



Lightning Climatology for Eglin AFB, Florida

By

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MARCH 1996

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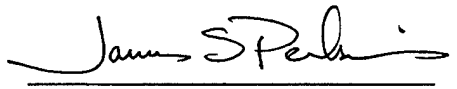
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PREFACE

This report documents the results of AFCCC Project 911229, completed by AFCCC's Simulation and Techniques Branch (AFCCC/SYT). The analysts were Capt. Brian M. Bjornson and Mr. William R. Schuab, Jr.

The customer, the 3246th Test Wing Directorate of Weather at Eglin AFB, Fla., requested a climatology of cloud-to-ground lightning strikes for May through September in an area 4 degrees latitude by 4 degrees longitude centered on Eglin AFB. The area of interest was divided into grid boxes 10 minutes of latitude by 10 minutes of longitude (approximately 10-nautical mile resolution) for a total of 576 grid boxes (24 by 24). Lightning strike observations for May through September from 1986-90 were matched with corresponding upper-air observations from either Eglin AFB, Fla., or Apalachicola, Fla., whichever had data, in that priority order. Upper-air observations of wind direction at 700 mb for 0000Z were matched with lightning observations that occurred from 2200Z the previous day to 0959Z; 1200Z upper-air observations were matched with lightning observations from 1000Z to 2159Z. After the 700-mb wind directions were categorized by eight direction sectors and calm, and the K-index values calculated and placed in four categories, the observations were summarized to obtain the average number of lightning strikes per hour for each 700-mb wind direction sector (or K-index category) by month for each grid box.

A personal computer graphics program was developed that enables the user to display the lightning strike climatology in graphs, tables, and isopleth analyses. Two monthly graphs, available for any grid box or combination of grid boxes, show the hourly average lightning strikes for any user-defined time period (month, hour combination) for each 700-mb wind sector or K-index category, and the diurnal variation in the hourly average lightning strikes for a user-selected 700-mb wind sector or K-index category. A third graph, available only for the entire area, shows the average number of occurrences and the percent occurrence frequencies of 700-mb wind direction sectors or K-index categories for 0000Z or 1200Z. Tables, also available for any grid box or combination of grid boxes, show the total lightning strikes and average number of lightning strikes per hour for each month and 700-mb wind sector or K-index category. Monthly isopleth analyses of the hourly average lightning strikes over the entire area are available for any combination of 700-mb wind sectors or K-index categories for a grid at a horizontal resolution of 10 nautical miles.

The lightning climatology adequately depicts spatial and temporal variations in lightning strikes expected with known thunderstorm patterns in the Eglin AFB area. AFCCC recommends use of the lightning climatology as another tool to assist with forecasting thunderstorms.

The authors extend special thanks to MSgt. Robert G. Pena and SSgt. Scott A. Straw who developed the lightning graphics program.

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Chapter 1

INTRODUCTION

1.1 Background. The 3246th Test Wing at Eglin AFB, Fla., uses a large area of the Florida Panhandle, southern Mississippi, and the northern Gulf of Mexico to test and evaluate precision guided munitions. Unfortunately, summertime thunderstorms are responsible for over 50 percent of the delays and test cancellations. In an effort to minimize the effect of summertime thunderstorms over the Eglin AFB range complex, the 3246th Test Wing Directorate of Weather requested that AFCCC produce a lightning climatology for May through September stratified by 700-mb wind direction sectors and K-index (thunderstorm potential indicator) categories. AFCCC recommended a personal computer graphics program to display the 17,000 plus graphs of the lightning climatology. This allowed Eglin staff meteorologists to manipulate and customize results for their customers. The area included in the lightning graphics is shown in Figure 1.

1.2 Related Studies. For many years, weather

forecasters at Eglin AFB have studied the problems of summertime thunderstorms that develop over the Gulf of Mexico at night, and daytime air-mass thunderstorms that develop over the land due to local convection. A Local Forecast Study (1953) noted that thunderstorms usually form in the afternoon along a west-to-east line between Crestview and Eglin AFB, and later move over the base if upper-level winds are from the northwest quadrant. Jones (1956, 1957) found that the 700-mb wind direction was more closely correlated to thunderstorm locations and times than wind direction at any other level. He showed that afternoon thunderstorms were most likely at the airfield when the 700-mb wind direction was from west through north through east. In recent related work, Lopez and Holle (1987) used cloud-to-ground (CG) lightning data to show that the mean 1000-mb to 700-mb wind direction determined the spatial patterns of lightning strikes across Central Florida. They also observed that the wind direction is closely related to atmospheric stability.

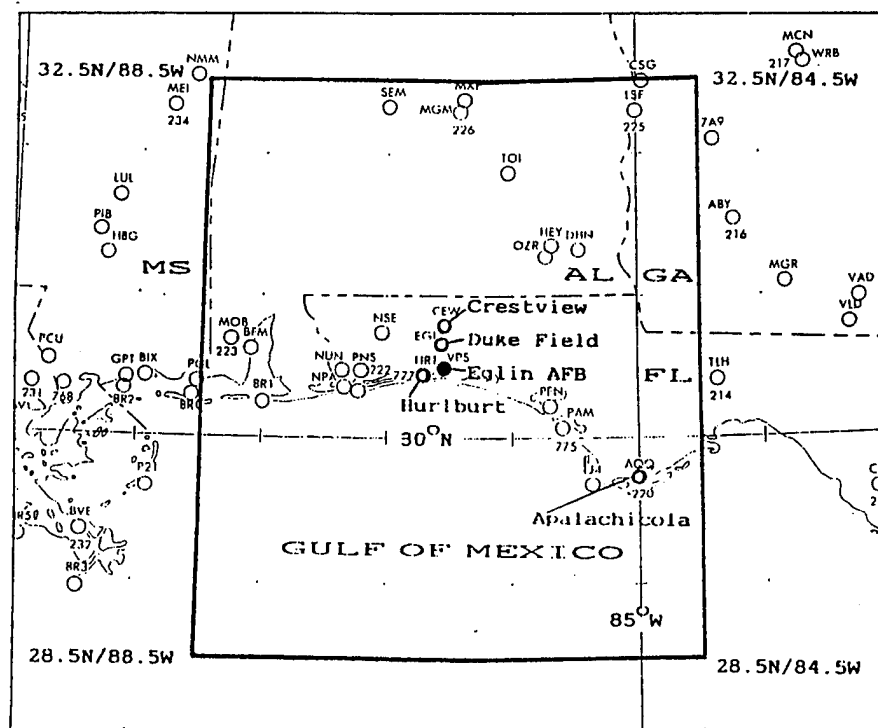


Figure 1. The area of interest. Analysis area is in bold lines.

CHAPTER 1

1.3 Analysis Procedure. As discussed in Section 2, we used 5 years (1986-90) of CG lightning-strike and atmospheric sounding data. The area of interest was divided into a square grid system to provide an effective resolution of 10 nautical miles for the summarized lightning strike data. Details of the grid system are given in Chapter 3, along with the methods used to stratify the lightning climatology by 700-mb wind direction and K-index categories. In Chapter 4, we discuss the features available in the personal computer graphics program developed to display the climatology stratified by either 700-mb wind direction or K-index, and provide illustrative examples.

1.4 Findings. The lightning climatology seemed consistent with expected diurnal and monthly variations in thunderstorm activity. For example, the occurrence of most strikes on average over the Gulf of Mexico during the night, then over land during the day showed well. Also, the monthly increase in the mean number of lightning strikes from May to a maximum in July, followed by decreases in August and September, followed the trend in monthly thunderstorm frequencies. Further, as illustrated in Chapter 4, the lightning climatology verified known preferred spatial orientations of thunderstorms at certain times based on the 700-mb wind direction. The K-index was closely related to changes in the average number of lightning strikes.

Chapter 2

DATA AND LIMITATIONS

2.1 Lightning Data. We used proprietary CG lightning-strike data purchased from GeoMet Data Services (GDS), Inc., of Tuscon, Ariz. The individual lightning strike records were stored in AFCCC's relational database (DB2) for easy access. During May through September of 1986-90, nearly 2 million strikes occurred in the area of interest. The strikes were recorded by direction finders manufactured by Lightning Location and Protection (LLP), Inc., of Tuscon. As described by Maier, et al. (1983), the LLP equipment that makes up the National Lightning Detection Network (NLDN) uses triangulation to locate the strikes. Thus, every observation of a CG lightning strike provided by GDS was made by at least two direction finders. Figure 2 shows the NLDN direction finders that GDS operated in and near the area of interest during 1986-90.

2.2 Lightning Data Limitations. In most evaluations of CG lightning strike data quality, the detection efficiency and strike location accuracy are discussed. The detection efficiency is the ratio of the number of CG strikes detected to the number that actually occurred. It's primarily a function of range or the distance of a strike from the direction finders. Over the NLDN, a detection efficiency of 70 percent is

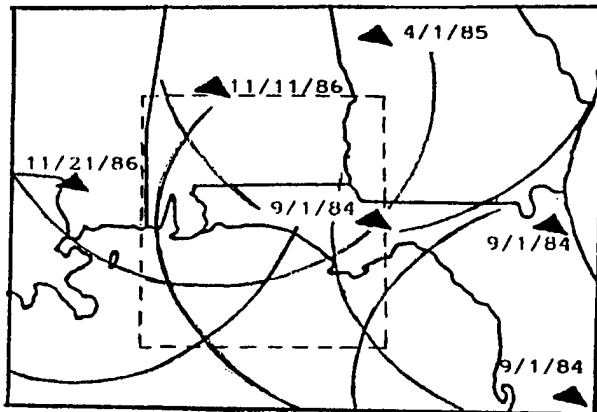


Figure 2. Triangles represent approximate locations of National Lightning Detection Network direction finders in and near the area of interest (dashed lines) during 1986-90. Dates (month/day/year) indicate when operation began. Circles around each direction finder show the nominal range of 215 nautical miles. Source: GDS (personal communication).

estimated for strikes within a 215-nautical mile range of direction finders (Orville, et. al., 1990). Beyond that nominal range, strikes are still detected, but at less efficiency. For the present work, Figure 2 shows that by late in 1986 most of the area of interest was well within the nominal range for a 70 percent lightning detection efficiency. Like detection efficiency, the strike location accuracy depends on the range of the strike; but, it also depends on the number of direction finders that record the strike, the distance between direction finders, and where the strike occurs in relation to the direction finders (Maier, et al., 1903). According to GDS, the lightning strike locations are generally accurate to within 3 to 5 nautical miles.

2.3 Upper-air Data. Atmospheric soundings from AFCCC's DATSAV Upper-air database, described in the AFCCC *DATSAV Data Base Handbook*, were used to obtain 700-mb wind data and to calculate the K-index. Three upper-air sites considered representative of the entire analysis area were selected for May through September from 1986-90: Eglin AFB, Fla.; Hurlburt Field, Fla.; and Apalachicola, Fla. (see Figure 1). The reason for using three upper-air sites was to insure that a maximum number of observations were available. That is, if a particular observation was missing for the primary site (Eglin AFB), then the observation for Hurlburt Field was used. If the Hurlburt Field observation was also missing, then the Apalachicola observation was used.

