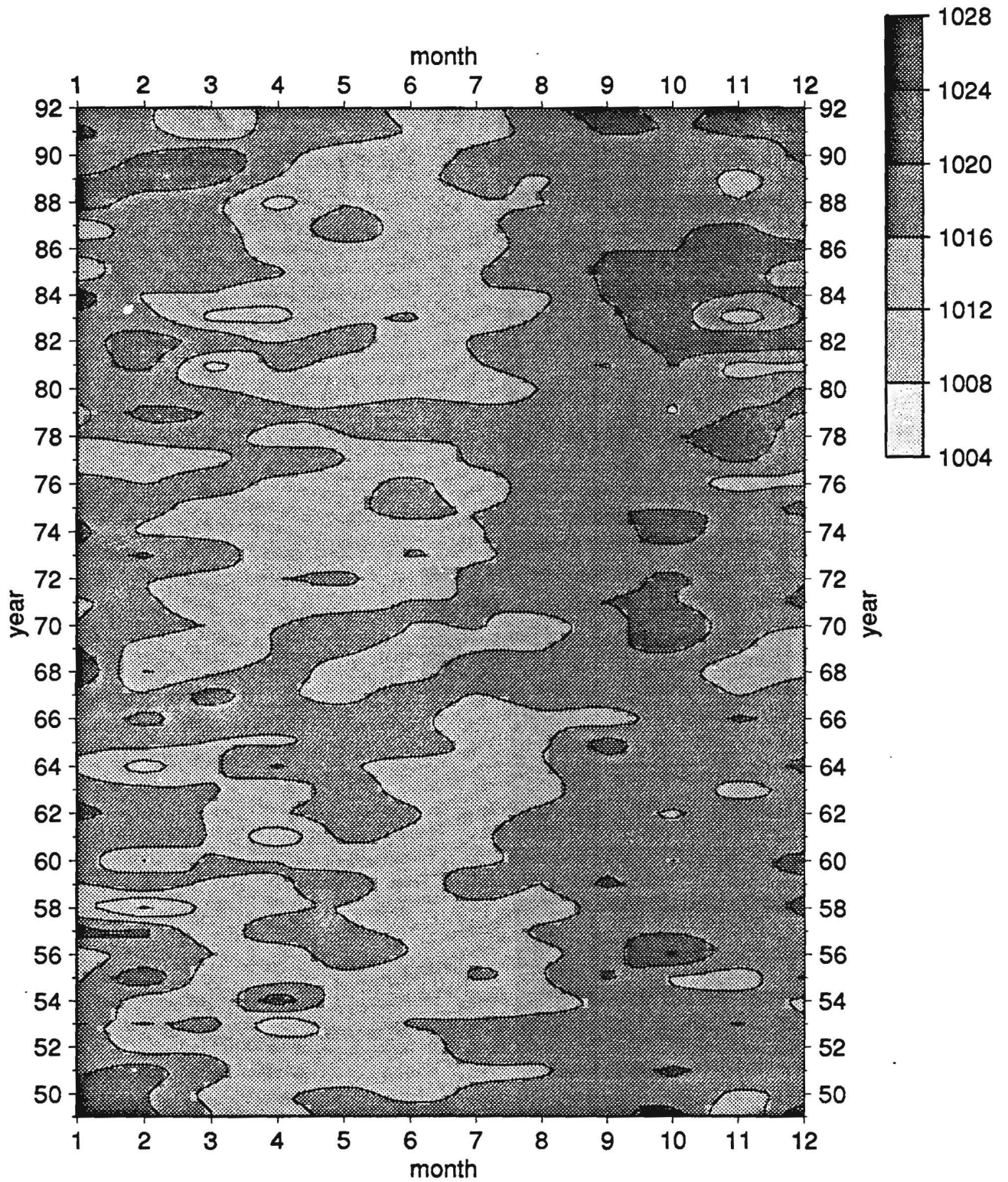




figure 53

Monthly Averaged Sea Level