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Lightning Climatology for Maxwell AFB, Alabama

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13. Abstract: This technical note documents a lightning climatology developed by AFCCC for Maxwell AFB, Ala. This climatology was developed from a database of cloud-to-ground lightning strikes that occurred from March through October during 1986-91. Analysis of the lightning climatology showed that patterns of lightning strikes compared favorably with known preferred locations and times of thunderstorm development. It also showed that stratification of the lightning data by 700-mb wind directions and K-index values is useful in revealing locations of lightning-strike patterns and their movement.

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PREFACE

This technical note documents results of AFCCC (formerly USAFETAC) Project 930348. The project analysts were Capt Christopher A. Donahue and Mr William R. Schaub, Jr.

A climatology of cloud-to-ground lightning strikes was developed for the Maxwell AFB area from a database of lightning strikes recorded annually from March through October, 1986-91. Upper-air reporting stations in the area were used to stratify the lightning strike observations by nine 700-mb wind direction categories, as well as by five K-index categories (the K-index is a measure of atmospheric stability which has proven useful for thunderstorm forecasting). The area was divided into grid boxes (10 minutes of latitude by 10 minutes of longitude) to provide a horizontal resolution of about 10 nautical miles. Lightning strike observations for each grid box were summarized by month to obtain the average hourly lightning strikes for each 700-mb wind direction category, and each K-index category.

The summarized lightning data was used to produce a microcomputer graphics program that enables the user to display the lightning strike climatology with bar graphs, tables, and isopleth analyses. One bar graph shows the average hourly lightning strikes by 700-mb wind direction or K-index category for any combination of grid boxes, months, and hours. Another graph shows the diurnal variation in the average hourly lightning strikes for any combination of grid boxes, months, and wind or K-index categories. A third bar graph option, based on one upper-air station representative of the entire area, shows the annual average number of occurrences, and percent occurrence frequencies of 700-mb wind direction categories, or K-index categories. The table option shows average hourly strikes by wind or K-index category for each month, for any combination of grid boxes and hours. Analyses of the average hourly lightning strikes over the entire area are also available for any combination of months, hours, and wind or K-index categories.

Analysis and testing of the lightning climatology confirmed that the patterns of lightning strikes depicted agree with the preferred locations and times that thunderstorms are known to occur in the southeastern United States. AFCCC recommends the lightning climatology be used as an additional tool for mission planning and weather forecasting.

Special thanks to MSgt Robert G. Peña and Amn Tobin A. Smith, who produced the lightning graphics program.

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Chapter 1

INTRODUCTION

1.1 Background. The 502nd Operations Support Squadron Weather Flight (502 OSS/OSW) at Maxwell AFB, Ala., provides weather forecasts for military flights over a large area surrounding Maxwell. Thunderstorms pose a threat to aviation in that area, especially from July through September. To enhance support to these flights, the 502nd OSS/OSW requested a personal computer based cloud-to-ground (CG) lightning strike climatology, stratified by 700-mb wind direction and K-index categories, for the area shown in Figure 1. AFCCC used a 6-year (March through October, 1986-91) database of lightning strike observations and upper-air observations to develop the climatology. An interactive microcomputer graphics program was designed to display the climatology using graphs, tables, and isopleth analyses.

1.2 Related Studies. The Terminal Forecast Reference Notebook (TFRN) for Maxwell AFB (Feldman, 1985) describes several factors related to thunderstorm activity at Maxwell. A primary contributing factor is the Gulf of Mexico, located 140 miles south of Maxwell. This close proximity to water leads to the development of thunderstorms during the warm season as the unstable maritime tropical air is heated. The TFRN reports that thunderstorm activity at Maxwell occurs most frequently during June, July, and August, with a peak in July. Orographic features also have been shown to play an important role in the development of thunderstorms in the vicinity of Maxwell. The station elevation for Maxwell is 168 feet MSL, but 70-80 miles to the northeast and northwest the elevation rises to nearly 2000 feet along the Appalachian Plateau. Airmass thunderstorms commonly develop along these higher elevations from the early spring through the early fall.

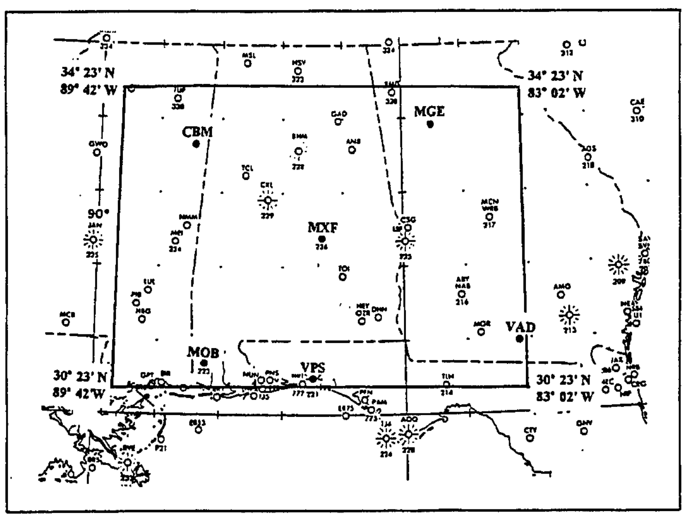

Figure 1. The area of interest (analysis area is in bold lines). Stations labeled in bold type are: Columbus AFB, Miss. (**CBM**), Dobbins AFB, Ga. (**MGE**) , Maxwell AFB, Ala. (**MXF**), Mobile, Ala., (**MOB**), Eglin AFB, Fla. (**VPS**), and Moody AFB, Ga. (**VAD**).

1.3 Analysis Procedure. CG lightning strike and atmospheric sounding data for 1986-91 was used to develop a lightning strike climatology stratified by 700-mb wind direction and K-index categories. The area of analysis in Figure 1 was divided into a grid system of square grid boxes, each box 10 minutes of latitude by 10 minutes of longitude, to provide an effective horizontal 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 data. In Chapter 4, the options available in the microcomputer graphics program are discussed, and illustrative examples of the display options are presented.

1.4 Findings. The lightning climatology appears consistent with expected diurnal and monthly variations in thunderstorm activity. The diurnal variations of lightning strikes near Maxwell AFB agreed closely with known diurnal variations in thunderstorm frequencies. Likewise, monthly variations in average hourly lightning strikes coincided with changes in monthly thunderstorm frequency; June through September had the highest average hourly lightning strikes, with the maximum in July. Monthly patterns in isopleth analyses of the average hourly lightning strike fields closely resembled the patterns in mean thunderstorms shown by Changery (1981). Additionally, the lightning climatology verified known preferred spatial orientations of thunderstorms at certain times based on the 700-mb wind direction.

Chapter 2

DATA AND LIMITATIONS

2.1 Lightning Data. The lightning data used was proprietary CG lightning strike observations purchased from GeoMet Data Services (GDS), Inc., of Tucson, Ariz. The individual lightning strike records were stored in AFCCC's relational database (DB2) for easy access. During March through October of 1986-91, more than 4.5 million strikes occurred in the area of analysis. The strikes were recorded by direction finders manufactured by Lightning Location and Protection (LLP), Inc., of Tucson, Ariz. 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.