2.4 Upper-air Data Limitations. Upper-air observations were available only twice daily at 0000Z (1800 Local Standard Time (LST)) and 1200Z (0600LST). No attempt was made to interpolate upper-air variables from other hours of the day to those times. As described in Chapter 3, it was assumed that the upper-air data for 0000Z was valid for lightning strikes that occurred from 2200Z to 0959Z. Similarly, upper-air data for 1200Z was assumed valid for strikes that occurred from 1000Z to 2159Z. Obviously, these assumptions ignore upper-air changes between soundings, but the changes are usually considered small. Furthermore, the quality of the DATSAV upper-air data is questionable as noted by Clouse and Lott (1986). The data used in this work was decoded and validated, but no further quality control was done.

Chapter 3

METHODOLOGY

3.1 Lightning Data Preparation. A total of 3,634,507 CG lightning-strike observations that occurred during 1986-90 in May through September were extracted from the relational database for the analysis area in Figure 1. Each lightning observation contained the year, month, day, hour, minute, and latitude and longitude in decimal degrees. The observations were sorted by year, month, day, and hour for merger with the upper-air data. Any particular hour, as a result of sorting, included lightning strikes that occurred on that hour and during the 59 minutes after that hour.

3.2 Upper-air Data Preparation. As stated in Chapter 2, atmospheric sounding data from Eglin AFB, Hurlburt Field, and Apalachicola (refer to Figure 1), was considered correlated so any station was representative of upper-air conditions over the entire analysis area. Using the three locations minimized the number of periods that could not be categorized. Of the three, Eglin AFB had first priority followed by Hurlburt and Apalachicola. If data was available for Eglin AFB it was used first. If not, data for Hurlburt was used. If Hurlburt data was missing, data for Apalachicola was used. The daily 700-mb wind direction and speed in knots for 0000Z (1000LST) and 1200Z (0600LST) were extracted for the three locations for May through September from 1986-90. Almost 95 percent (1448 of 1530) of the total possible upper-air observations had 700-mb wind data for the period (480 from Eglin; 103 from Hurlburt; and 865 from Apalachicola). The upper-air observations were sorted by year, month, day, and hour for merger with the lightning observations.

3.3 Wind Stratified Lightning Data Set. To produce the lightning climatology stratified by 700-mb wind direction categories, the lightning and upper-air observations were merged based on the following conditions: Lightning strikes that occurred from 1000Z to 2159Z were matched with the 1200Z upper-air observations. Lightning strikes that occurred from 2200Z the previous day to 0959Z were matched with the 0000Z upper-air observations.

After combining the data sets, every lightning strike observation contained a 700-mb wind direction and speed, including missing values. Those lightning observations that contained missing wind direction and speed were deleted, since a wind direction category could not be assigned. This reduced the original number of lightning strike observations to 1,543,068 observations.

3.3.1 Wind Direction Categories. The 700-mb wind direction and speed in each lightning strike observation were used to assign one of nine wind direction categories to each observation. The first category, C (calm), was assigned to an observation if the wind speed was less than 5 knots regardless of wind direction. The other eight categories: N (north), NE (northeast), E (east), SE (southeast), S (south), SW (southwest), W (west), and NW (northwest) were assigned if the speed was equal to or greater than 5 knots, and the direction was within the following ranges:

- N: direction equal to or greater than 330° but less than 15°
- NE: direction equal to or greater than 15° but less than 60°
- E: direction equal to or greater than 60° but less than 105°
- SE: direction equal to or greater than 105° but less than 150°
- S: direction equal to or greater than 150° but less than 105°
- SW: direction equal to or greater than 195° but less than 240°
- W: direction equal to or greater than 240° but less than 285°
- NW: direction equal to or greater than 285° but less than 330°

CHAPTER 3

3.4 The K-index. As discussed in *The Use of the Skew-T, Log P Diagram in Analysis and Forecasting* (1990), the K-index is an indicator of thunderstorm potential. It is calculated from upper-air temperatures and dew-point temperatures, and works best for predicting non-severe air mass thunderstorms. The K-index has been correlated to probabilities of thunderstorm occurrence. Table 1 shows K-index categories and related thunderstorm probabilities developed for use in the summer in the central United States.

Table 1. K-index Categories and Thunderstorm Probabilities. Developed for use in summer in the Central United States. Adapted from *The Use of the Skew-T, Log P Diagram in Analysis and Forecasting* (1990).

K-index	Percent Probability of Thunderstorms
less than 15	zero
15 - 20	20
21 - 25	20 - 40
26 - 30	40 - 60
31 - 35	60 - 80
36 - 40	80 - 90
greater than 40	near 100

The index covers a wide range from negative to positive; the more positive, the greater the probability of thunderstorms. The equation to calculate the K-index (K) is:

$$K = \{(T_{850} - T_{500}) + Td_{850} - (T_{700} - Td_{700})\} \quad (1)$$

where T_{850} = 850 mb temperature (°C)

T_{500} = 500 mb temperature (°C)

Td_{850} = 850 mb dew-point temperature (°C)

T_{700} = 700 mb temperature (°C)

Td_{700} = 700 mb dew-point temperature (°C)

The first term in equation 1 parameterizes the vertical temperature lapse rate, while the second term indicates moisture content in the lower atmosphere, and the last term represents the vertical extent of moisture.

3.5 K-index Stratified Lightning Data Set. As before, the original lightning and upper-air data were used, except the necessary data for K-index calculations: 850-mb and 700-mb temperatures and dew-point temperatures, and the 500-mb temperature was evaluated. This time, only 83 percent (1271 of 1530) of possible upper-air observations were available with all of the necessary information (493 from Eglin; 156 from Hurlburt; and 622 from Apalachicola). Again, the upper-air observations were sorted by year, month, day, and hour, and matched with lightning strike observations according to conditions given in paragraph 3.3 above. As a result, every lightning strike observation contained temperature data for calculating a K-index, including missing values. Where the necessary temperature data was missing, the observations were deleted because a K-index could not be calculated. This reduced the original number of lightning strike observations to 1,318,654 observations.

3.5.1 K-index Categories. The K-index in each lightning strike observation was used to determine one of four K-index categories listed below:

- CAT1: K-index less than 20
- CAT2: K-index from 20 to 25
- CAT3: K-index from 26 to 30
- CAT4: K-index greater than 30

It should be pointed out that the open-ended categories 1 and 4 can inject a bias in the lightning climatology. Since those categories allow for wider ranges of values, their numbers may overshadow categories 2 and 3 in very stable or unstable cases.

3.6 Frequency Distribution Data Sets. The upper-air data was used separately to produce frequency distributions by month and hour for the nine 700-mb wind direction sectors and four K-index categories. For 700-mb wind sectors, every 0000Z and 1200Z upper-air observation from either EglinAFB, Hurlburt, or Apalachicola with reported 700-mb wind direction and speed was used to determine the sector. Next, the total and average were calculated for each sector by month and hour. Then the total was calculated for all nine sectors by month and hour. The percent

occurrence frequency for each sector by month and hour was calculated as follows:

$$\text{Percent Occurrence Frequency} = \frac{\text{Sector Total}}{\text{Total for All Sectors}} \quad (2)$$

A data set was then built that contained the average number of occurrences and percent occurrence frequency for each wind sector by month and hour. By the same process, except with temperature variables needed to calculate K-index, another data set was built that contained the average number of occurrences and percent occurrence frequency for each K-index category by month and hour. The data sets were used to display frequency distribution charts in the lightning graphics described in Chapter 4.

3.7 The Grid System. To prepare each stratified lightning data set for summarization at a horizontal resolution of approximately 10 nautical miles, the area of analysis in Figure 1 was divided into a grid system centered on Eglin AFB. The grid point spacing was set at 10 minutes of latitude and 10 minutes of longitude. As a result, the grid system contained a 25 by 25 array of 625 grid points and 576 individual grid boxes. A partial sketch of the grid system is shown in Figure 3 for reference. To simplify analysis, the grid system was assumed square. Actually, the distances between degrees of longitude on the earth increase toward the equator, while the distances between degrees of latitude decrease slightly. Therefore, the square grid system masks the fact that the real areas enclosed by grid boxes are not square and increase from north to south. For the Eglin AFB area, the distance between degrees of longitude increases from about 51 nautical miles per degree at 32.5°N to about 53 nautical miles per degree at 25.5°N. The distance between degrees of latitude from north to south varies little at nearly 60 nautical miles. As a result, the overall horizontal resolution for lightning strike analysis is 10 nautical miles. It varies from about 9 nautical miles at the higher latitude to about 10 nautical miles at the lower latitude. Due to the variable resolution, a bias exists for higher counts of lightning strikes in grid boxes at lower latitudes. That is, given an equal number of lightning strikes in two equal areas, one area at higher latitudes and the other area at lower latitudes, more strikes would be counted in the lower

grid boxes. However, for purposes of this analysis the bias is considered minor.

3.8 Gridding the Data. To obtain values for the total strikes in individual grid boxes, a grid box number was calculated and assigned to each lightning observation by first converting the latitude and longitude from degrees to minutes. From procedures given in Hoke, et. al. (1985), the following equations were used to calculate the grid-point Cartesian coordinates (x,y) for each lightning observation:

$$x = \{(\text{LATMIN} - \text{LAT1})/\text{MIN}\} + 1 \quad (3)$$

$$y = \{(\text{LONMIN} - \text{LON1})/\text{MIN}\} + 1 \quad (4)$$

where LATMIN = latitude of lightning strike in minutes

LOWMIN = longitude of lightning strike in minutes
LAT1 = latitude in minutes at lower right corner of grid system

LON1 = longitude in minutes at lower right corner of grid system

MIN = grid spacing in minutes of latitude or longitude

Next, grid-point indexes (I,J) were defined as follows:

$$I = \text{INT}(x) \quad (5)$$

$$J = \text{INT}(y) \quad (6)$$

where the operator INT acts to keep only the whole part of the numbers for x and y. Lastly, the grid box number (BOXNUM) for each lightning observation was calculated from the following:

$$\text{BOXNUM} = I + \{\text{SQRTBOX}(J-1)\} \quad (7)$$

where SQRTBOX equals 24, the square root of the total number of individual grid boxes in the grid system. For example, as shown in Figure 1, the lower right corner of the analysis area is located at 20.5° N/ 04.5° W. From equations 1 through 4, the values of I and J for that point are both one. From Equation 5, the grid box number for a lightning strike at that point is one. As shown in Figure 3, the influx varies from 1 on the bottom row to 25 at the top. The index J varies