Pressure Anomaly (mb) 1/49-12/92 LaGuardia

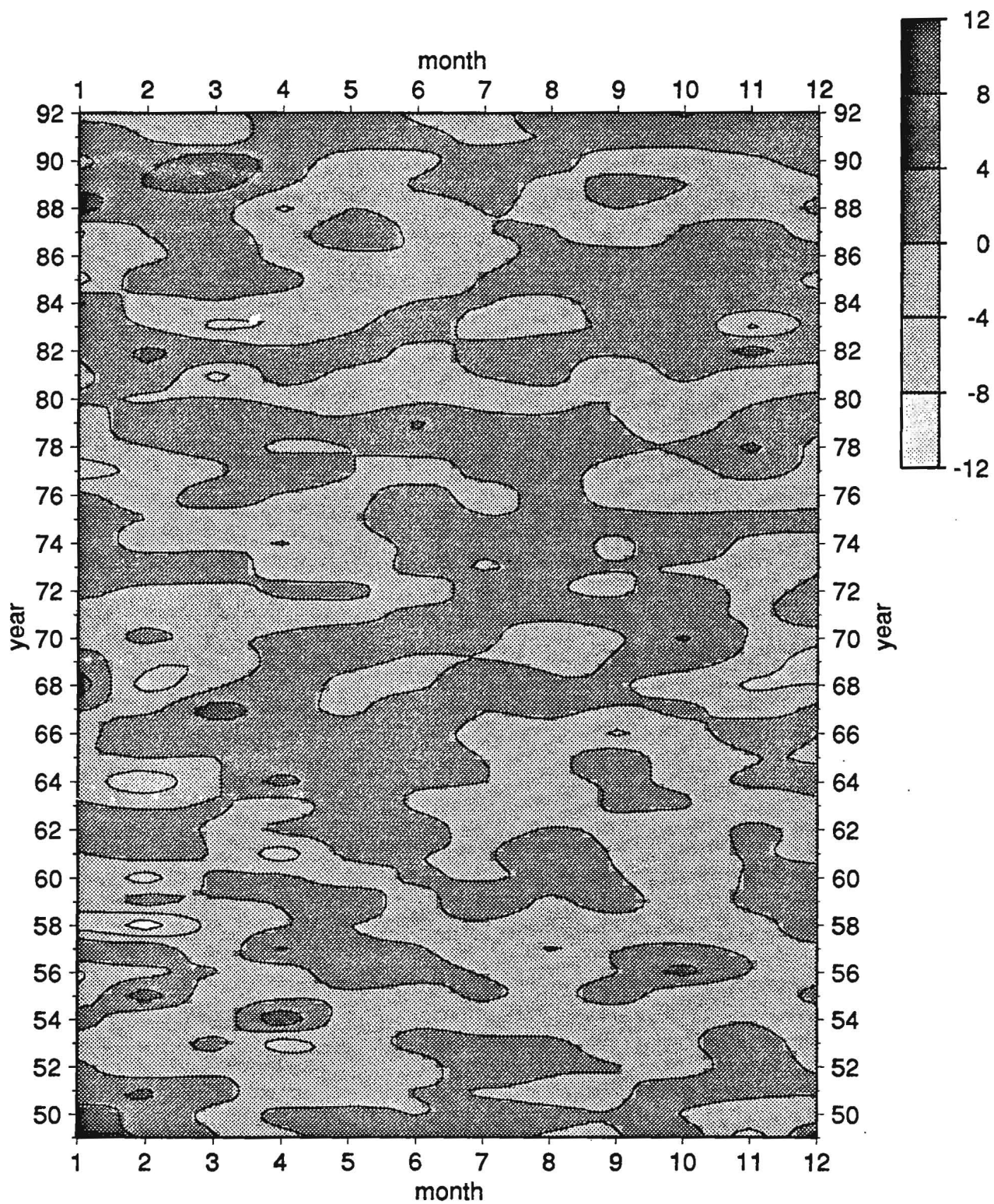