2.2 Lightning Data Limitations. Detection efficiency, strike location accuracy, and period of record are the most important factors to consider when evaluating the quality of a CG lightning strike data set. These aspects of the data set used for this study are discussed below.

2.2.1 Detection Efficiency. The detection efficiency is the ratio of the number of CG strikes detected to the number that actually occurred. It is primarily a function of the distance of a strike from the direction finders. MacGorman, et al. (1984), reported detection efficiencies of 70 to 85 percent for strikes within 54 nautical miles of direction finder networks in Oklahoma and Florida. Over the NLDN, a detection efficiency of 70 percent is 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.

2.2.2 Location Accuracy. 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., 1983). According to GDS, the lightning strike locations are generally accurate to within 1/2 to 2 nautical miles.

2.2.3 Period of Record. As previously stated, a 6-year period of record was used for the CG lightning strike data in this analysis. In a recent study that compared CG lightning strikes to thunder events, Changnon (1993) showed that, due to the high interannual variability in lightning strikes, a short period of record may not be representative of long-term conditions. For that reason, the average hourly lightning strike values presented in this work are considered marginally representative as compared to values that could be obtained from a longer period of record. Orville (1991) suggested that at least 10 years of lightning strike data may be necessary to produce a truly representative climatology.

2.3 Upper-Air Data. Atmospheric soundings from USAFETAC's DATSAV Upper-Air database, described in the *USAFETAC DATSAV Data Base Handbook* (1977), were used to obtain the 700-mb wind data, as well as, the temperature and dewpoint data used to calculate K-index values. Three upper-air sites within the analysis area were selected: Centreville, Ala., Jackson, Miss., and Eglin AFB, Fla.

2.4 Upper-Air Data Limitations. Upper-air observations were available only twice daily at 0000Z and 1200Z. No attempt was made to interpolate upper-air variables from other hours of the day to those times. The upper-air data for 0000Z was treated as valid for lightning strikes that occurred from 1800Z to 0559Z. Similarly, upper-air data for 1200Z was assumed valid for strikes that occurred from 0600Z to 1759Z. Obviously, those assumptions ignore upper-air changes between soundings, but the changes are usually considered small. The data used in this work was decoded and validated for data elements, but no further quality control was done.

Chapter 3

METHODOLOGY

3.1 Lightning Data Preparation. A total of 4,435,579 CG lightning strike observations that occurred during 1986-91 in March through October were extracted from the relational database for the area of analysis in Figure 1. Each observation contained the year, month, day, hour, minute, latitude, and longitude of the strike. The data set was sorted by year, month, day, and hour for merging with the upper-air data. After sorting, any particular hour included lightning strikes that occurred on that hour and during the 59 minutes after that hour. For example, lightning strikes for 1800Z included all that occurred from 1800Z to 1859Z.

3.2 Upper-air Data Preparation. Data was taken from three upper-air reporting stations: Centreville, Ala., Jackson Miss., and Eglin AFB, Fla., in order to minimize the number of times 700-mb wind was missing. If data was available for Centreville, it was used first. If Centreville data wasn't not available, data for Jackson were used. If Centreville and Jackson were both missing, data for Eglin was used. The 700-mb wind direction and speed; 850-mb, 700-mb, and 500-mb temperatures; and 850-mb and 700-mb dewpoint temperatures were extracted. The data set contained almost 100 percent of the total possible upper-air wind observations for the period (2,905 of 2,940): 2,664 were taken from Centreville, 231 from Jackson, and 10 from Eglin. The upper-air data sets were sorted by year, month, day, and hour for merger with the lightning data set.

3.3 Wind Stratified Lightning Data Set. To stratify the lightning climatology by 700-mb wind direction categories, the lightning and upper-air data sets were merged based on the following conditions:

- Lightning observations that occurred between 0600Z and 1759Z were matched with the 1200Z upper-air observations.

- Lightning observations that occurred between 1800Z the previous day and 0559Z were matched with the 0000Z upper-air observations.

After merging the data sets, nearly every lightning observation within the area of analysis contained a 700-mb wind direction and speed. Those lightning observations that contained missing wind direction and speed were deleted, since a wind direction category could not be assigned. The effect on the original number of lightning strike observations was minimal, because only about one percent of the observations were deleted.

3.3.1 Wind Direction Categories. The 700-mb wind direction and speed corresponding with each lightning strike observation was 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. One of the other eight categories - N (north), NE (northeast), E (east), SE (southeast), S (south), SW (southwest), W (west), or 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 between 340° and 360° or between 000° and 020°

NE direction equal to or greater than 020° but less than 070°

E direction equal to or greater than 070° but less than 115°

SE direction equal to or greater than 115° but less than 160°

S direction equal to or greater than 160° but less than 205°

SW direction equal to or greater than 205° but less than 250°

W direction equal to or greater than 250° but less than 295°

NW direction equal to or greater than 295° but less than 340°

3.3.2 Wind Frequency Distribution Data Set. The upper-air data for Centreville were used separately to produce frequency distributions by month and hour for the nine 700-mb wind direction categories. Every 0000Z and 1200Z upper-air observation with reported 700-mb wind direction and speed was used to determine the category. Next, the 6-year total and annual average number of occurrences were calculated for each category by month and hour. The percent occurrence frequency (POF) for each category by month and hour was calculated as follows:

POF = 6-year total each category/6-year total all categories (1)

The data set containing the annual average number of occurrences and POF for each wind category by month for either 0000Z or 1200Z was used to display frequency distribution charts in the lightning graphics described in Chapter 4.

3.4 The K-index. As discussed in *The Use of the Skew-T, Log P Diagram in Analysis and Forecasting* (1979), 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. Table 1 shows K-index categories and related thunderstorm probabilities developed for use in the summer in the central United States.

TABLE 1. Thunderstorm probabilities for given K-index categories. (Adapted from *The Use of the Skew-T, Log P Diagram in Analysis and Forecasting* (1979)).

K-index	Probability of Thunderstorms
Less than 15	near zero
15-20	20%
21-25	20-40%
26-30	40-60%
31-35	60-80%
36-40	80-90%
> 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:

$$\mathbf{K = \{(T_{850} - T_{500}) + Td_{850} - (T_{700} - Td_{700})\}} \quad (2)$$

where:

T_{850} = 850 mb temperature (°C)

T_{500} = 500 mb temperature (°C)

Td_{850} = 850 mb dewpoint temperature (°C)

T_{700} = 700 mb temperature (°C)

Td_{700} = 700 mb dewpoint temperature (°C)

The first term in equation 2 parameterizes the vertical temperature lapse rate, 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 was used, but this time the necessary data for K-index calculations was extracted: 850-mb and 700-mb temperatures and dewpoint temperatures, and the 500-mb temperature. All necessary data was available in 97 percent (2849 of 2940) of the upper-air observations (2642 from Centreville, 202 from Jackson, and 5 from Eglin). Again, the upper-air observations were sorted by year, month, day, and hour, and matched with lightning strike observations according to condition given in 3.3 above. As a result, every lightning strike observation contained temperature data needed for calculating the K-index.