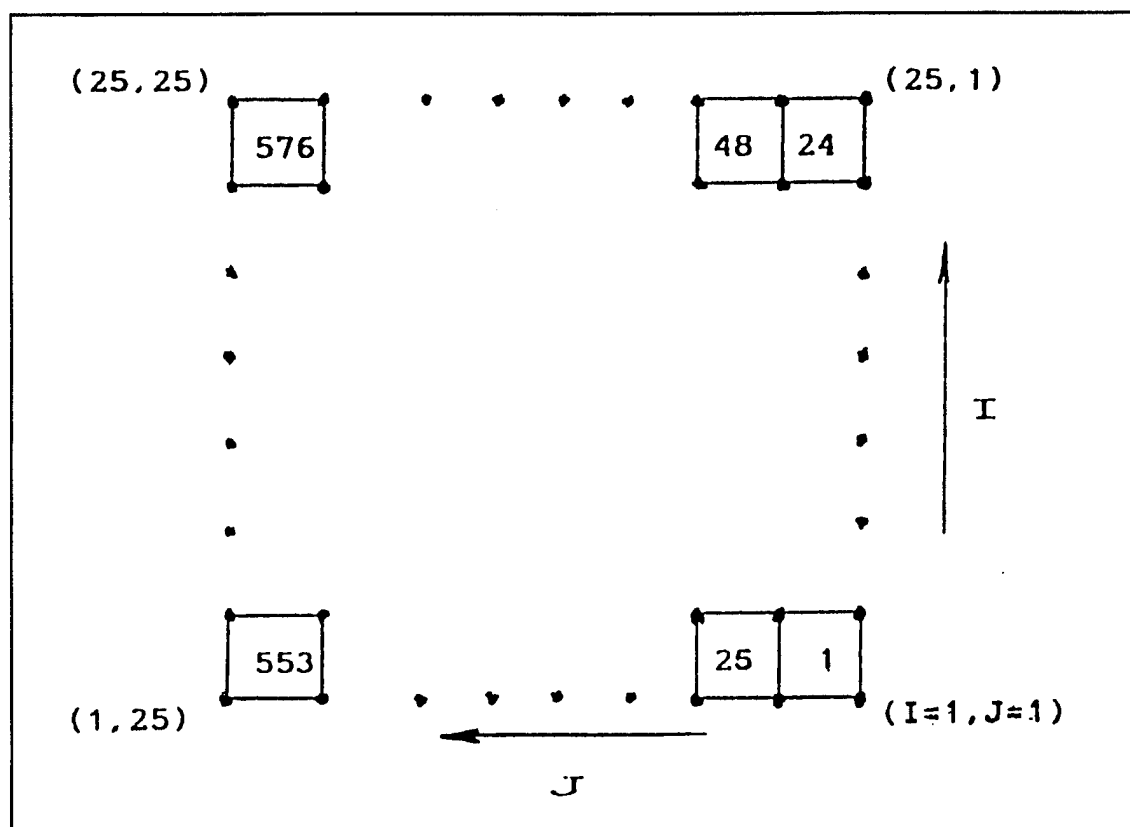


Figure 3. Sketch of the grid system.

from 1 on the right side of the grid system to 25 on the left side. The grid box numbers increase from 1 in the lower right corner to 24 in the upper right corner, and so on to box number 576 in the upper left corner. Once the above gridding procedure was complete, every lightning strike observation had a grid box number for identification.

3.9 Lightning Data Summarization. The data sets of lightning stratified by 700-mb wind sector and K-index were summarized for each grid box. The average number of lightning strikes per hour were calculated for each 700-mb wind sector or K-index category and month. As a result, each grid box in the analysis area had stratified lightning strike climatologies for use in the graphics program discussed in the next chapter.

Chapter 4

LIGHTNING CLIMATOLOGY AND RESULTS

4.1 The Lightning Graphics Program. A personal computer graphics program was developed by Pena and Straw (1992) to display the Eglin AFB lightning climatology. The user-friendly graphics program runs on IBM-compatible computers that have the following minimum features: a 286 microprocessor with a hard drive; DOS 3.2 or higher; and EGA or better graphics. If a math co-processor is available, it decreases the run time. A screen print option is included that works with any Epson-compatible dot matrix or HP Laser Jet printer.

4.1.1 Graphics Displays. The lightning graphics program uses the stratified lightning strike climatologies, and the frequency distribution climatologies of 700-mb wind sectors and K-index categories, to present several displays. The displays and input options include bar graphs, contour analyses, and tables listed below:

Graph A: Bar graph of the hourly average lightning strikes stratified by 700-mb wind sectors or K-index categories.

- One, several, or all of the grid boxes, months (May through September), and hours (0000Z through 2300Z) may be selected.
- All wind sectors or K-index categories are displayed in every output.

Graph B: Bar graph of the hourly average lightning strikes by hour.

- One, several, or all of the grid boxes, months, and 700-mb wind sectors (or K-index categories) may be selected.
- All hours are displayed in every output.

Graph C: Bar graphs of the average number of occurrences and percent occurrence frequencies of 700-mb wind sectors (or K-index categories).

- All of the area must be selected.
- One, several, or all months may be selected.
- Either 0000Z or 1200Z may be selected.

Contours: Isopleth analyses of the hourly average lightning strikes over the entire grid that has a horizontal resolution of 10 nautical miles.

- All of the area must be selected.
- One, several, or all months, hours, and 700-mb wind sectors (or K-index categories) may be selected.

Table: Table with counts of total strikes and hourly average lightning strikes for each month and 700-mb wind sector (or K-index category).

- One, several, or all grid boxes and hours may be selected.

4.2 Using the Program. Upon entry into the lightning graphics program, the user must first select the grid box or boxes for study. As each individual grid box is selected, the user is provided the latitude and longitude for the upper left corner of the grid box. Figure 4 shows how the screen appears with the whole area of analysis (all 576 grid boxes) selected. The area of analysis is purposely compressed from top to bottom to allow space on the screen for the other two sections. The accuracy of the climatology is not affected. Next, the user selects the display type (graph, contour analysis, or table), and input options. The section to the right of the area of analysis will contain information on the display type and input options. The words "Area Selected" simply confirm that an area was selected for study. After the display type and input options are selected, the user issues the output command. If a graph or table was selected, it will appear in the bottom section of Figure 4 (next page). Contour analyses are presented as a separate whole screen. As an option, the user may select a printed copy of the output.

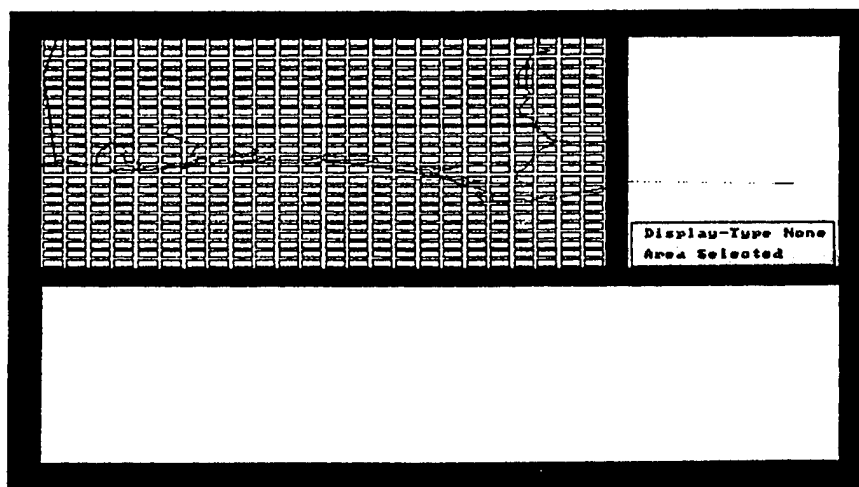


Figure 4. Area of analysis as depicted in the graphics program. All 576 grid boxes selected for analysis.

4.3 Wind Stratified Lightning Climatology

Examples. In this section, we show examples from the wind stratified lightning climatology and remark on patterns and trends. As expected, the patterns and trends in lightning strikes are closely related to those of thunderstorms. In some cases, the lightning climatology confirms previous findings regarding thunderstorm development and behavior.

4.3.1 Afternoon Lightning and 700-mb Wind Direction. It's been shown by Cale (1963) and in the Surface Observation Climatic Summaries for Duke Field/Eglin Aux #3, FL (1991) that Eglin AFB reaches a maximum in thunderstorm frequency during July.

Therefore, July was used to illustrate the dependence of the hourly average lightning strikes during the afternoon on the 700-mb wind direction. An area of 400-square nautical miles centered on Duke Field (Eglin Auxiliary #3) was analyzed. Duke Field, located 10 nautical miles north of Eglin at $30^{\circ} 39' N/86^{\circ} 31' W$, was chosen because the runway complex is there, and weather observations are taken from that point. As shown in Figure 5, display type A was used on the area covered by four grid boxes for the hours of 1800Z (1200LST) through 2300Z (1700LST) in July. The graph shows that the highest hourly average lightning strikes (nearly 40) occur on July afternoons when 700-mb winds are from the southwest.

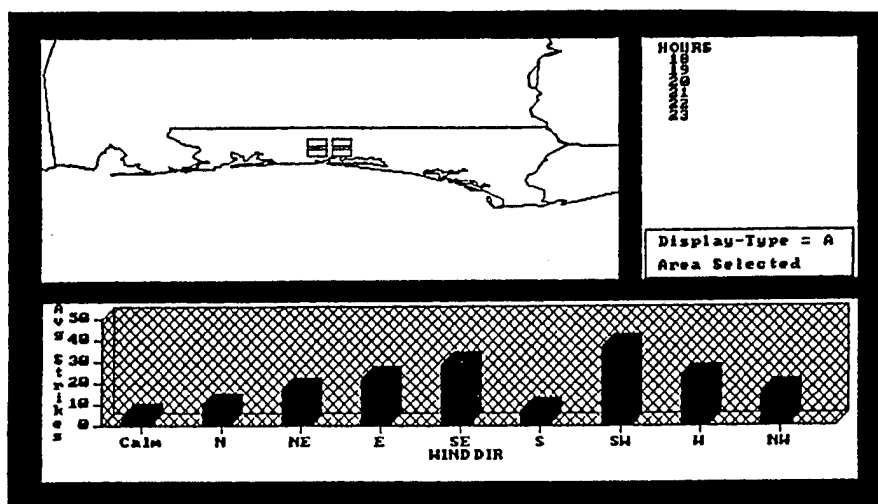


Figure 5. Average number of lightning strikes per hour for all 700-mb wind sectors for the period from 1800Z (1200LST) through 2300Z (1700LST) in July at Duke Field, Fla. Analysis is for an area of 400-square nautical miles centered on Duke Field.

4.3.2 Lightning and Time of Day. The graph in Figure 6 is an example of display type B. It shows the diurnal variation in the hourly average lightning strikes for all 700-mb wind direction sectors in July for the same area centered on Duke Field. The highest average

number of lightning strikes (over 20) corresponds with the study by Cale (1963) that showed the time of maximum thunderstorm occurrences at Eglin AFB was 2000Z (1400LST).

