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Lightning Climatology for Holloman AFB, New Mexico

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MARCH 1996

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13. Abstract: This technical note documents a climatology study AFCCC completed on the occurrence of lightning strikes at Holloman AFB, New Mexico. It depicts spatial and temporal variations in lightning strikes expected with known thunderstorm patterns in the Holloman AFB area.

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PREFACE

This technical note results of AFCCC Project 921031. The project analysts were Mr. William R. Schaub, Jr., and Capt Christopher A. Donahue.

The customer, the 49th Operations Support Squadron (Weather Flight), at Holloman AFB, N.M., requested a lightning climatology for a large area around Holloman AFB to more accurately coordinate with flight mission leaders on the safest routes to avoid lightning and thunderstorms. Of particular interest was the F-117A Stealth aircraft for which lightning information was critical to flight planning and safety.

A climatology of cloud-to-ground lightning strikes was developed for the Holloman AFB area from a database of lightning strikes that occurred from March through October during 1988-91. Upper-air reporting stations in the area were used to stratify the lightning-strike observations by nine 700-mb wind direction categories including calm. 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 to obtain the average hourly lightning strikes for each 700-mb wind direction category by month.

The summarized lightning data was used to produce a microcomputer graphics program that enables the user to display the lightning-strike climatology in graphs, tables, and isopleth analyses. One graph shows the average hourly lightning strikes by 700-mb wind direction 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 700-mb wind direction categories. A third graph, 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 for either 0000Z or 1200Z for any combination of months. A table option shows average hourly strikes for each 700-mb wind direction category and all categories, and for each month and all months, for any combination of grid boxes and hours. Isopleth analyses of the average hourly lightning strikes over the entire area are also available for any combination of months, hours, and 700-mb wind direction categories.

Analysis of the lightning climatology showed that the patterns of lightning strikes compared favorably with known preferred locations and times of thunderstorms in New Mexico, eastern Arizona, and western Texas. AFCCC recommends use of the lightning climatology as another tool for mission planning and weather forecasting.

The author is grateful to Maj. Lauraleen O'Connor for her review and comments. He also appreciates the fine work by Capt. Christopher A. Donahue who summarized the data. Special thanks to MSgt Robert G. Pena and A1C Kenneth G. Weston who produced the lightning graphics program.

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Chapter 1

INTRODUCTION

1.1 Background. The 49th Operations Support Squadron Weather Flight (49 OSS/OSW) at Holloman AFB, N.M., provides weather forecasts for military flying missions over a large area that includes New Mexico, eastern Arizona, and western Texas.

Thunderstorms pose a threat to aviation in that area, especially from July through September during the southwest monsoon. As an example of weather support provided by the 49th OSS/OSW, consider the F-117A Stealth mission. Due to F-117A weather sensitivities, timely thunderstorm and lightning advisories are critical to flight planning and safety. To enhance their support to flying missions, the 49th OSS/OSW requested a personal computer-based cloud-to-ground (CG) lightning-strike climatology, stratified by 700-mb wind direction categories for the analysis area shown in Figure 1.

AFCCC used a 4-year (1988-91) database of lightning-strike observations and upper-air observations to develop the lightning climatology for March through October. An interactive microcomputer graphics program was produced to display the climatology in graphs, tables, and isopleth analyses.

1.2 Related Studies. For many years, weather forecasters at Holloman AFB have studied the patterns of thunderstorm development and movement in that area. As described in *Studies on Local Forecasting* (1943), Holloman AFB (then known as Alamogordo Army Air Base) is in a flat valley between the San Andreas Mountains 26 miles to the west and the Sacramento Mountains from 50 miles north-northeast to 11 miles east. The field elevation at Holloman AFB is 4,093 feet MSL (mean sea level), and the mountains average 8,000 to 9,000 feet MSL. Bartlett (1943) noted that during July through September thunderstorms develop almost daily by early afternoon over the mountains. He also recognized that winds aloft were the key to predicting thunderstorm movement; thunderstorms that formed south of Holloman AFB were carried over the field when winds aloft were from the southeast through southwest. Gudencge, et al. (1954), found that summertime thunderstorms occurred most often in the afternoon and evening at