3.5.1 K-index Categories. Using the K-index corresponding to each lightning strike observation, the data was assigned to one of the five 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 from 31 to 35

CAT5: K-index greater than 35

It should be pointed out that the open-ended categories 1 and 5 can inject a bias in the lightning climatology, since these categories allow a wider range of values.

*3.5.2 **Frequency Distribution Data Sets.*** The upper-air data were used separately to produce frequency distributions by month and hour for the five K-index categories in a manner similar to that used for the upper-air wind data (see section 3.3.2).

3.6 The Grid System. To prepare the wind stratified lightning data set for summarization at a horizontal resolution of approximately 10 nautical miles, the area of analysis was divided into a grid system with the grid point spacing set at 10 minutes of latitude and 10 minutes of longitude. As a result, the grid system contained an array of 960 grid boxes (40 in the east-west direction by 24 in the north-south direction). To simplify analysis, the grid boxes were assumed square. Actually, the distances between degrees of latitude on the earth vary slightly from pole to equator, while the distances between degrees of longitude increase from pole to equator. Therefore, the true area enclosed by the grid boxes is not square, and increases from north to south. Due to the variable resolution, a bias exists for higher counts of lightning strikes in grid boxes at lower latitudes. However, for purposes of this analysis the bias is considered minor.

3.7 Gridding the Data. To calculate the total number of strikes within individual grid boxes, a grid box number was assigned to each lightning observation by first converting the latitude and longitude of the strike from degrees to minutes. The following equations were used to calculate the grid-point Cartesian coordinates (x,y) for each lightning observation (Hoke, et al. (1985)):

$$x = \{(LON1 - LONMIN)/MIN\} + 1 \qquad (3)$$

$$y = \{(LAT1 - LATMIN)/MIN\} + 1 \qquad (4)$$

where:

LATMIN = latitude of lightning strike in minutes

LONMIN = longitude of lightning strike in minutes

LAT1 = latitude in minutes at upper-left corner of grid system

LON1 = longitude in minutes at upper-left corner of grid system

MIN = grid spacing in minutes of latitude or longitude

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

$$I = INT(x) \qquad (5)$$

$$J = INT(y) \qquad (6)$$

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 as follows:

$$BOXNUM = I + \{SIDEBOX(J-1)\} \qquad (7)$$

where SIDEBOX is the number of grid boxes in the east-west direction (40 in this case). As an example, referring to Figure 1, the upper-left corner of the area of analysis is located at 34° 23'N/89° 42'W. From equations 3 through 6, the values of I and J for that point are both one. From equation 7, the grid box number for a lightning strike at that point is one. The index I varies from 1 on the left side of the grid system to 40 on the right side. The index J varies from 1 at the top to 24 at the bottom. The grid box numbers increase from 1 in the upper-left corner to 40 in the upper-right corner, and so on to box number 960 in the lower-right corner. Once the above gridding procedure was complete, every lightning strike observation had a grid box number for identification.

3.8 Lightning Data Summarization. The data sets were summarized to obtain the average number of strikes for each grid box by month, hour, and wind direction or K-index category. As a result, each grid box in the area of analysis contains a stratified lightning strike climatology for use in the graphics program discussed in the next chapter.

Chapter 4

LIGHTNING CLIMATOLOGY AND RESULTS

4.1 The Lightning Graphics Program. A microcomputer graphics program was developed by AFCCC's Small Computer Branch to display the Maxwell AFB lightning climatology. The minimum requirements to run the program are: IBM or IBM-compatible 286-based personal computers; 640 KB main memory; MS-DOS Version 3.2 or later; EGA or better graphics; Epson-compatible dot matrix printer for hard copies; and about 15 MB hard-drive space. The program is not validated to operate under Microsoft Windows and it will not run from floppy drives. A math coprocessor decreases run time but is not required.

4.1.1 Program Particulars. Before describing the graphics displays, a few particulars about the program follow:

• For consistency, average hourly CG lightning strike values are displayed throughout the program. If several months and/or hours are selected for a display, the average hourly values collected by the program for the display are divided by the number of months and hours, so that the displayed values are always hourly averages.

• The program uses the average hourly lightning strike value for a grid box at a grid point defined by the upper-left corner of the grid box.

• If several grid boxes are selected for a graph or table, the value displayed is the sum of the average hourly values for the grid boxes. Thus, area averages are displayed. In contrast to graph and table displays, isopleth analyses display contours of the average hourly lightning strikes based on each grid point (grid box) value.

• All hours are shown in UTC.

4.1.2 Graphics Displays. The lightning graphics program uses the wind/K-index stratified lightning strike climatology to present several displays, as described below.

• Bar graphs of the daily (diurnal) variations of the average hourly lightning strikes by hour (0000Z through 2300Z). One, several, or all grid boxes; months; and wind direction or K-index categories may be selected.

• Bar graphs of the variations of average hourly lightning strikes by 700-mb wind direction or K-index categories. One, several, or all grid boxes; months (Mar-Oct); and hours (0000Z-2300Z) may be selected.

• Bar graphs of the annual average number and percent occurrence frequencies of 700-mb wind direction or K-index categories for the entire area. One, several, or all months may be selected.

• Tables of the average hourly lightning strikes for each (or all) wind direction or K-index category; and for each month and all months. One, several, or all grid boxes and hours may be selected.

• Isopleth analyses of the average hourly lightning strikes over the entire area. One, several, or all months, hours, and wind/K-index categories may be selected.

4.2 Examples of Diurnal Lightning Strike Variations. To illustrate the diurnal variations in lightning strikes around Maxwell AFB, the month of July was chosen since it has the highest thunderstorm frequency as shown in the Terminal Forecast Reference Notebook (TFRN) for Maxwell AFB. An area centered on Maxwell AFB, consisting of six grid boxes on each side (about 3,600 square nautical miles) was used to obtain the graph shown in Figure 2. Figure 2 shows that most lightning strikes occur between 1700Z and 0100Z (1200L - 2000L), with the highest average value (about 1200 strikes per hour within the 3600 sq. mi. box) at 2100Z. As another example of diurnal variations in lightning strikes, the same area around Maxwell AFB is shown in Figure 3 for June. Figure 3 shows two diurnal maxima in the average hourly strikes: one maximum of about 650 strikes at 2100-2200Z, and a secondary maximum of about 200 strikes at 1000Z.