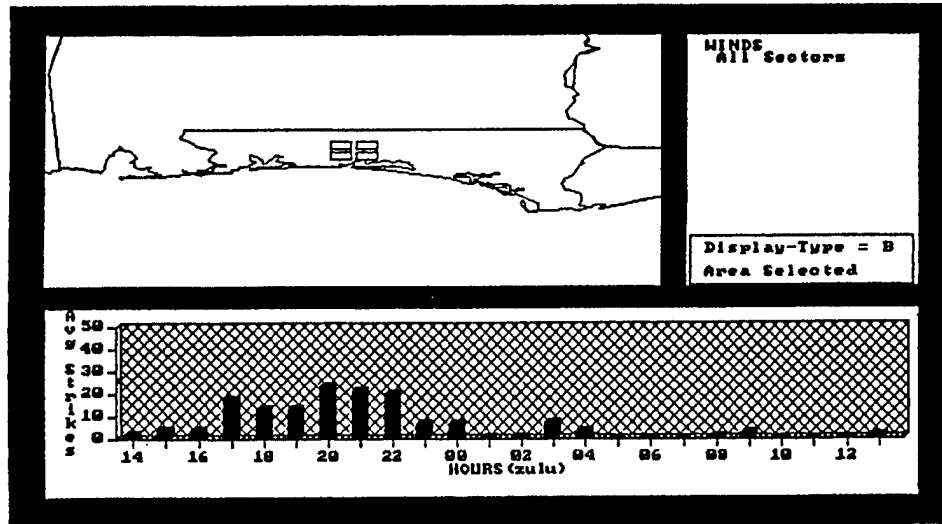


Figure 6. Diurnal variation of the average number of lightning strikes per hour for all 700-mb wind sectors in July at Duke Field. Analysis is for the same area as in Figure 5.

4.3.3 Frequency Distribution of 700-mb Wind Directions. Again, July was used to demonstrate the average number of occurrences and percent occurrence frequencies of 700-mb wind direction sectors with display Type C shown in Figure 7. The message in the area of analysis reminds the user that the whole area is selected, because the 700-mb wind direction sector statistics are representative of the

whole area. In the graph, which is for 1200Z (0600LST), the columns to the left of each direction label represent the average number of occurrences, while the columns to the right represent the percent occurrence frequencies. The graph shows that the most frequent 700-mb wind directions west, with a yearly average of about five occurrences and an occurrence frequency over 20 percent.

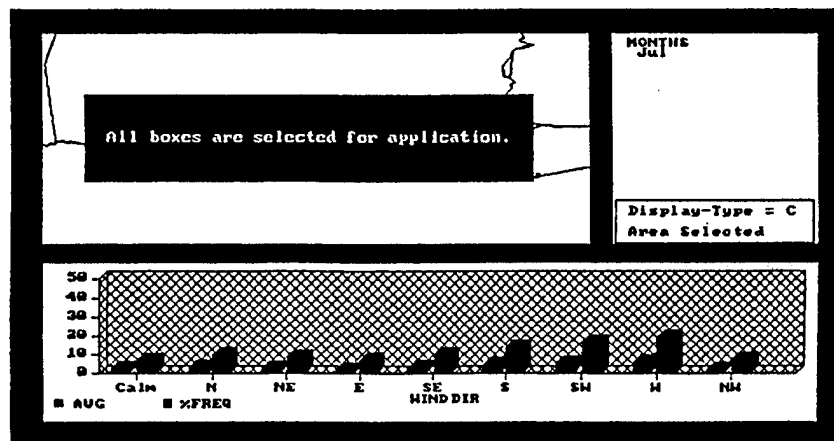


Figure 7. Average number of occurrences and percent occurrence frequencies of 700-mb wind direction sectors for the whole area of analysis for 1200Z (0600LST) during July.

4.3.4 Monthly Lightning Statistics. Another part of the wind stratified lightning climatology is a table display that shows the total number of lightning strikes and hourly average strikes for each month and 700-mb wind direction sector. As an example, the table display in Figure 8 is for the same area around Duke Field and the same hours as in Figure 5. The numbers for total strikes are the 5-year totals for the hours selected; the numbers for average are the average strikes per hour obtained by dividing the total strikes by five (for the years) and by six (for the hours). The hourly average strikes for July in the table can be used to obtain the exact values for the bars displayed in Figure 5. The table shows that the highest hourly average lightning strikes during the afternoon for May

are associated with either 700-mb winds less than 5 knots (Category C) or 700-mb winds from the west; those for June through August are associated with southwest or west 700-mb winds, and those for September are associated with 700-mb winds from the east. Also evident in the table is an overall trend toward higher average numbers of strikes per hour from May through July, followed by a decreasing trend from August to September. Similar trends were found by Cale (1963) in the frequency of observed thunderstorms per month, and are also reflected in the percent occurrence frequencies of thunderstorms from hourly observations produced for Duke Field in the *Surface Climatic Summaries for Duke Field/Eglin Aux #3, FL* (1991).

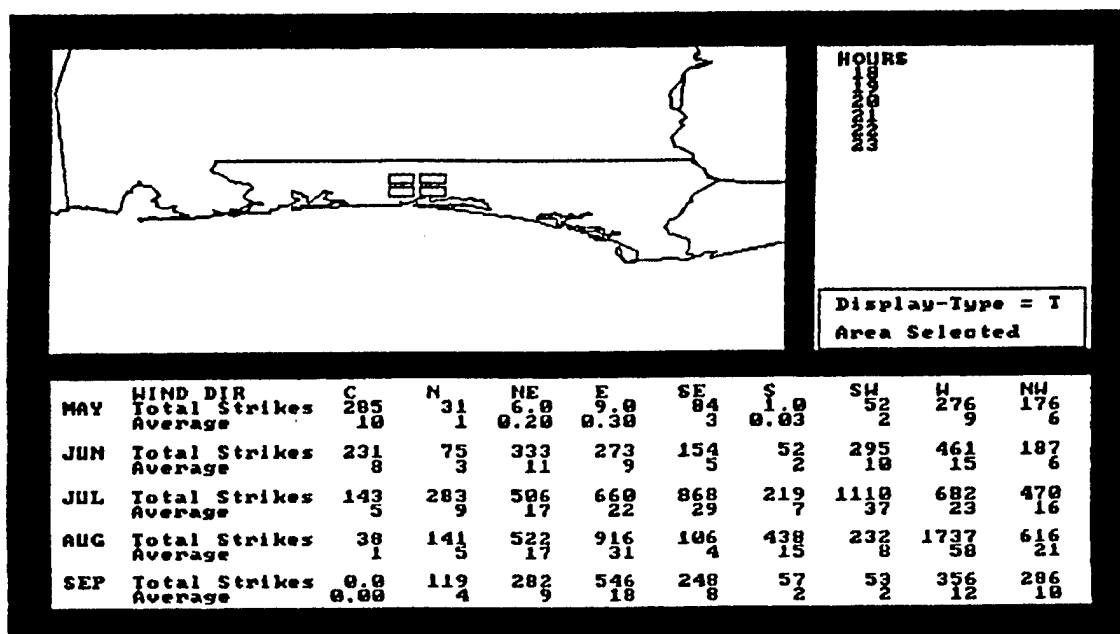


Figure 8. Total number of lightning strikes and average number of lightning strikes per hour for each month and 700-mb wind sector, for the period from 1800Z (1200LST) through 2300Z (1700LST) in July at Duke Field, Fla. Analysis is for same area as in Figure 5.

4.3.5 Lightning Strike Contours. The contours display option provides isopleth analyses of the hourly average lightning strikes over the entire area with a horizontal resolution of 10 nautical miles. The display occupies a full screen, but with some top-to-bottom compression that does not affect the accuracy. The grid points for the contouring routine are the upper left corners of each grid box, and the grid-point values

are the average number of lightning strikes per hour calculated for each grid box. The contour interval depends on the range of values in each case. Maximum and minimum strike values are given in a legend. Latitude and longitude (longitude with a negative sign) lines are labeled every half degree. In the next paragraph, examples of lightning strike patterns are related to known thunderstorm patterns for the Eglin AFB area.

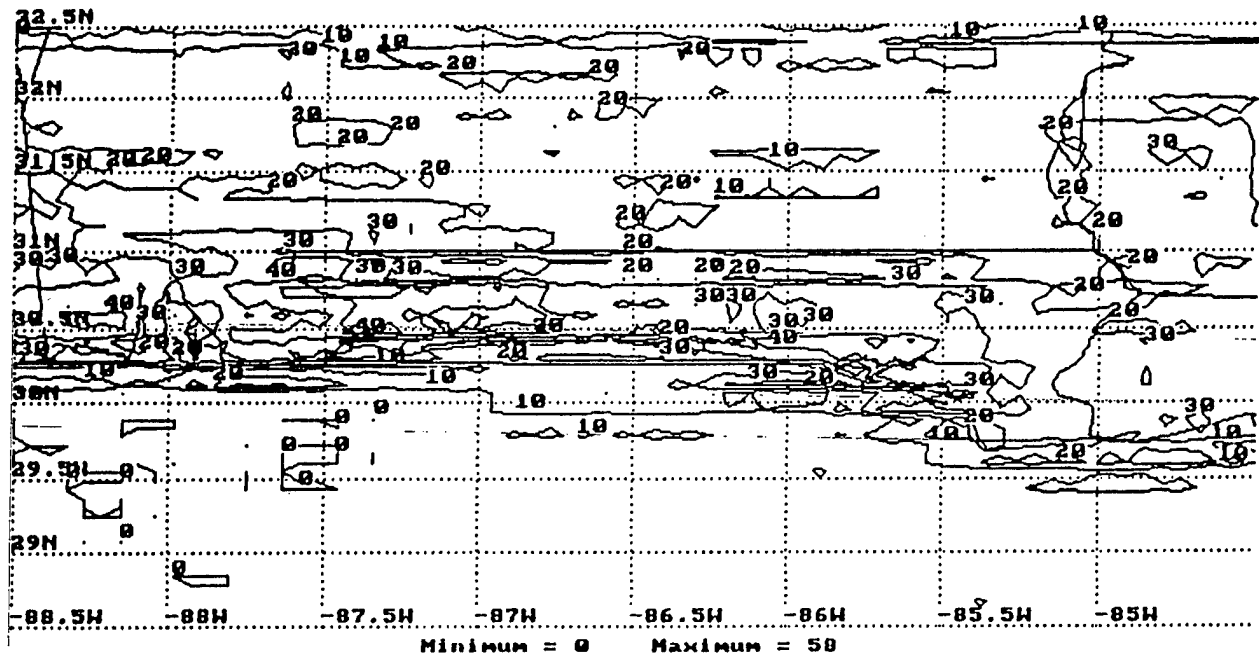


Figure 9. Isopleth analysis of the hourly average lightning strikes for all 700 mb wind sectors for the period from 1800Z (1200LST) through 0000Z (1800LST) in August. Area of analysis is as in Figure 1.