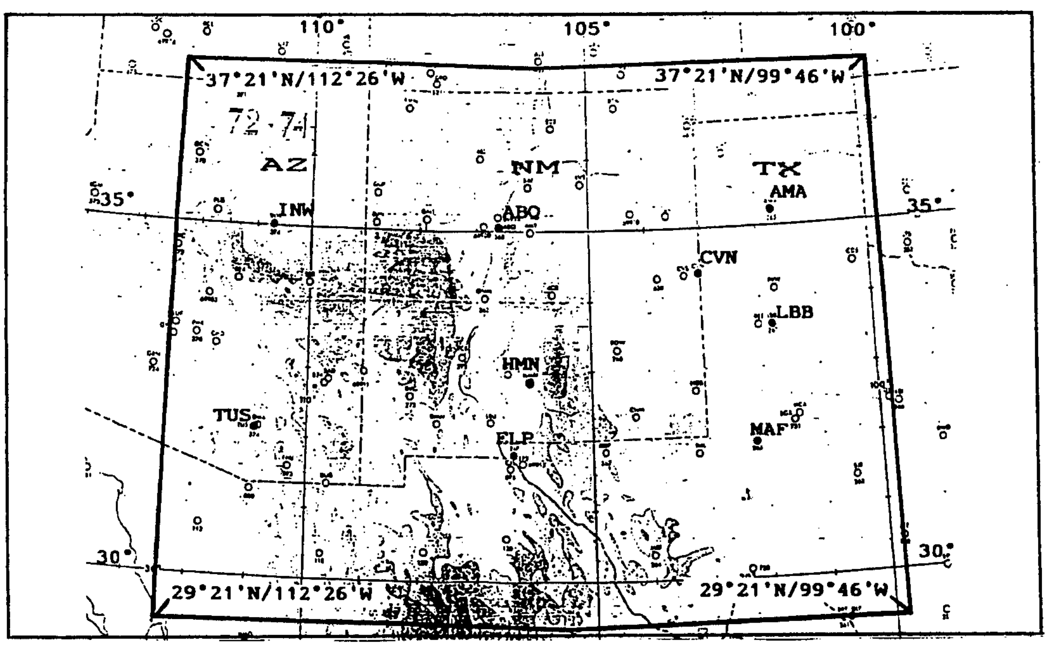

Figure 1. The area of interest. Analysis area is in bold lines. Labeled stations are: Winslow (INW) and Tucson (TUS) in Arizona; Albuquerque (ABQ), Holloman AFB (HMN); El Paso (ELP) in Texas, and Clovis (CVN) in New Mexico; and Amarillo (AMA), Lubbock (LBB), and Midland (MAF) in Texas.

Holloman AFB when winds from the surface to 15,000 feet MSL were from the southeast. When winds were from the southwest, more thunderstorms occurred over the mountains to the west of Holloman AFB. Loose (1972) showed that thunderstorms were most likely at Holloman AFB when the 700-mb wind direction was from 180 to 300 degrees or from 360 to 070 degrees, provided the 500-mb wind direction was similar. In recent related work, Watson, et al. (1992), used CG lightning data to show that upper-air winds are closely related to lightning-strike patterns over the southwestern United States during the summer monsoon.

1.3 Analysis Procedure. As discussed in Chapter 2, CG lightning-strike and atmospheric sounding data for 1988-91 were used to develop a lightning-strike climatology stratified by 700-mb wind direction 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 by 700-mb wind direction categories. In Chapter 4, the options available in the microcomputer graphics program produced to display the lightning climatology are discussed, and illustrative examples are used to compare the lightning climatology to known thunderstorm patterns.