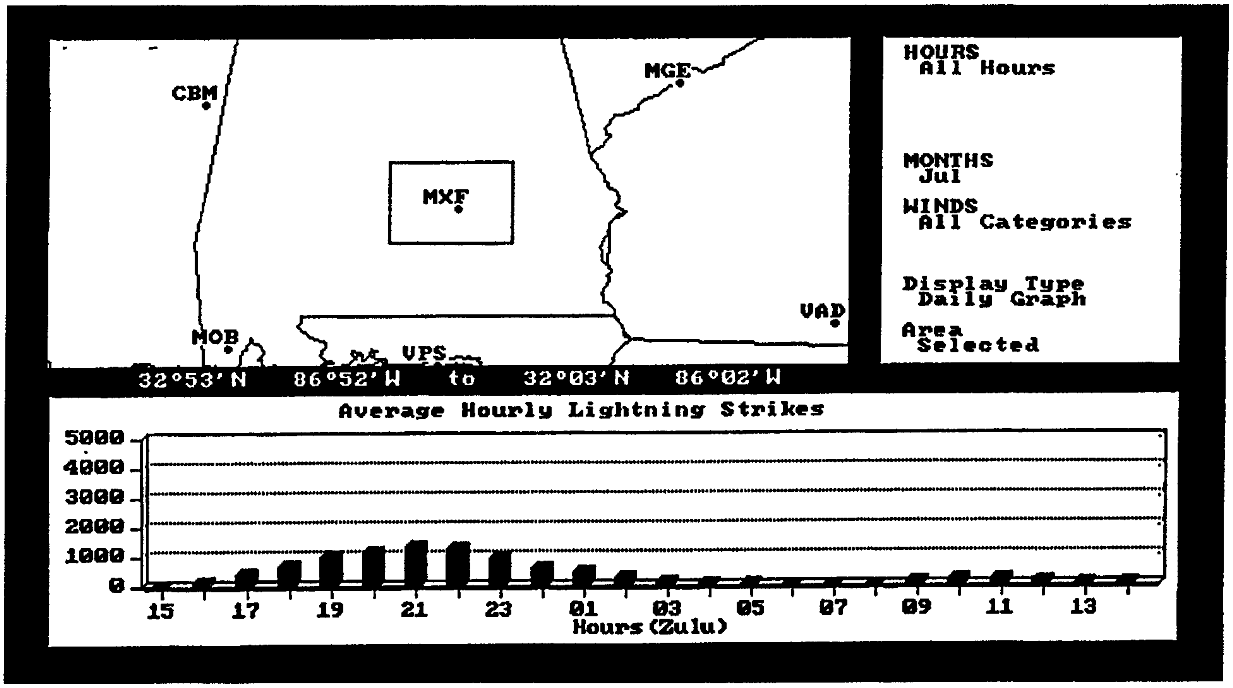

Figure 2. Diurnal variations of average hourly lightning strikes in the vicinity of Maxwell AFB, during July (the analysis area is depicted by the box surrounding Maxwell in the upper-left portion of the figure).

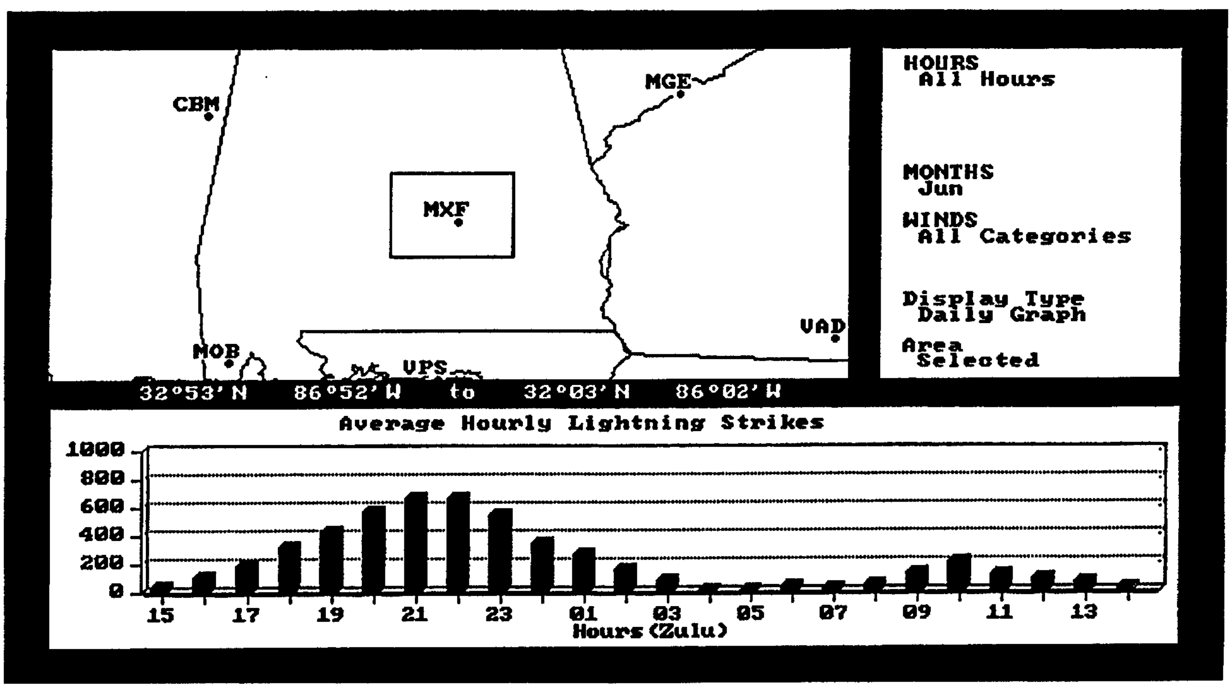

Figure 3. Diurnal variations of average hourly lightning strikes in the vicinity of Maxwell AFB, during June (the analysis area is depicted by the box surrounding Maxwell in the upper-left portion of the figure).

4.3 Monthly Lightning strike Variations. It is well known that over the southeastern United States most thunderstorms occur during the summer months of June, July, and August. The TFRN for Maxwell shows that for all hours and all months, the frequency of thunderstorms based on hourly observations increases to a maximum in July with the highest frequencies in July through September. This pattern is reflected in the monthly variations of average hourly lightning strikes. To illustrate this, the same area around Maxwell was used as in Figures 2 and 3 to produce a table of average hourly lightning strikes by 700-mb wind directions for all hours. As seen in Table 2, the months of June through August have the highest average hourly lightning strikes, with the maximum in July. The table also shows a predominance of strikes when the 700-mb winds are from the southwest through northwest, except during July, when a high percentage of strikes occur with easterly winds.

TABLE 2. Monthly variations in average hourly lightning strikes, stratified by 700-mb wind direction.

For 0-23 Hours Zulu

	CALM	N	NE	E	SE	S	SW	W	NW	ALL
MAR	0	0	0	0	0	2	24	7	2	35
APR	0	0	0	0	0	7	14	39	2	62
MAY	0	3	4	0	7	3	16	43	18	94
JUN	9	36	3	12	3	22	84	29	19	217
JUL	49	33	42	62	21	29	41	46	64	387
AUG	7	11	39	28	21	11	15	43	33	208
SEP	1	0	3	4	4	10	11	19	4	56
OCT	0	0	0	0	0	0	3	12	1	16
ALL	66	83	91	106	56	84	208	238	143	1.0K

4.4 Wind Stratified Lightning Climatology Example. The month of July was again chosen to illustrate the wind stratified lightning strike climatology in the 3,600- square-nautical-mile area around Maxwell AFB. The period from 1700Z to 0100Z, which was shown in Figure 2 to contain the majority of the lightning strikes during July, was used to determine which 700-mb wind direction was associated with most of the strikes during that time. As shown in Figure 4, the 700-mb winds were mostly from the east or northwest when the highest values of average hourly lightning strikes occurred. The frequency distribution graphs of 700-mb wind direction categories for July given in Figure 5 (0000Z on the top, 1200Z on the bottom) show southwest through northwest winds predominate, with a secondary maximum found for easterly winds. Although Figure 5 also shows a relatively high frequency of northerly winds at 0000Z, Figure 4 shows that relatively few lightning strikes are associated with those northerlies.