4.3.6 Lightning Strike Patterns. Local forecasting studies (1978) for Eglin AFB, dating back to 1943, mention that thunderstorms tend to develop over the land during the day, and over the Gulf of Mexico at night. The same pattern shows in lightning strike isopleth analyses. As examples, Figure 9 shows the lightning strike analysis for 1800Z (1200LST) through 0000Z (1800LST) during August for all 700-mb wind sectors, and Figure 10 shows the analysis for 0600Z (0000LST) through 1200Z (0600LST) during August for all 700-mb wind sectors. Some other lightning strike patterns are like thunderstorm patterns that occur with specific 700-mb wind directions. A local forecast study (1953) and another by Jones (1956) noted that early morning thunderstorms over the Gulf of Mexico near the coast often move into the Eglin AFB area with the sea breeze. Furthermore, the effect seemed more pronounced when 700-mb steering was from the southeast through southwest. Examples are shown in Figures 11 and 12 for June with 700-mb winds from the southeast through southwest. Figure 11 for 1500Z (0900LST) shows an area of lightning strikes over the

Gulf of Mexico to the west-southwest of Eglin AFB. Figure 12 shows that by 1600Z (1000LST) the area of strikes has weakened and moved just west of Eglin AFB. Another typical summertime thunderstorm pattern, identified in a local forecast study (1953), is their formation in west-to-east lines during the afternoon a few nautical miles north of Eglin AFB. An example is shown in Figure 13 for August at 2200Z (1600LST) for all 700-mb wind directions. The most concentrated area of strikes appears in a line about 20 nautical miles north of Eglin AFB, over Crestview, Fla. For the last example, studies by Jones (1956, 1957) revealed that thunderstorms that form north of Eglin AFB in the late morning often move over Eglin AFB if 700-mb winds are from directions west through north through east. The lightning strikes show the same behavior as seen in Figures 14 and 15. The analysis in Figure 14 is for July at 1600Z (1000LST) with 700-mb winds from west through north through east. A line of lightning strikes north of the base (along 31°N) moves south to just north of Duke Field (along 30.7°N) by 1700Z (1100LST) as shown in Figure 15.

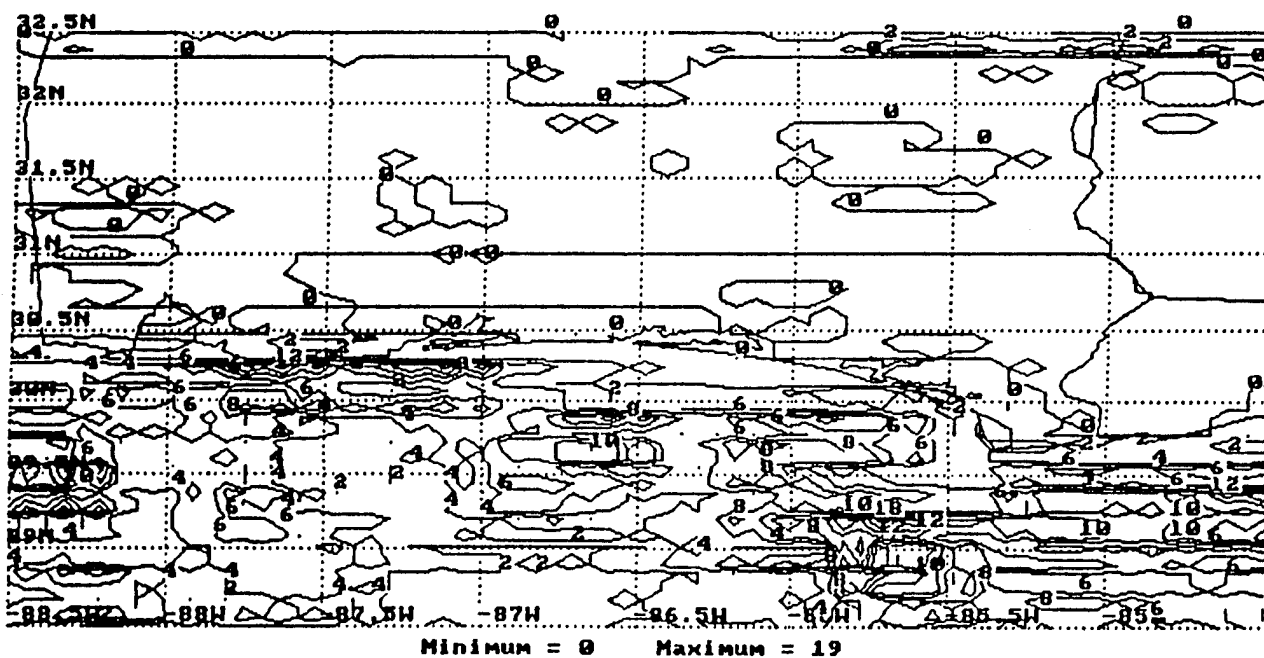


Figure 10. Isopleth analysis of the hourly average lightning strikes for all 700 mb wind sectors, except for the period from 0600Z (0000LST) through 1200Z (0600LST) in August.

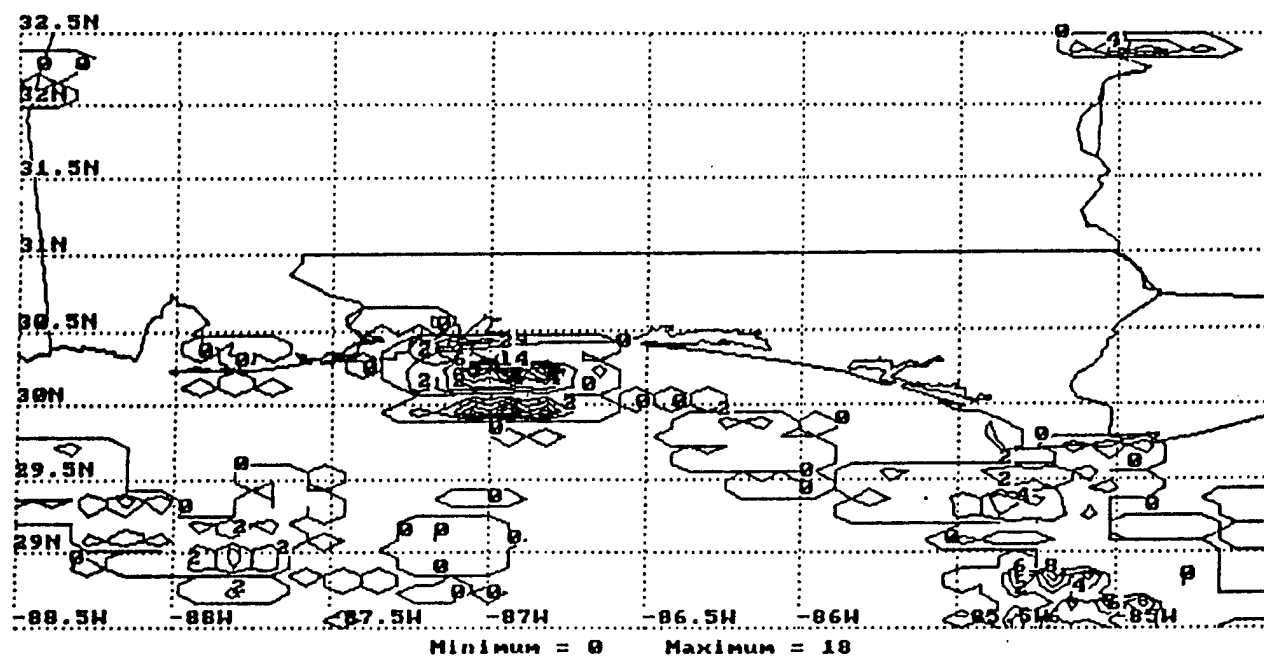


Figure 11. Isopleth analysis of the hourly average lightning strikes for all 700 mb wind sectors, except for 700-mb wind sectors from southeast through southwest for 1500Z (0900LST) in June.

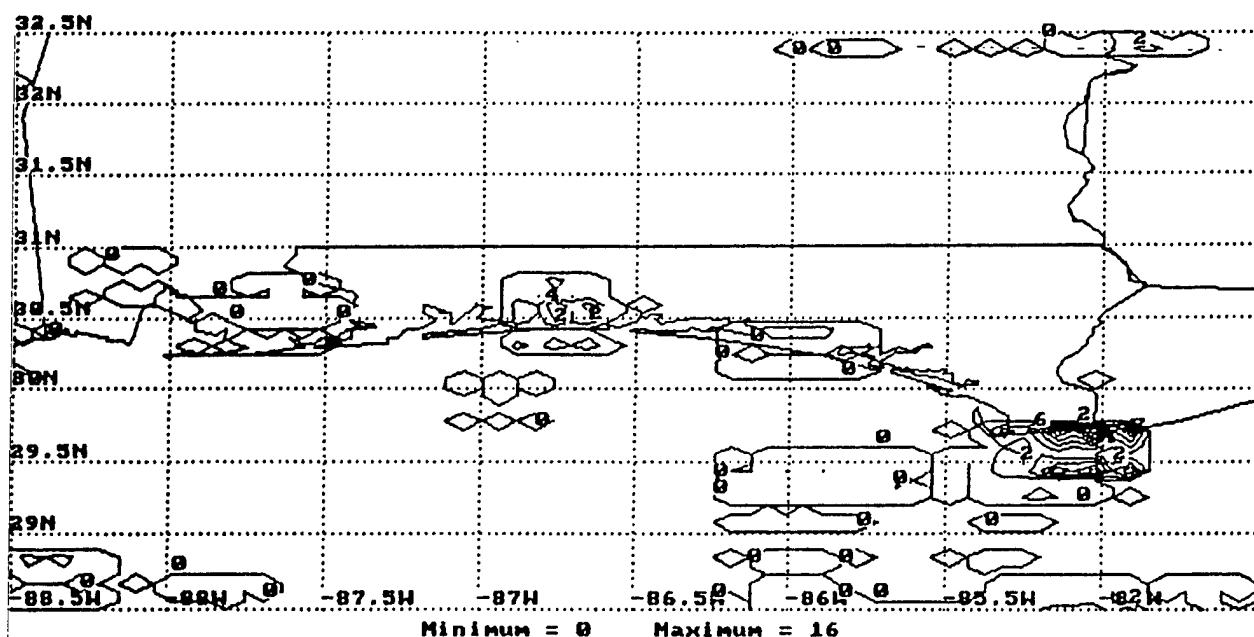


Figure 12. Isopleth analysis of the hourly average lightning strikes for all 700 mb wind sectors, except for 1600Z (1000LST) in June.

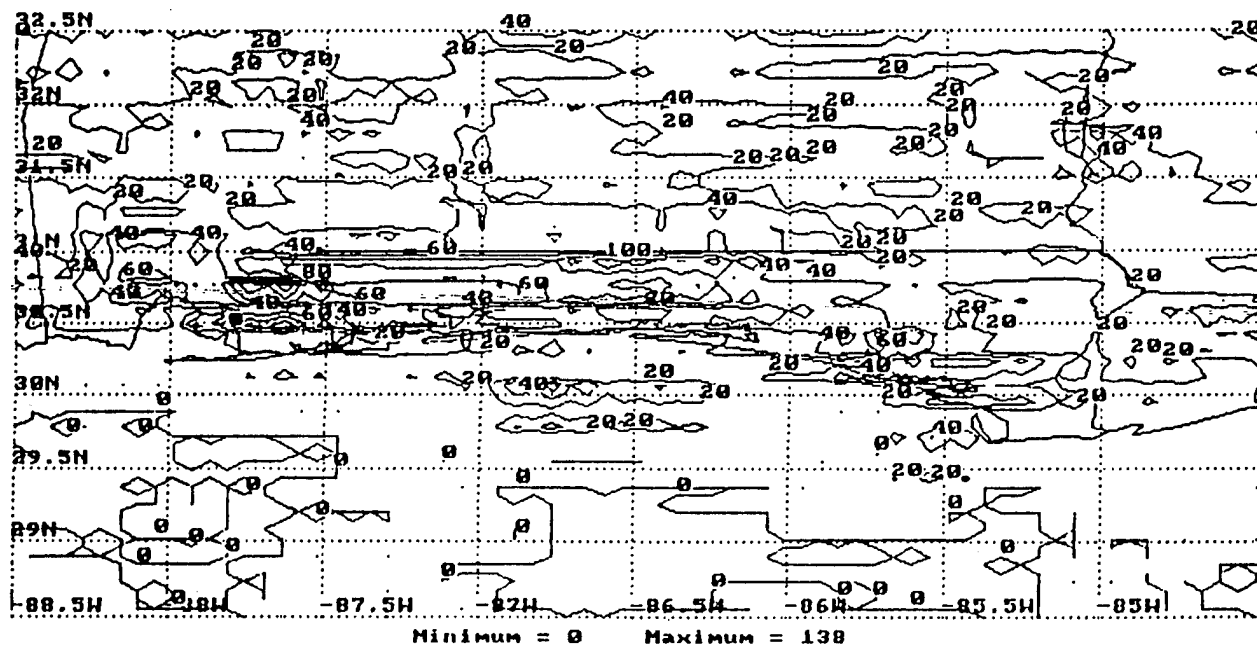


Figure 13. Isopleth analysis of the hourly average lightning strikes for all 700-mb wind sectors, except for 2200Z (1600LST) in August.