1.4 Findings. The lightning climatology appeared consistent with expected diurnal and monthly variations in thunderstorm activity. The diurnal variations of lightning strikes near Holloman AFB agreed closely with known diurnal variations in thunderstorm frequencies. Even a secondary daily maximum in average hourly lightning strikes was evident in September to match a secondary maximum in hourly observations of thunderstorms for that month. Likewise, monthly variations in average hourly lightning strikes coincided with changes in monthly thunderstorm frequency; July through September had the highest average hourly lightning strikes, with the maximum in August. Monthly patterns in contour analyses of the average hourly lightning-strike fields closely resembled the patterns in mean thunderstorms shown by Changery (1981). As further illustrated in Chapter 4, 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 were 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 1988-91, over 6 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. Figure 2 shows the NLDN direction finders that GDS operated in and near the area of analysis during 1988-91.

2.2 Lightning Data Limitations. Most evaluations of CG lightning-strike data quality include discussions of detection efficiency and strike location accuracy. The period of record is also important for a representative database.

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 range or 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.

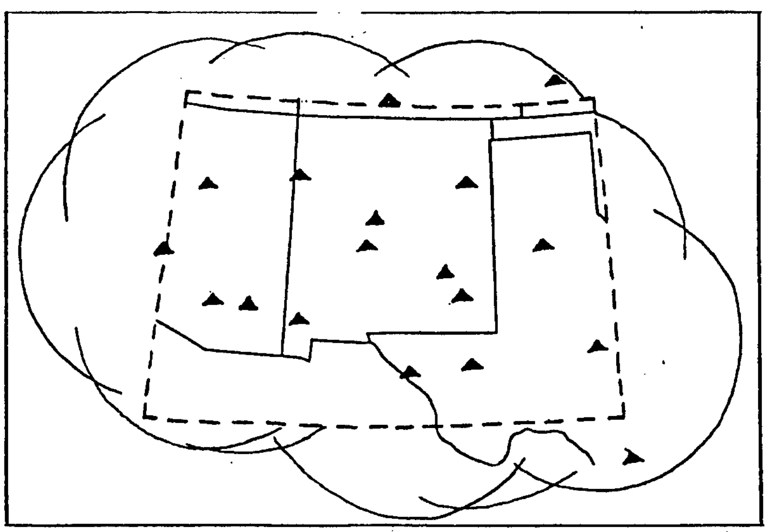

Figure 2. Lightning direction finder locations. Triangles represent approximate locations of NLDN direction finders in and near the area of analysis (dashed lines) during 1988-91. Scalloping around the analysis area shows the nominal range of 215 nautical miles. Source: GDS (personal communication).

For the present work, Figure 2 shows that during 1988-91 most of the area of interest was well within the nominal range for a 70-percent lightning detection 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, the period of record for the CG lightning-strike data was 4 years for the area of analysis in Figure 1. 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 longer-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 (e.g., 5- to 10-year) 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 AFCCC's DATSAV Upper-Air database, described in AFCCC DATSAV Data Base Handbook (1977), were used to obtain 700-mb wind data. Six upper-air sites within the area of analysis were selected for March through October from 1988-91: Tucson and Winslow in Ariz.; Albuquerque, N.M.; and Amarillo, El Paso, and Midland in Texas (see Figure 1).

As described in Chapter 3, data from the three northernmost upper-air sites was used for the northern part of the analysis area, and data from the others was used for the southern part.