4.5 K-index Stratified Lightning Climatology Example. It is no surprise that increasing K-index values relate to increases in the average number of hourly strikes. As expected, Figures 6 through 8 demonstrate that as the K-index increases, so does the average hourly strike rate. These figures also show an interesting pattern: When the K-index is low (Figure 6) the few strikes that are observed occur at midday (1700-1800Z, 1200-1300L). When the K-index is higher (Figures 7 and 8) the peak activity is later (2100 to 2200Z, 11600-1700L). With very high K-index (Figure 8) a secondary maximum is observed near sunrise (1000-1100Z, 0500-0600L). Figure 9 shows the percent occurrence frequencies for each K-index category for July, 00Z. Note that K-indexes of 31 or higher are observed about 60 percent of the time.

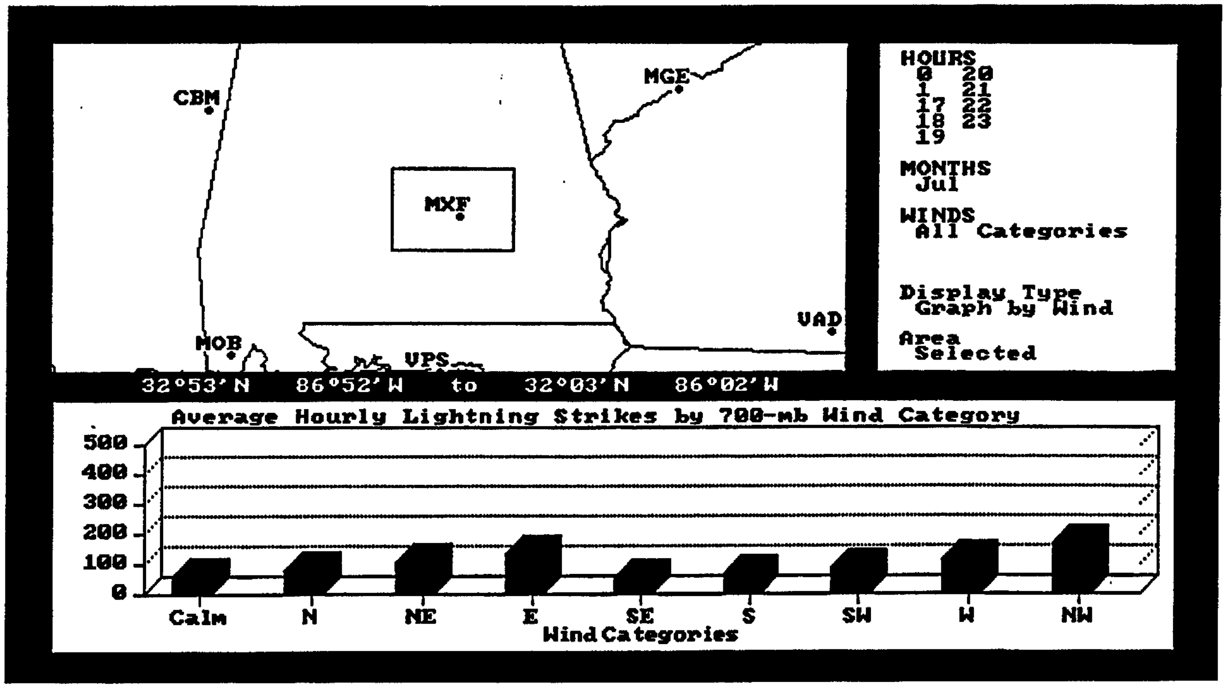

Figure 4. Variations in average hourly lightning strikes by 700-mb wind direction, from 1700Z to 0100Z, in the vicinity of Maxwell AFB, during July.

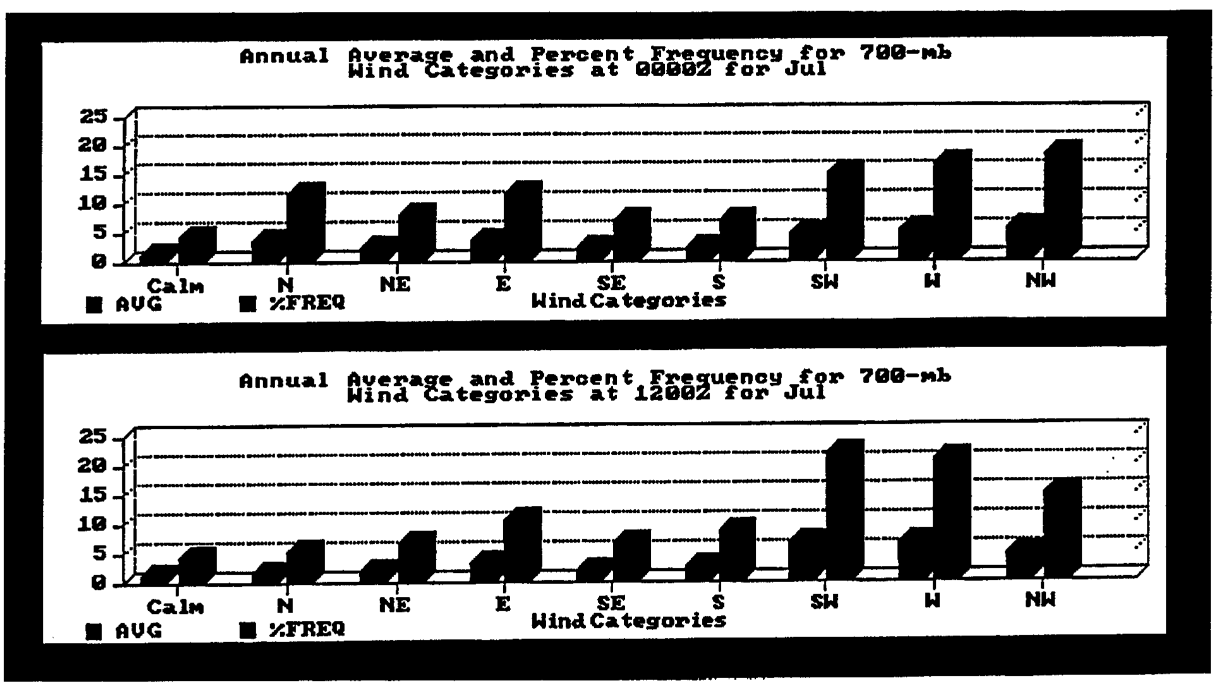

Figure 5. Frequency distributions of 700-mb wind directions for 0000Z (top), and 1200Z (bottom) at Maxwell AFB, during July.