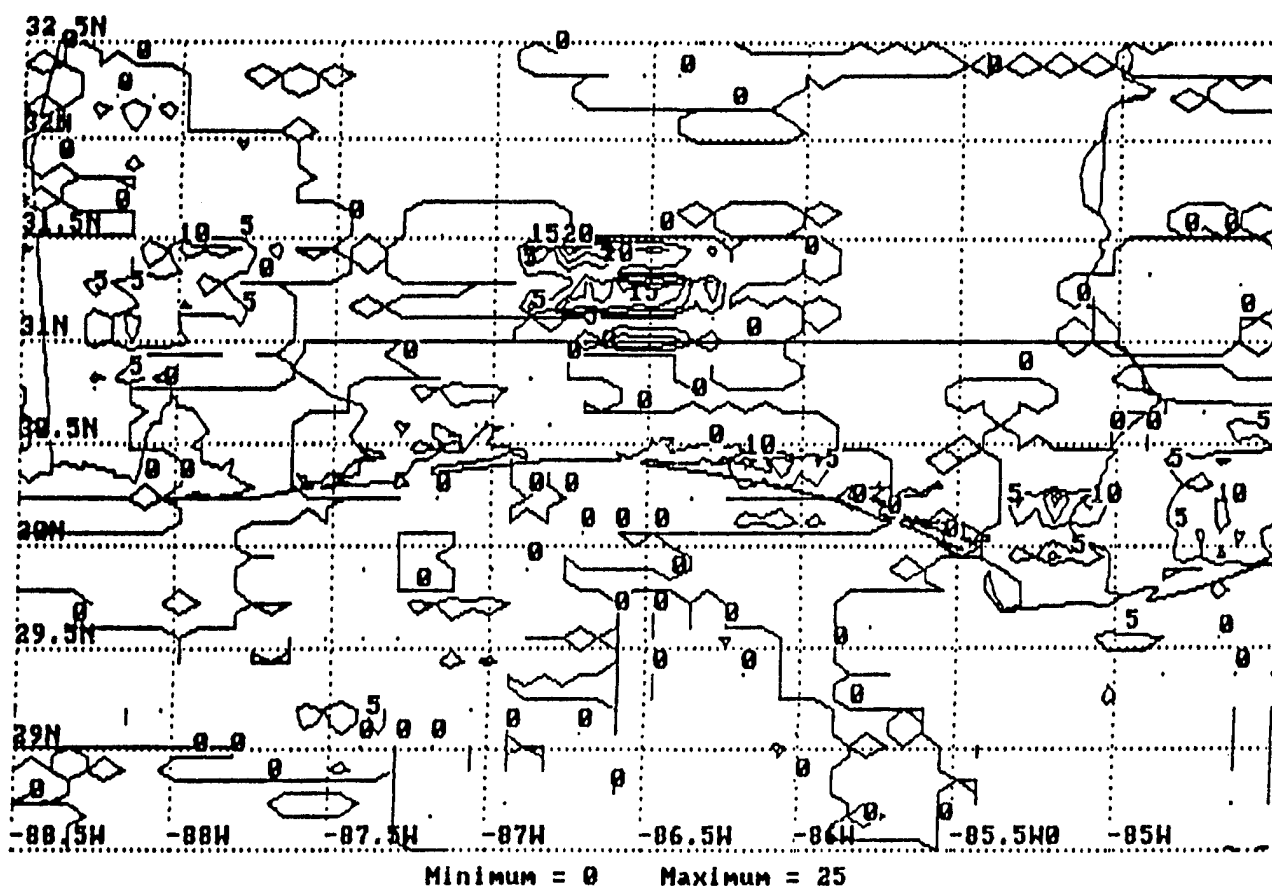


Figure 14. Isopleth analysis of the hourly average lightning strikes for all 700-mb wind sectors, except for 700-mb wind sectors from west through north through east for 1600Z (1000LST) in July.

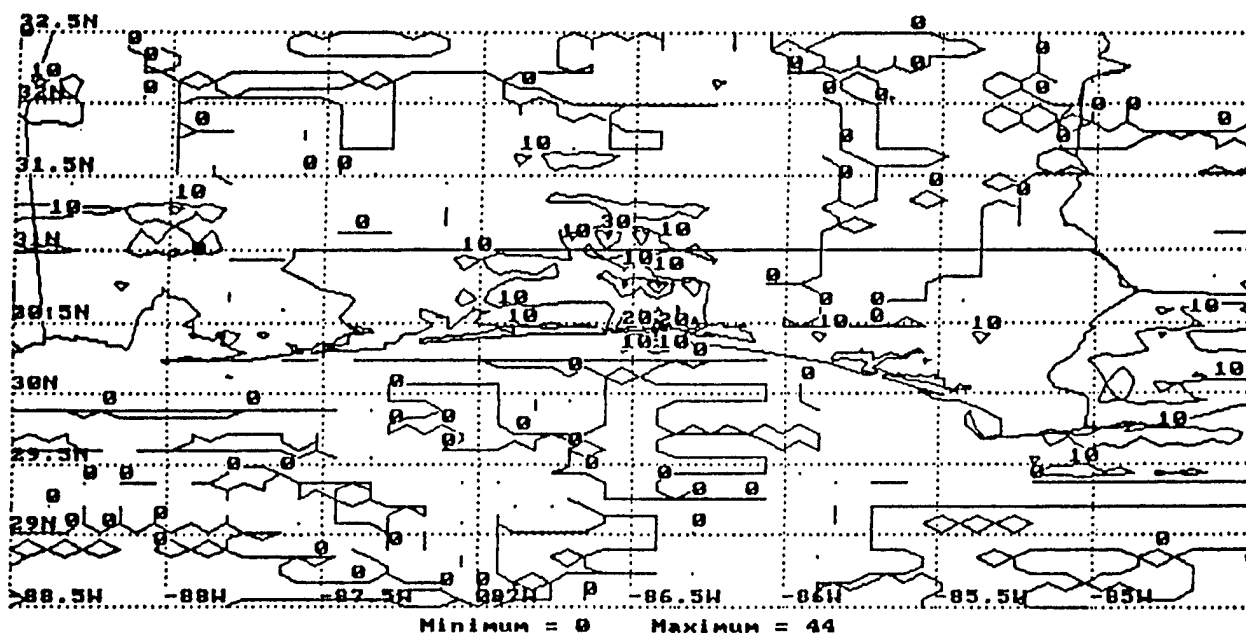


Figure 15. Isopleth analysis of the hourly average lightning strikes for all 700-mb wind sectors, except for 700-mb wind sectors from west through north through east for 1700Z (1100LST) in July.

4.4 K-index Stratified Lightning Climatology Examples. As before, the patterns and trends in lightning strikes were closely related to those of thunderstorms, but highly dependent on the K-index. In most cases, the K-index was closely related to changes in the hourly average lightning strikes. Some patterns in lightning strikes stratified by K-index agreed with known preferred patterns for thunderstorms.

4.4.1 Afternoon Lightning and K-index. The July

lightning strike climatology was used to illustrate the relationship between K-index category and changes in the hourly average lightning strikes during the afternoon. Using the same area centered on Duke Field and the same hours as in Figure 5, it is obvious from Figure 16 that the hourly average lightning strikes increase rapidly as the K-index category (and thus the thunderstorm potential) increases. Nearly 100 lightning strikes per hour on average around Duke Field during July afternoons are associated with a K-index greater than 30.

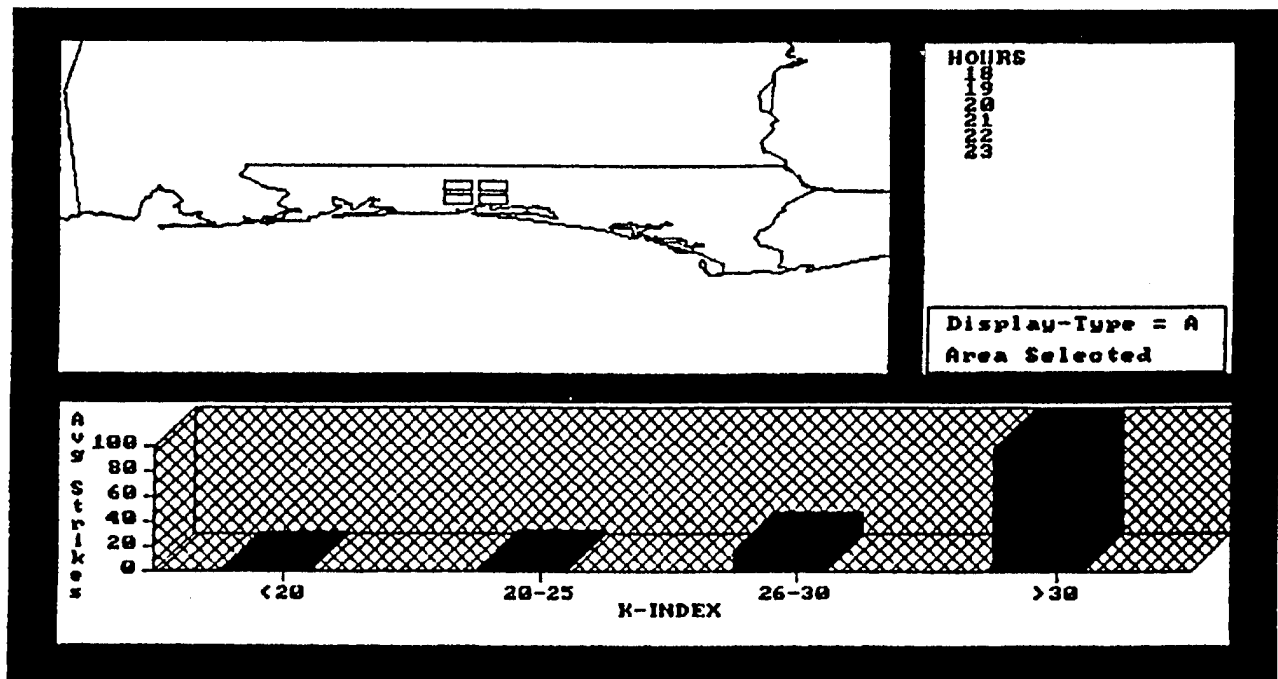


Figure 16. Hourly average lightning strikes for all 700-mb wind sectors, except for all K-index categories.