2.4 Upper-Air Data Limitations. Upper-air observations were available only twice daily at 0000Z (1700 Mountain Standard Time (MST)) and 1200Z (0500MST). 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 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 6,082,312 CG lightning-strike observations that occurred during 1988-91 in March through October were extracted from the relational database for the area of analysis in Figure 1. Each lightning observation contained the year, month, day, hour, minute, and latitude and longitude in decimal degrees. The dataset of lightning observations was sorted by year, month, day, and hour for merger 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. Due to the large area of analysis (refer to Figure 1), the area was divided along 33 degrees North latitude for purposes of applying upper-air data. The 700-mb wind direction and speed for Albuquerque, N.M.; Winslow, Ariz.; and Amarillo, Texas, were considered correlated so that data from any of the three was representative for the area north of 33 degrees. Similarly, data for El Paso, Texas; Tucson, Ariz.; and Midland, Texas, was considered representative for the area along and south of 33 degrees. Using three upper-air reporting stations for each part of the area of analysis minimized the number of times with missing 700-mb wind data. In the north, Albuquerque data had first priority, followed by Winslow and Amarillo. If data was available for Albuquerque, it was used first. If not, data for Winslow was used. If Winslow data was missing, data for Amarillo was used. In the south, the order of priority was El Paso, Tucson, and Midland. The 700-mb wind direction and speed in knots for 0000Z (1700MST) and 1200Z (0500MST) were extracted from the six locations for March through October from 1988-91. For the northern part of the area, the data set contained almost a 100 percent (1,953 of 1,960) of the total possible upper-air observations with 700-mb wind data for the period (1,846 from Albuquerque, 94 from Winslow, and 13 from Amarillo). The dataset for the southern part contained 99 percent (1,944 of 1,960) of possible observations (1,857 from El Paso; 68 from Tucson; and 19 from Midland). The upper-air datasets were sorted by year, month, day, and hour for merger with the lightning dataset.

3.3 Wind Stratified Lightning Dataset. To stratify the lightning climatology by 700-mb wind direction categories, the datasets of lightning and upper-air observations were merged based on the following conditions: Lightning observations that occurred above 33 degrees North latitude from 0600Z to 1759Z were matched with the 1200Z upper-air observations from the dataset for the northern part of the area. The rest of the lightning observations for that time period were matched with 1200Z upper-air observations from the dataset for the southern part.

Lightning observations that occurred above 33 degrees North latitude from 1800Z the previous day to 0559Z were matched with the 0000Z upper-air observations from the dataset for the northern part of the area. The rest of the lightning observations for that time period were matched with 0000Z upper-air observations from the dataset for the southern part.

After merging the datasets, every lightning observation over the area of analysis contained a 700-mb wind direction and speed, including missing values. Those lightning observations that contained missing wind direction and speed (southern part of the area only) 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 in 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. 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 between 340° and 360° or direction between 000° and 020°

NE direction equal to or greater than 021° 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°

3.4 Wind Frequency Distribution Dataset. The upper-air data for El Paso from 1988-91 was 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 4-year total and annual average were calculated for each category by month and hour. Then the 4-year total was calculated for all nine categories by month and hour. The percent occurrence frequency (POF) for each category by month and hour was calculated as follows:

POF = 4-year total each category 4-year total (1)
all categories

A dataset was built that contained the annual average number of occurrences and POF for each wind category by month for either 0000Z or 1200Z. It was used to display frequency distribution charts in the lightning graphics described in Chapter 4.

3.5 The Grid System. To prepare the wind stratified lightning dataset for summarization at a horizontal resolution of approximately 10 nautical miles, the area of analysis in Figure 1 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 on array of 3,773 grid points (77 in the east-west direction by 49 in the north-south direction) and 3,648 individual grid boxes. A partial sketch of the grid system is shown in Figure 3 for reference. 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 real areas enclosed by grid boxes are not square and increase from north to south. For the Holloman AFB area, the distance between degrees of latitude from north to south varies little at nearly 60 nautical miles. The distance between degrees of longitude from north to south increases from about 48 nautical miles per degree at 37° N to nearly 53 nautical miles per degree at 29° N. 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. However, for purposes of this analysis the bias is considered minor.

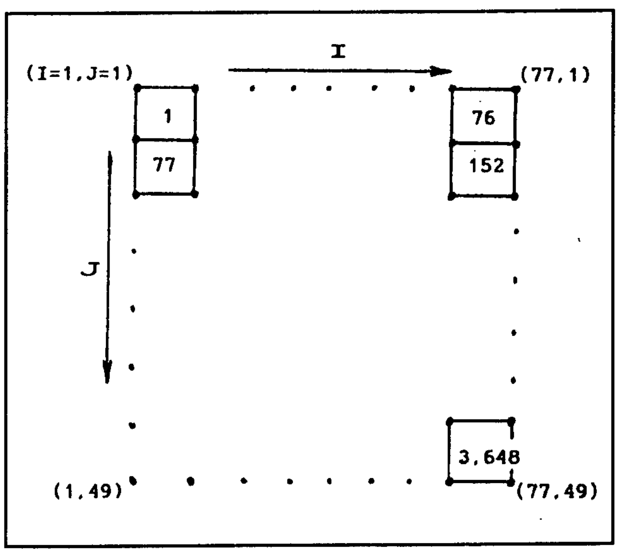

Figure 3. Sketch of the grid system.