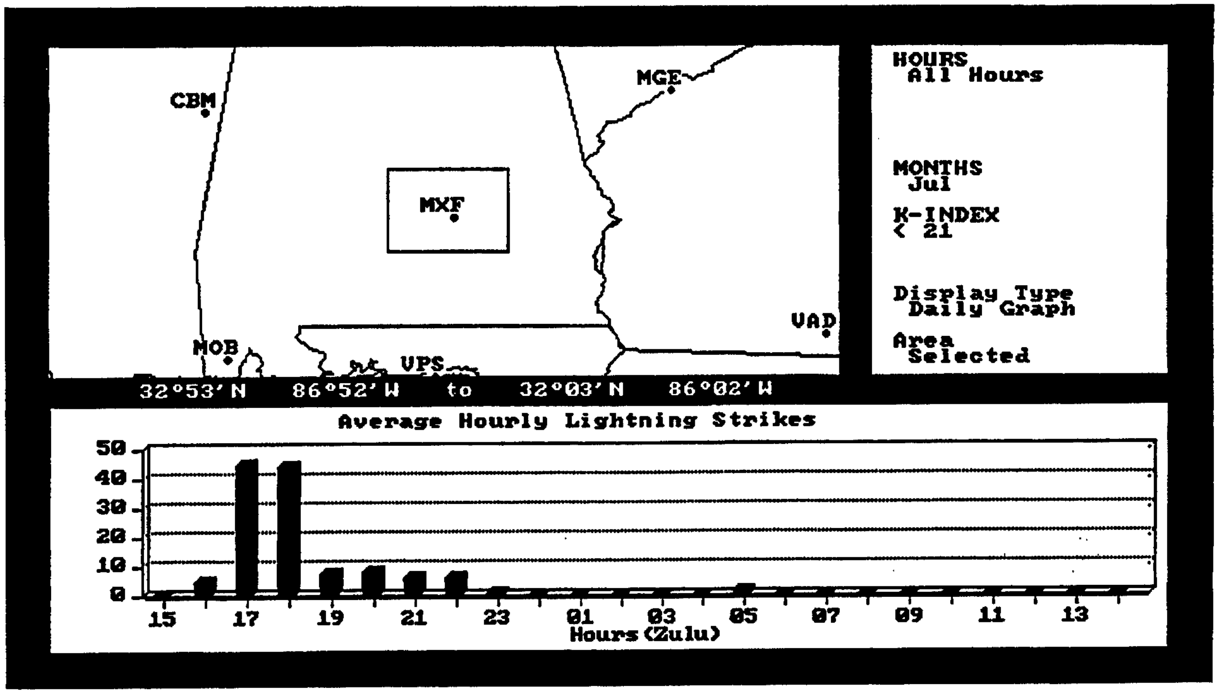

Figure 6. Diurnal variation of average hourly lightning strikes for cases when the K-index is low (< 21).

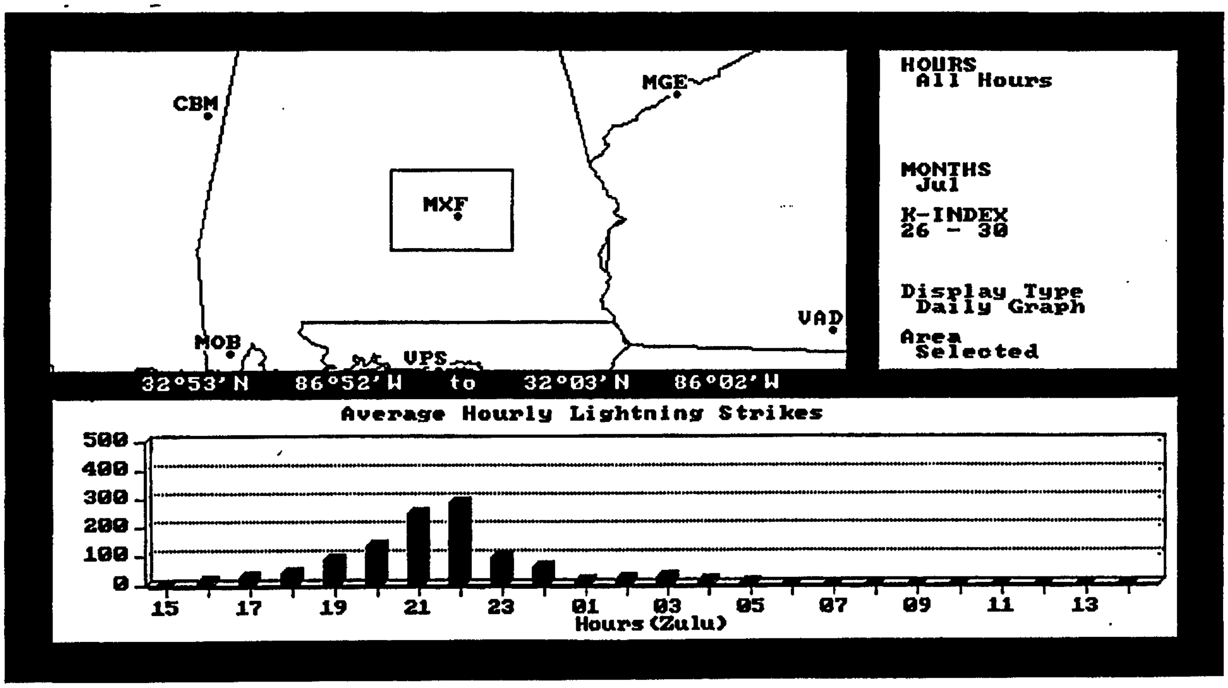

Figure 7. Diurnal variation of average hourly lightning strikes for cases when the K-index is between 26 and 30.