4.4.2 Lightning Times and K-index. In the following examples, July was used in display Type B to show the diurnal variation in the average number of lightning strikes by hour for the Duke Field area. In the case shown in Figure 17 (next page), relatively stable conditions were set with the K-index category less than 20. The graph shows that sporadic, small numbers of lightning strikes occur on average during daylight hours, mostly in the late afternoon, as might be expected with isolated air-mass thunderstorms. In the opposite case shown in Figure 18 (next page), with relatively unstable conditions set by a K-index category greater than 30, the diurnal variation is more

like the one in Figure 6, with the highest hourly average lightning strikes (about 150) occurring at 2000Z (1400LST).

4.4.3 Frequency Distribution of K-index Categories. July was used again, this time in display Type C shown in Figure 19 (see Page 19), to show the average number of occurrences and percent occurrence frequencies of K-index categories. The graph for 1200Z (0600LST) shows that atmospheric conditions during July are typically unstable with almost 20 occurrences per year of K-index over 30, and an occurrence frequency near 60 percent.

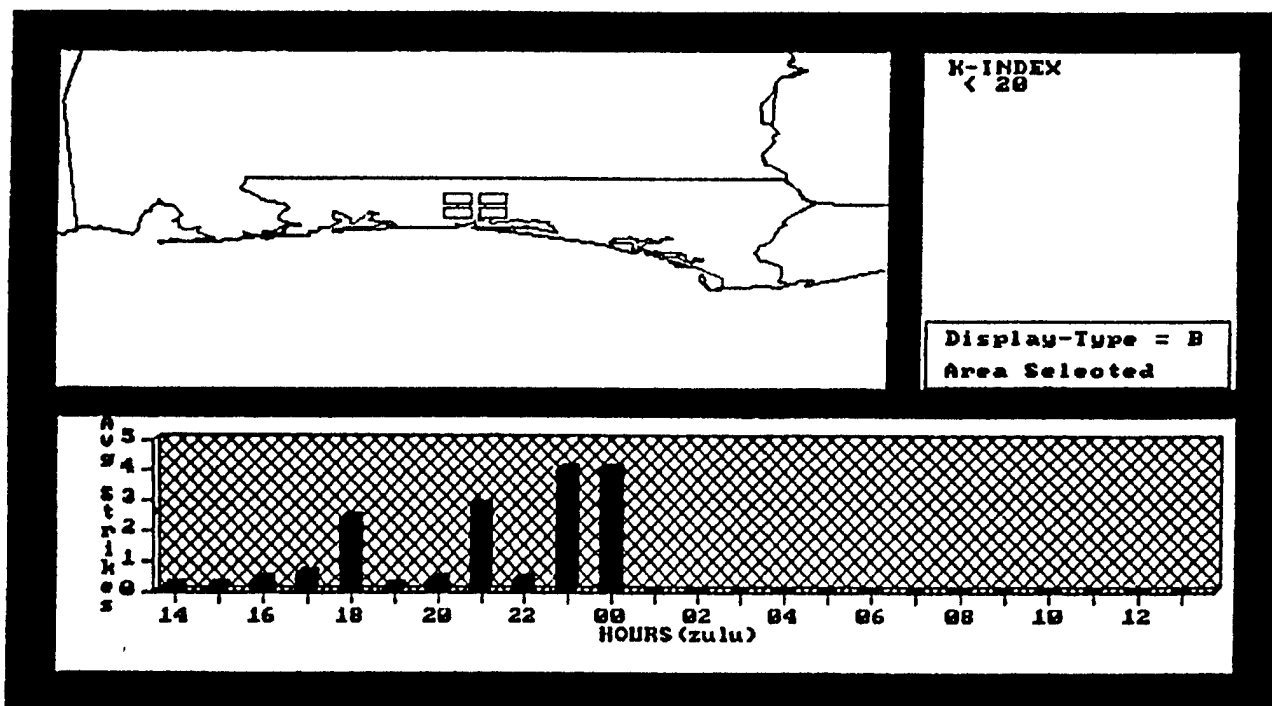


Figure 17. Diurnal variation of the hourly average lightning strikes for all 700-mb wind sectors, except for all K-index less than 20.

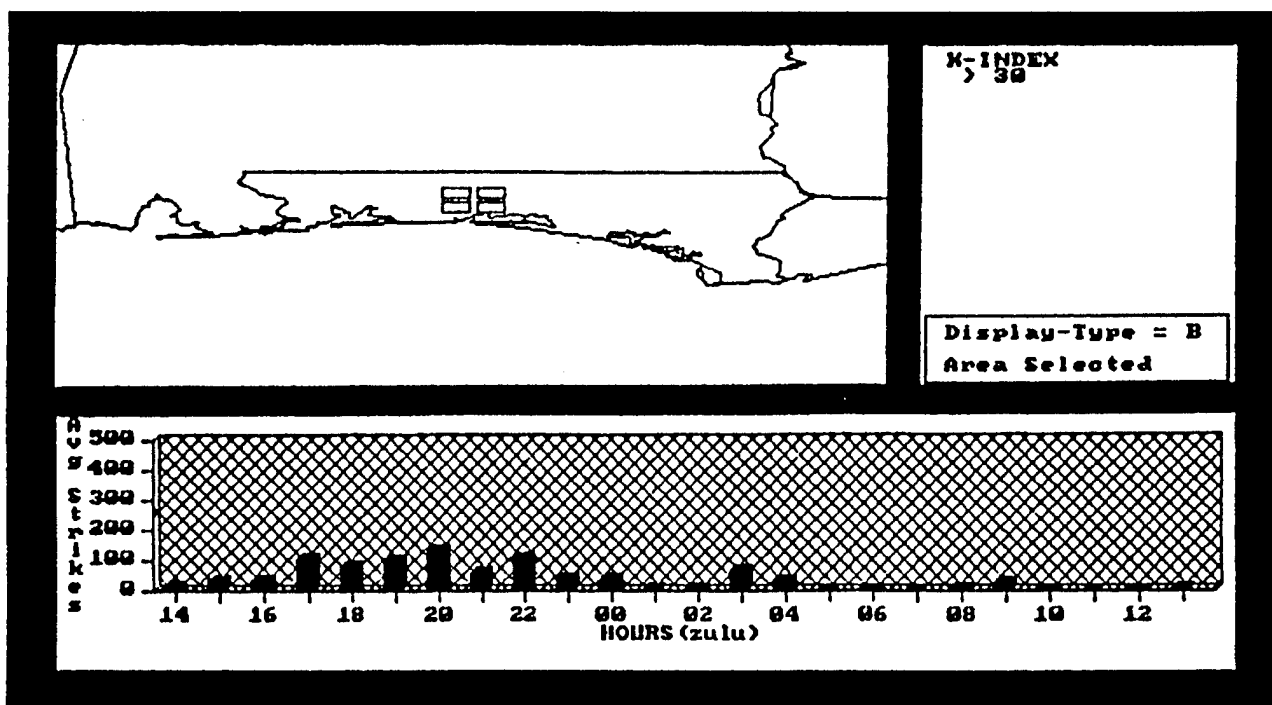


Figure 18. Diurnal variation of the hourly average lightning strikes for all 700-mb wind sectors, except for all K-index greater than 30.

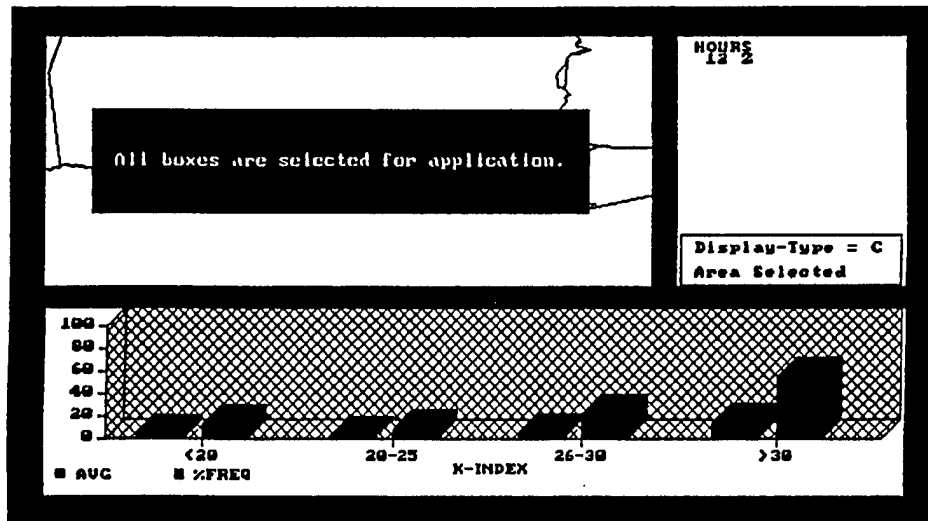


Figure 19. Average number of occurrences and percent occurrence frequencies of 700-mb wind direction sectors, except for all K-index categories.

4.4.4 Monthly Lightning Statistics with K-index. The table in Figure 20 is for afternoon hours in the area around Duke Field. As mentioned before, numbers in the open-ended K-index categories (less than 20 and greater than 30) tend to overshadow those in the middle two categories. In May, the lower two K-index

categories are associated with the greater hourly average lightning strikes. During June through August, the majority of hourly average lightning strikes shift into the higher two K-index categories, with the maximum in August.