3.6 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 of the strike 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:

$$x = \{(LON1 - LONMIN)/MIN\} + 1 \quad (2)$$
$$y = \{(LAT1 - LATMIN)/MIN\} + 1 \quad (3)$$

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:

$$I = INT(x) \quad (4)$$
$$J = INT(y) \quad (5)$$

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:

$$BOXNUM = I + \{SIDEBOX(J-1)\} \quad (6)$$

where SIDEBOX is the number of grid boxes in the east-west direction (76 in this work). As an example, referring to Figure 1, the upper-left corner of the area of analysis is located at 37° 21' N/112° 26' W. From equations 2 through 5, the values of I and J for that point are both one. From equation 6, the grid box number for a lightning strike at that point is one. As shown in Figure 3, the index I varies from 1 on the left side of the grid system to 77 on the right side. The index J varies from 1 at the top to 49 at the bottom. The grid box numbers increase from 1 in the upper-left corner to 76 in the upper-right corner, and so on to box number 3,648 in the lower-right corner. Once the above gridding procedure was complete, every lightning-strike observation had a grid box number for identification.

3.7 Lightning Data Summarization. The dataset of lightning stratified by 700-mb wind direction categories was summarized to obtain the average number of strikes for each grid box by month, hour, and wind direction category. As a result, each grid box in the area of analysis had a wind stratified lightning-strike climatology for use in the graphics program discussed in the next section.

Chapter 4

LIGHTNING CLIMATOLOGY AND RESULTS

4.1 The Lightning Graphics Program. A microcomputer graphics program was written by Pena and Weston (1993) to display the Holloman 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 Zulu (Greenwich Mean Time). To obtain Mountain Standard Time (MST), subtract 7 hours from Zulu.

4.1.2 Graphics Displays. The lightning graphics program uses the wind stratified lightning-strike climatology and 700-mb wind direction climatology to present several displays. The displays and input options include bar graphs, tables, and isopleth analyses as listed 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 700-mb wind direction categories may be selected.

- Bar graphs of the variations of average hourly lightning strikes by 700-mb wind direction categories (Calm, N, NE, E, SE, S, SW, W, and NW).

  - 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 categories for the entire area (based on El Paso, Texas data) for 0000Z and 1200Z.

  - One, several, or all months may be selected.

- Tables of the average hourly lightning strikes for each 700-mb wind direction category and all categories; 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 700-mb wind direction categories may be selected.

4.2 Examples of Diurnal Lightning-Strike Variations. To illustrate diurnal variations in lightning strikes around Holloman AFB, the month of August was chosen since it has the highest thunderstorm frequency as shown in the Surface Observation Climatic Summaries (SOCS) for Holloman AFB, N. M., (1992). An area centered on Holloman AFB, consisting of six grid boxes on each side and about 3,600 square nautical miles, was used to obtain the graph shown in Figure 4 for all 700-mb wind direction categories. Figure 4 shows that most lightning strikes occur between 1700Z (1000 MST) and 0800Z (0100MST). The highest average value (about 650) at 2000Z (1300 MST) agrees closely with the SOCS for Holloman AFB (1992) which shows that the highest frequency of thunderstorms reported on hourly observations at Holloman AFB occurs from 1500 MST to 1700 MST. As another example of diurnal variations in lightning strikes, the same area around Holloman AFB is shown in Figure 5 for September. Figure 5 shows two diurnal maximums in the average hourly strikes: one maximum of about 200 strikes at 2300Z (1600 MST); the other secondary maximum of about 130 strikes at 0600Z (2300 MST). The same pattern exists in the frequencies of thunderstorms based on hourly observations during September in the SOCS for Holloman AFB (1992): one maximum occurs from 1500 MST to 1700 MST; the other lesser maximum occurs from 0000 MST to 0200 MST.