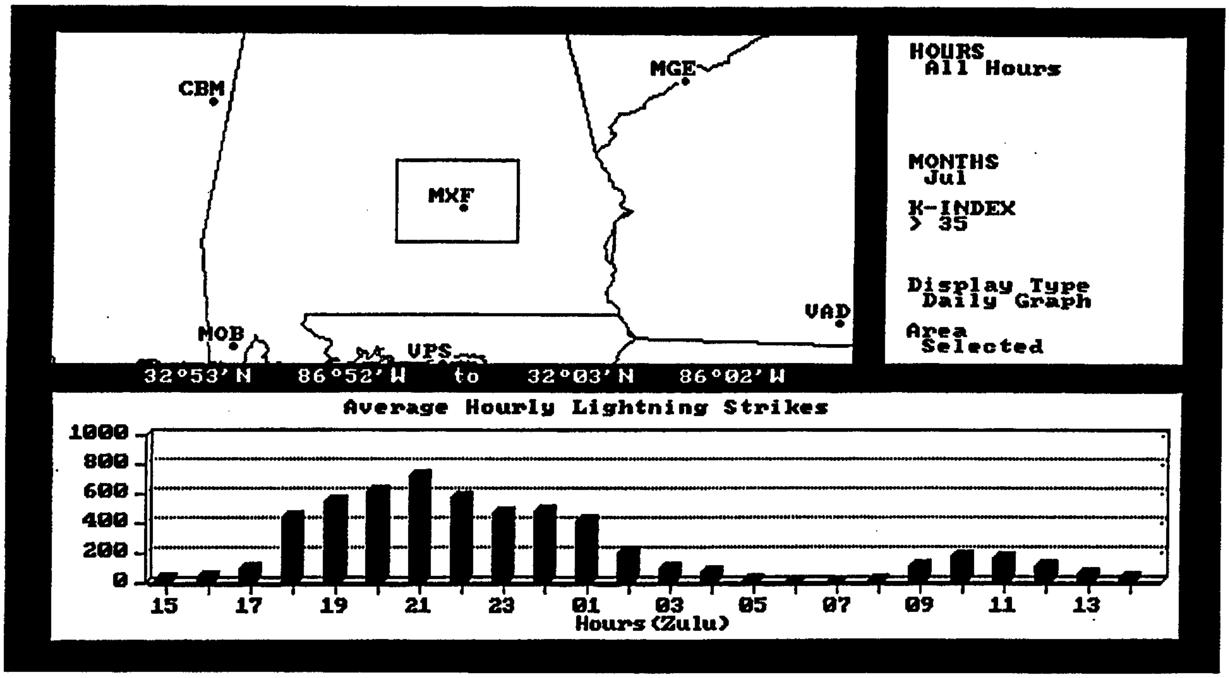

Figure 8. Diurnal variation of average hourly lightning strikes for cases when the K-index is ≥ 35.

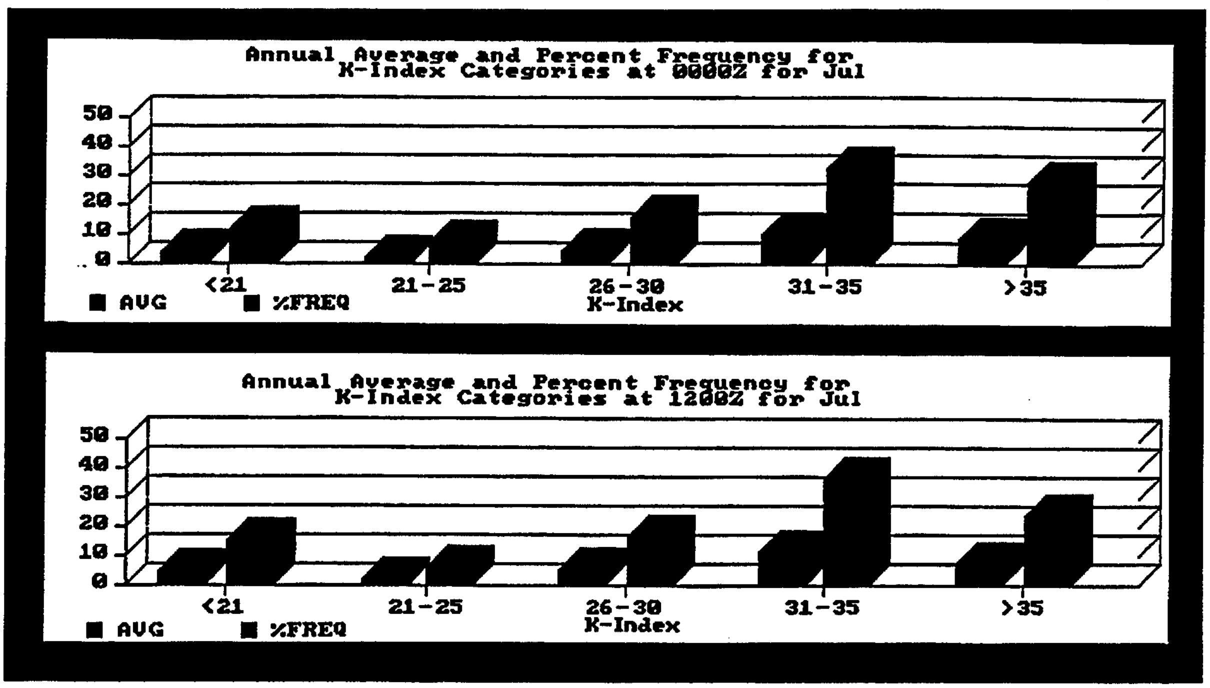

Figure 9. Frequency distributions of K-index categories for 0000Z (top) and 1200Z (bottom), during July.

4.6 Lightning Strike Contours. Examples of the contour plots produced by the Maxwell Lightning PC program are provided in Figures 10 and 11 (unfortunately they are a bit difficult to interpret when reproduced in black and white). These contour plots can reveal some interesting regional patterns, as shown in these examples. Both figures are for June, with all wind directions selected. Figure 10 is from 2100Z while Figure 11 is from 1000Z (the times of the two diurnal peaks shown in Figure 5). At 2100Z the greatest thunderstorm activity is located along the western tip of the Florida panhandle. At 1000Z the preferred location for thunderstorm activity is along a northeast to southwest line centered on Maxwell, with the greatest activity to the northeast (these locations agree well with those reported by Changery).

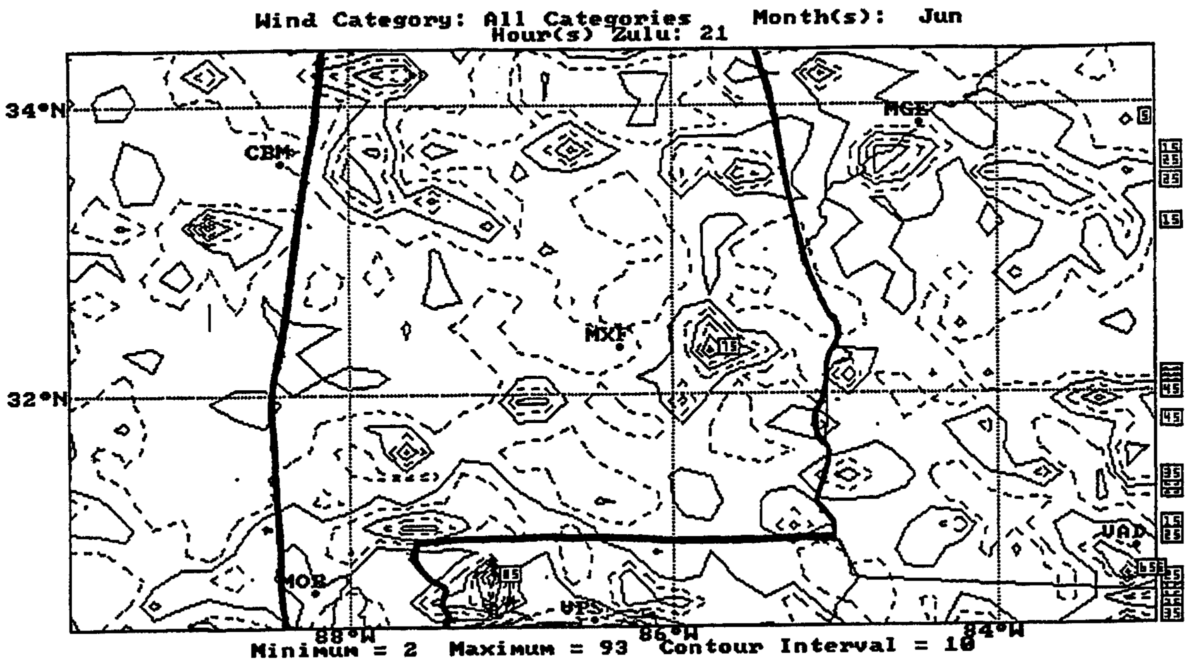

Figure 10. Isopleth analysis of the average hourly lightning strikes, for June at 2100Z (all wind categories)