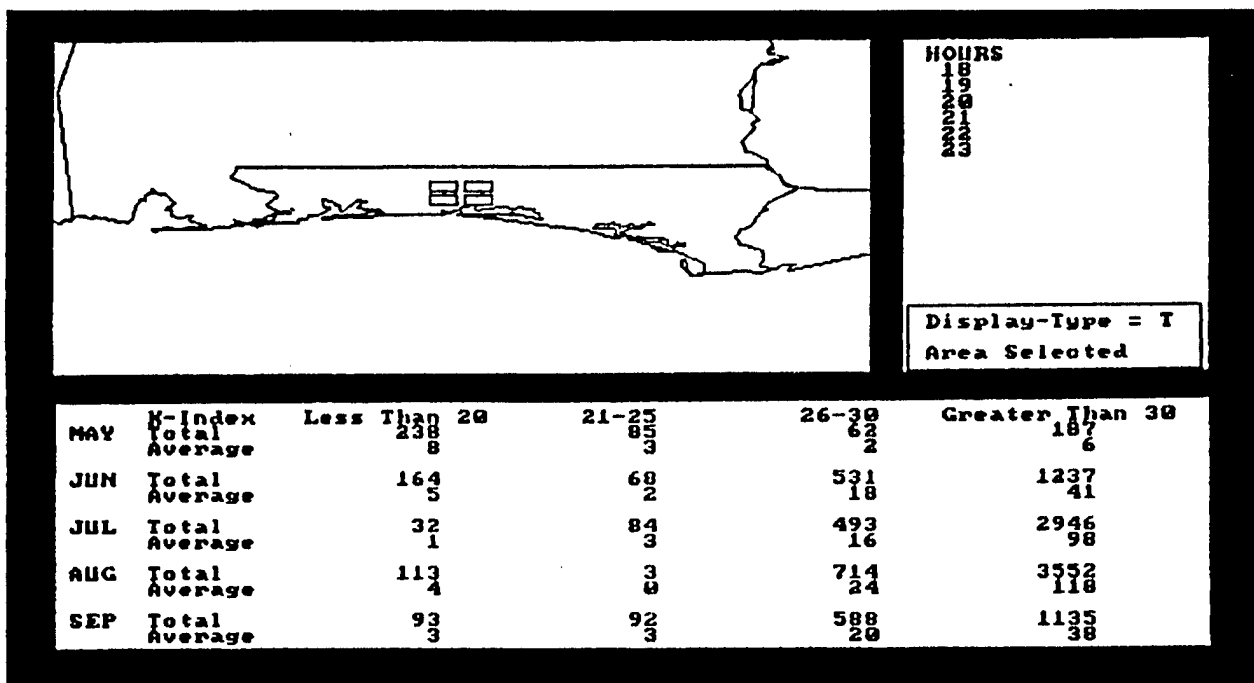


Figure 20. Total number of lightning strikes and hourly average lightning strikes for each month and 700-mb wind sector, except for each month and K-index category.

4.4.5 Lightning Strike Contours and K-index. To evaluate the contour patterns of lightning strikes stratified by K-index, in relation to known patterns of thunderstorm behavior, the same time periods used in paragraph 4.3.5 were examined. The patterns of lightning strikes over the land in the day and Gulf of Mexico at night (Figures 9 and 10) were seen again. Also, the example of early morning lightning strikes moving from the Gulf of Mexico toward Eglin AFB (Figures 11 and 12) was seen, but only with lightning strikes where the K-index was less than 20. Apparently, the lightning strikes in that situation are typically associated with weakened or dissipating

thunderstorms (Pfeiffer, 1944). As in Figure 13, the pattern of lightning strikes in west-to-east lines north of Eglin AFB was seen where the K-index was greater than 30 (see Figure 21). A comparison of Figures 13 and 21, shows that most of the lightning strikes in Figure 13 occurred when the K-index was greater than 30. By contrast, Figure 22 for the same time, but with the K-index less than 20, shows only isolated areas of lightning strikes to the west and north-northeast of Eglin AFB. Lastly, although evident in the wind stratified lightning strike analyses in Figures 14 and 15, the tendency for lines of lightning strikes to move over Eglin AFB from the north was not obvious in any of the analyses stratified by K-index.

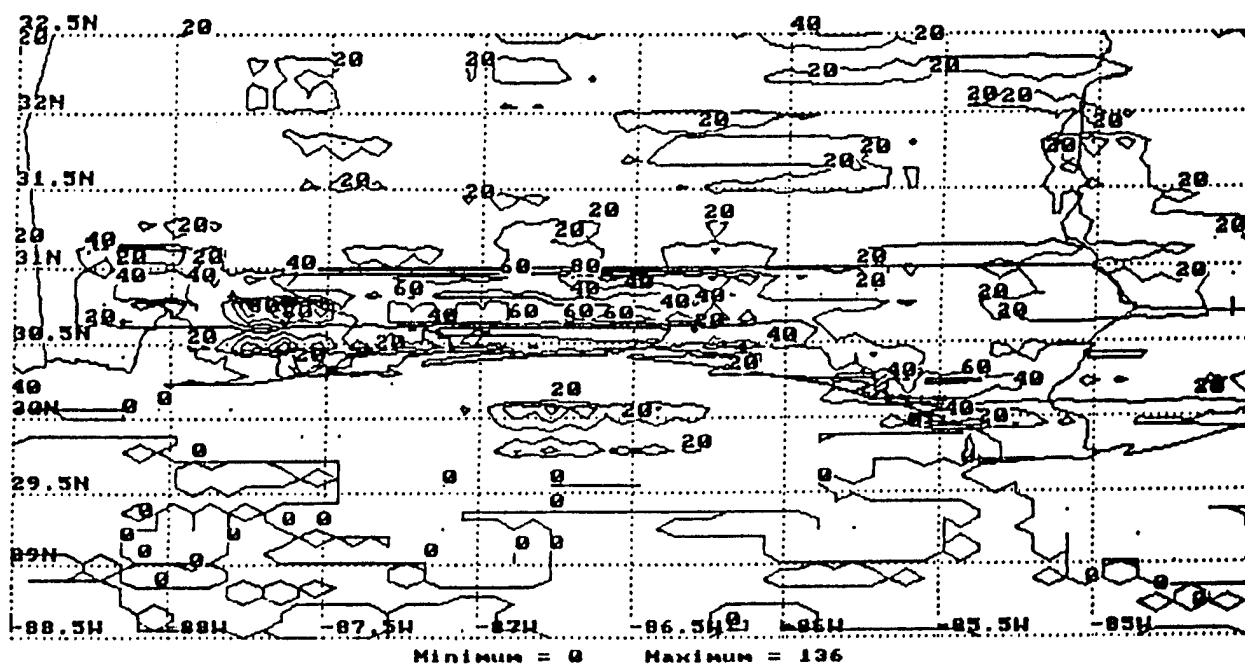


Figure 21. Isopleth analysis of the hourly average lightning strikes for all 700-mb wind sectors, except for K-index greater than 30.

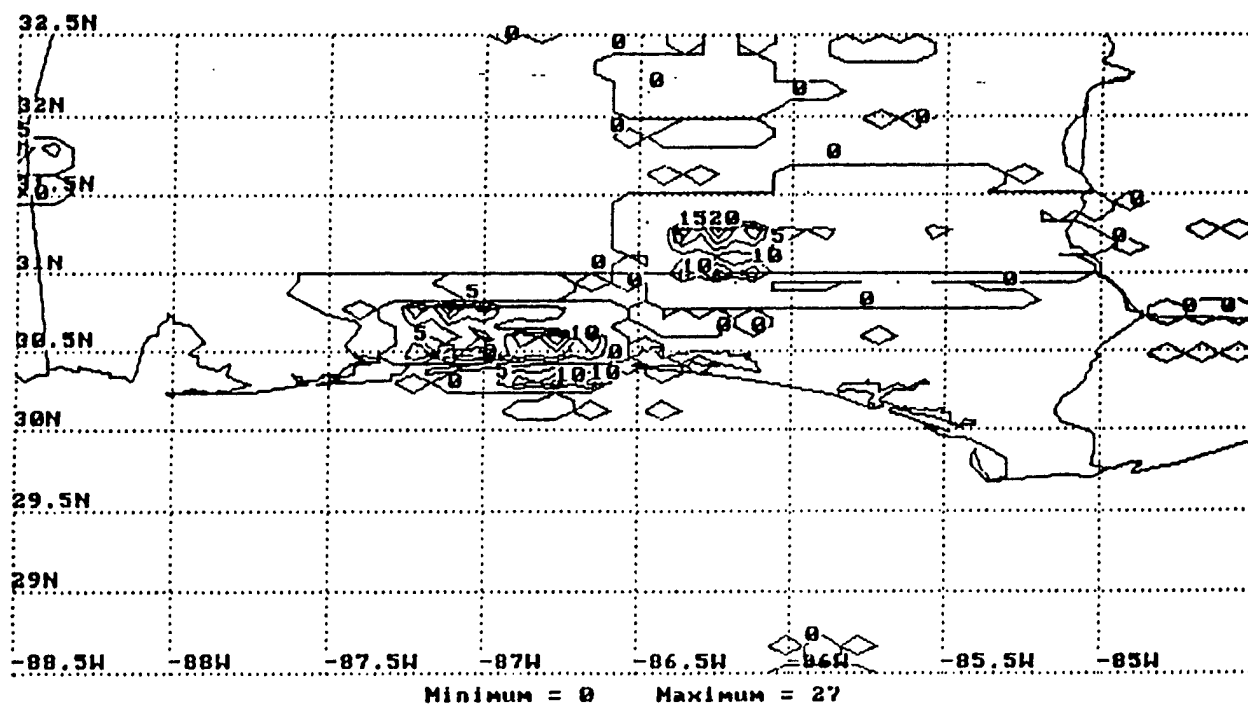


Figure 22. Isopleth analysis of the hourly average lightning strikes for all 700-mb wind sectors, except for K-index less than 20.

Chapter 5

SUMMARY

5.1 Discussion. The cloud-to-ground lightning strike climatology stratified by 700-mb wind direction sectors and K-index categories was developed to help weather forecasters predict summertime thunderstorms in the vicinity of Eglin AFB, Florida. Despite limitations in the lightning strike data and upper-air data used, it was shown by comparison to known spatial and temporal variations in summertime thunderstorms that the lightning strike climatology adequately depicts several of the variations. The wind stratified part of the climatology appeared to work best at showing preferred lightning strike locations and movement based on the 700-mb wind direction. The K-index stratified part seemed important in assessing changes

in the numbers of lightning strikes, and also in separating isolated lightning strike situations from widespread lightning activity. Undoubtedly, the lightning strike climatology holds much more information about lightning strike patterns than what was presented in this report.

5.2 Recommendation. AFCCC recommends use of the lightning climatology as another tool to predict summertime thunderstorms at Eglin AFB. When used in combination with analyses of the synoptic situation, the lightning climatology has potential to improve thunderstorm forecasts.

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GLOSSARY

AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center / Formerly known as the USAF Environmental Technical Application Center (USAFETAC)
BOXNUM	grid box number
C	calm
CG	cloud-to-ground (lightning)
DATSAV	AFCCC's database of weather observations stored on magnetic tape
DOS	Disk Operating System
E	east
EGA	Enhanced Graphics Adapters
GDS	GeoMet Data Services
HP	Hewlett Packard
I	grid point index
IBM	International Business Machines
J	grid point index
K-index	indicator of thunderstorm potential
LATMIN	latitude of lightning strike in minutes
LAT1	latitude in minutes at lower right corner of grid system
LLP	Lightning Location and Protection
LONMIN	longitude of lightning strike in minutes
LON1	longitude in minutes at lower right corner of grid system
LST	Local Standard Time
mb	millibar(s)
MIN	grid spacing in minutes of latitude or longitude
N	north
NE	northeast
NLDN	National Lightning Detection Network
NW	northwest
S	south
SE	southeast
SQRTBOX	square root of the total number of individual grid boxes in the grid system
SW	southwest
T₅₀₀	500-mb temperature in degrees Celsius
T₇₀₀	700-mb temperature in degrees Celsius
T₈₅₀	850-mb temperature in degrees Celsius
Td₇₀₀	700-mb dew-point temperature in degrees Celsius
Td₈₅₀	850-mb dew-point temperature in degrees Celsius
W	west
X	Cartesian coordinate
V	Cartesian coordinate
Z	Zulu (Greenwich Mean Time)