figure 54

Monthly Averaged Sea Level Pressure (mb) 1/49-12/92 Bridgeport

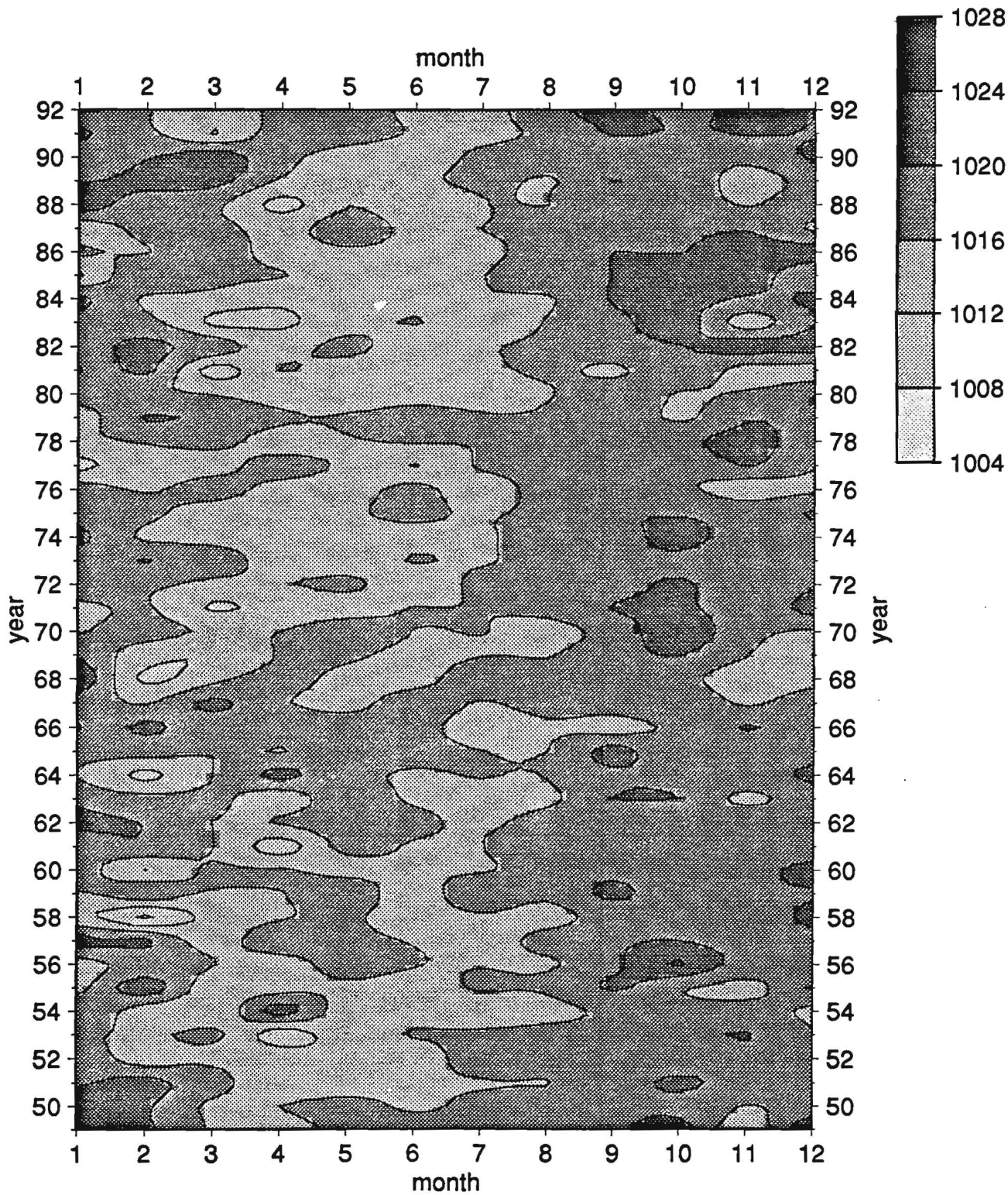
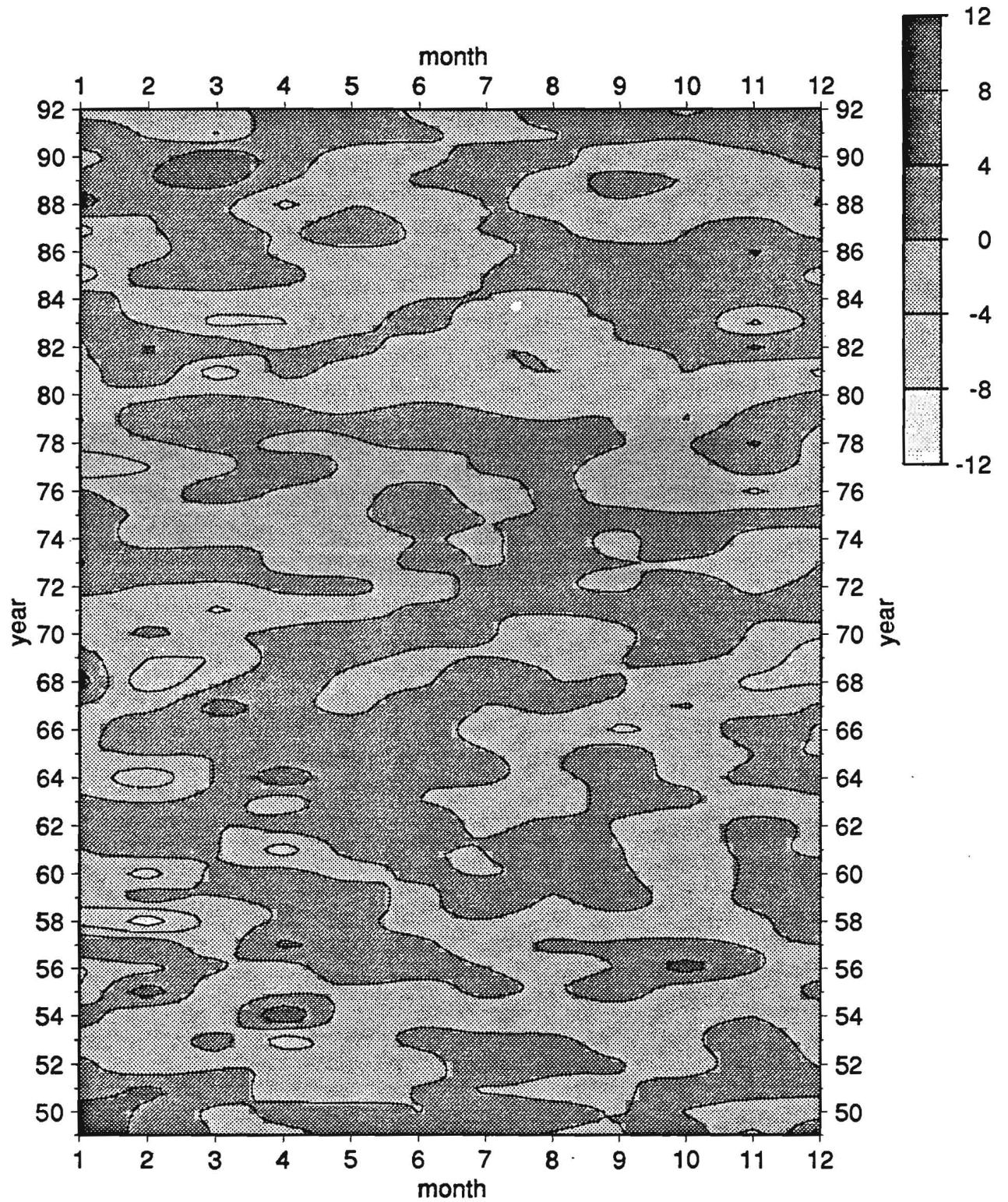