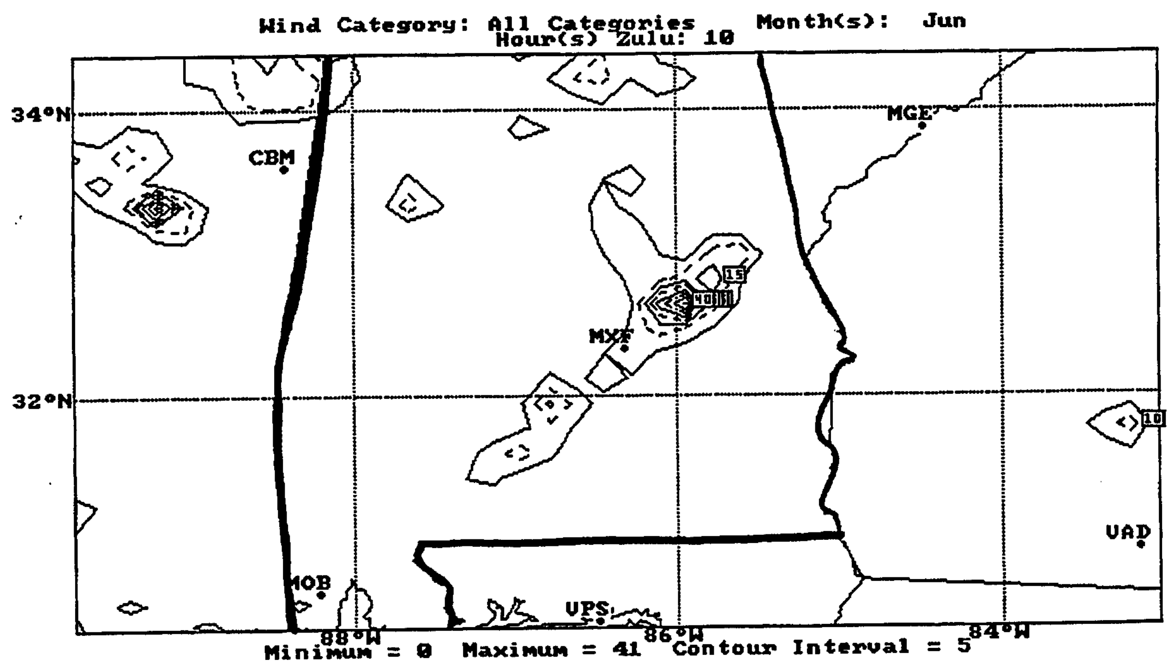

Figure 11. Isopleth analysis of the average hourly lightning strikes, for June at 1000Z (all wind categories).

Chapter 5

Summary

5.1 Discussion. The CG lightning strike climatology stratified by 700-mb wind directions and K-index categories was developed to help weather forecasters more accurately predict thunderstorms in the vicinity of Maxwell AFB, Ala. Despite minor limitations in the lightning strike and upper-air data used, it was shown that the lightning strike climatology adequately depicts several of the known temporal and spatial variations in summertime thunderstorms. The wind stratification appears effective at showing preferred lightning strike locations and movement based on the 700-mb wind direction. Undoubtedly, the lightning strike climatology holds much more information about lightning strike patterns than that presented in this report.

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

REFERENCES

Changery, M.J., *National Thunderstorm Frequencies for the Contiguous United States,* NUREG/CR-2252, National Climatic Center (NOAA), Asheville, N.C., 1981.

Changnon, S.A., Relationships between Thunderstorms and Cloud-to-Ground Lightning in the United States, *Journal of Applied Meteorology*, pp. 32, 88-105, 1993.

Feldman, N.S., *Terminal Forecast Reference Notebook (TFRN) for Maxwell AFB.* Detachment 9, 24 WS, Maxwell AFB Ala., 1985.

Hoke, J.E., J.L. Hayes, and L.G. Renninger, *Map Projections and Grid Systems for Meteorological Applications*, AFGWC/TN—79/003 Revised, Air Force Global Weather Central, Offutt AFB, Neb., 1985.

MacGorman, D.R., M.W. Maier, and W.D. Rust, *Lightning Strike Density for the Contiguous United States from Thunderstorm Duration Records*, NUREG/CR-3759, National Severe Storms Laboratory (NOAA), Norman, Okla., 1984.

Maier, M.W., et al., "Locating Cloud-to-Ground Lightning with Wideband Magnetic ... Direction Finders," *Preprints, Fifth Symposium on Meteorological Observations and Instrumentation,* Boston, Mass., pp. 497-504, 1983.

Orville, R.E., R.W. Henderson, and R.B. Pyle, "The National Lightning Detection Network--Severe Storm Observations," *Preprints, Sixteenth Conference on Severe Local Storms, Conference on Atmospheric Electricity*, Boston, Mass., pp. 327-330, 1990.

Orville, R.E., Lightning Ground Fash Density in the Contiguous United States - 1989, *Monthly Weather Review*, pp. 119, 573-577, 1991.

USAFETAC DATSAV Data Base Handbook, USAFETAC/TN—77-2, USAF Environmental Technical Applications Center, Scott AFB, Ill., December 1977.

The Use of the Skew T, Log P Diagram in Analysis and Forecasting, AWS/TR—79/006,Revised, Air Weather Service, Scott AFB, Ill., December 1979 (Revised March 1990).

GLOSSARY

AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center (formerly USAFETAC)
BOXNUM	Grid box number
CG	Cloud-to-ground (lightning)
DATSAV	AFCCC's database of surface and upper-air data
DB2	AFCCC's relational database
EGA	Enhanced Graphics Adapters
GDS	GeoMet Data Services, Inc.
I	Grid-point index
IBM	International Business Machines Corp.
INT	Operator that acts to keep only the whole part of a number
J	Grid-point index
KB	Kilobyte
LAT1	Latitude in minutes at upper-left corner of grid system
LATMIN	Latitude of lightning strike in minutes
LLP	Lightning Location and Protection, Inc.
LON1	Longitude in minutes at upper-left corner of grid system
LONMIN	Longitude of lightning strike in minutes
mb	Millibar(s)
MB	Megabyte
MIN	Grid spacing in minutes of latitude or longitude
MS-DOS	Microsoft-Disk Operating System
NLDN	National Lightning Detection Network

POF	Percent occurrence frequency
SIDEBOX	Number of grid boxes in east-west direction
SOCS	Surface Observation Climatic Summaries
USAFETAC	United States Environmental Technical Applications Center (renamed AFCCC)
x	Grid-point Cartesian coordinate
y	Grid-point Cartesian coordinate
Z	Zulu (Greenwich Mean Time)