figure 55

Monthly Averaged Sea Level Pressure Anomaly (mb) 1/49-12/92 Bridgeport



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figure 57

Monthly Averaged Total Sky Cover Anomaly (tenths) 1/49-12/92 LaGuardia

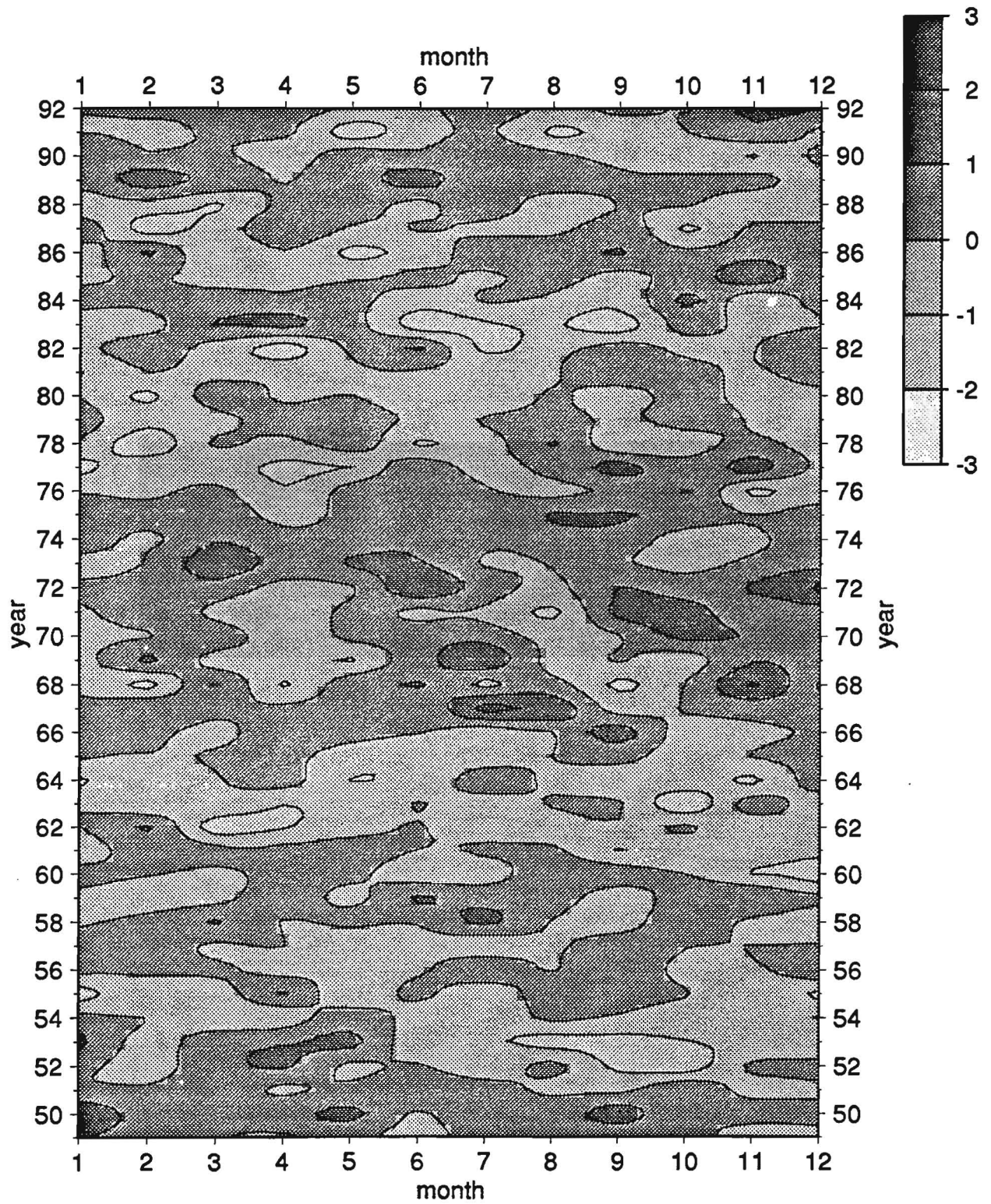








figure 60

Monthly precipitation (cm) 1/49-12/92 LaGuardia

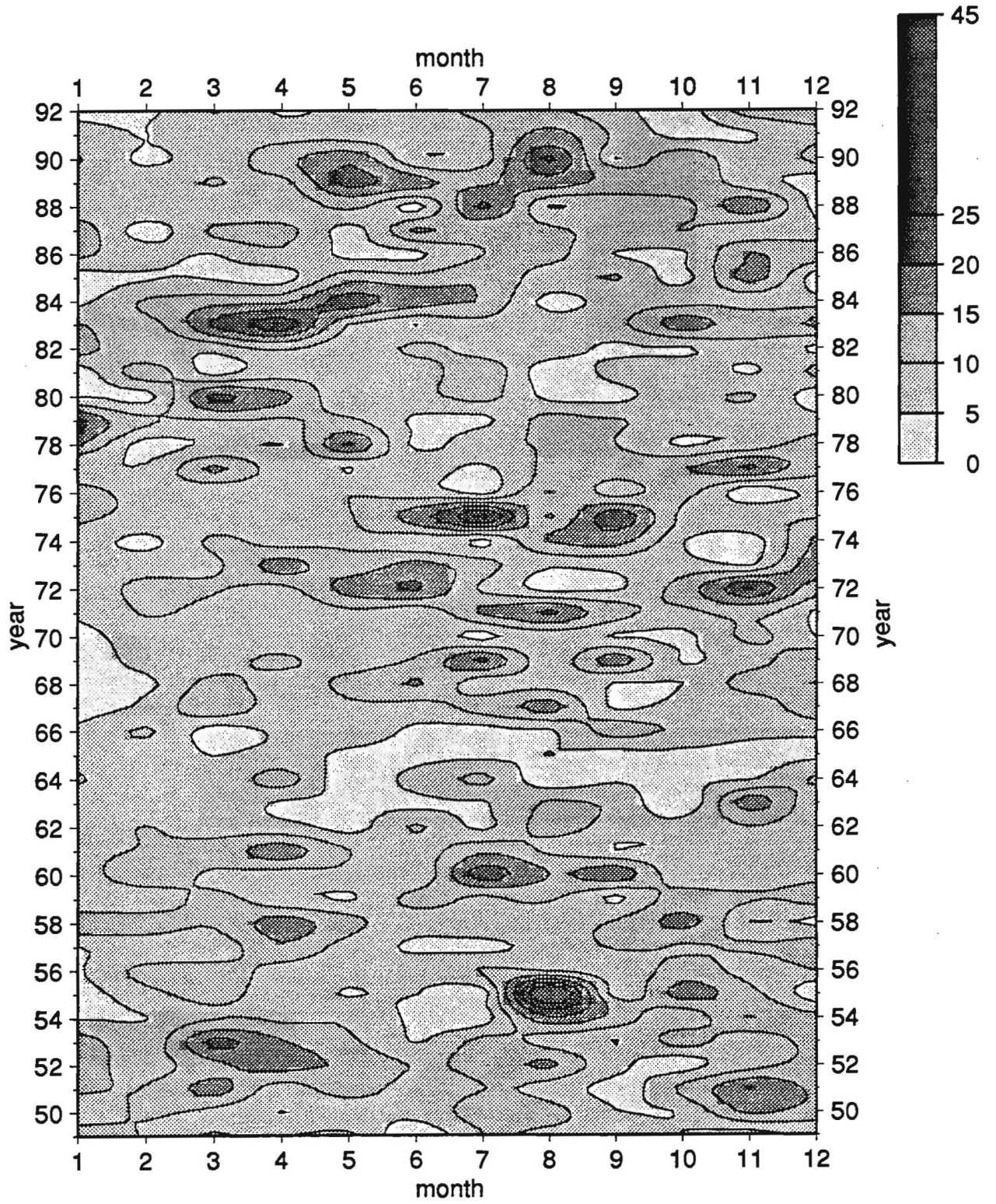
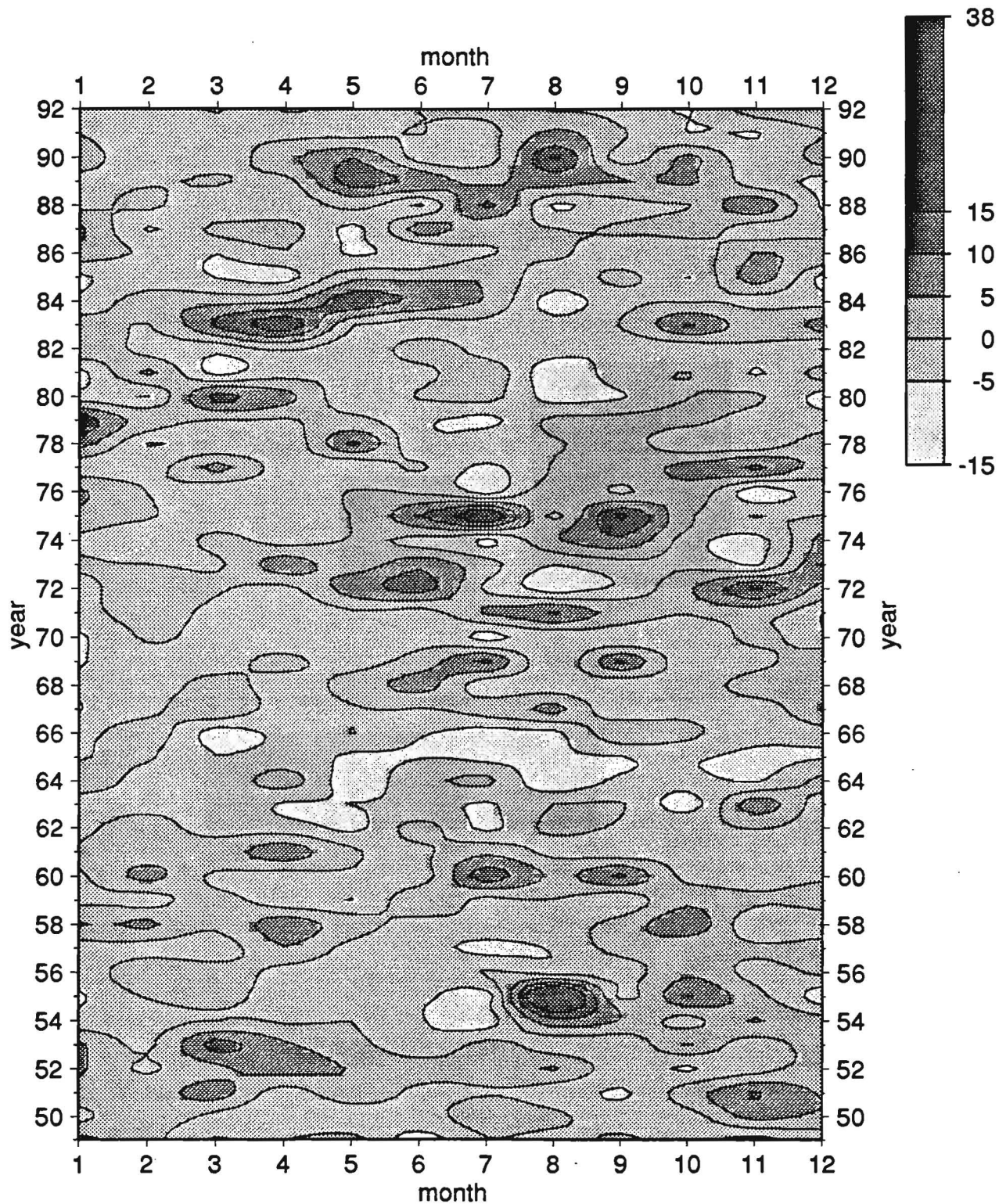




figure 61

Monthly precipitation anomaly (cm) 1/49-12/92 LaGuardia



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figure 63

Monthly precipitation anomaly (cm) 1/49-12/92 Bridgeport