4.3 Monthly Lightning-Strike Variations. It is well known that over the Southwestern United States most thunderstorms occur during the summer months of July, August, and September. The SOCS for Holloman AFB, New Mexico (1992) shows that for all hours and all months, the frequency of thunderstorms based on hourly observations increases to a maximum in August with the highest frequencies in July through September. A similar trend occurs in the monthly variations of average hourly lightning strikes. To illustrate this, the same area around Holloman AFB was used as in Figures 4 and 5 to obtain a table of average hourly lightning strikes by 700-mb wind directions for all hours. As seen in Table 1, the months of July through September have the highest average hourly lightning strikes based on all 700-mb wind direction categories, with the maximum in August. The table also shows a predominance of strikes when the 700-mb winds are from the southeast through southwest, especially during the summer.

4.4 Wind Stratified Lightning Climatology Example. The month of August was chosen again to illustrate the wind stratified lightning-strike

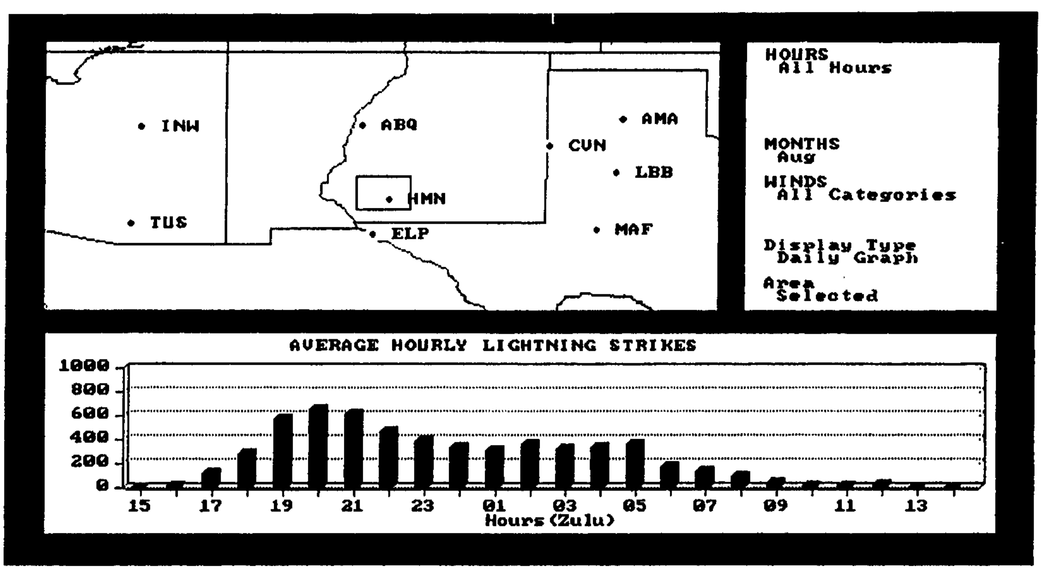

Figure 4. Diurnal variation in lightning strikes around Hollomon AFB, N.M. during August. Graph shows average hourly lightning strikes for all 700-mb wind directions within an area of about 3,600 square nautical miles centered on Holloman AFB (HMN).

climatology in the 3,600- square-nautical-mile area around Holloman AFB. The period from 1700Z (1000 MST) to 0800Z (0100 MST) shown in Figure 4 was used to determine which 700-mb wind direction was associated with most of the strikes during that time. As shown in Figure 6 (next page), the 700-mb winds were mostly from the south when the highest value of average hourly lightning strikes occurred. This is also evident from the frequency distribution graphs of 700-mb wind direction categories for August shown in Figure 7. Although Figure 7 shows that there is an equal frequency of 700-mb winds from the south and east for 0000Z (1700 MST), Figure 6 shows that relatively few lightning strikes occur with 700-mb winds from the east.

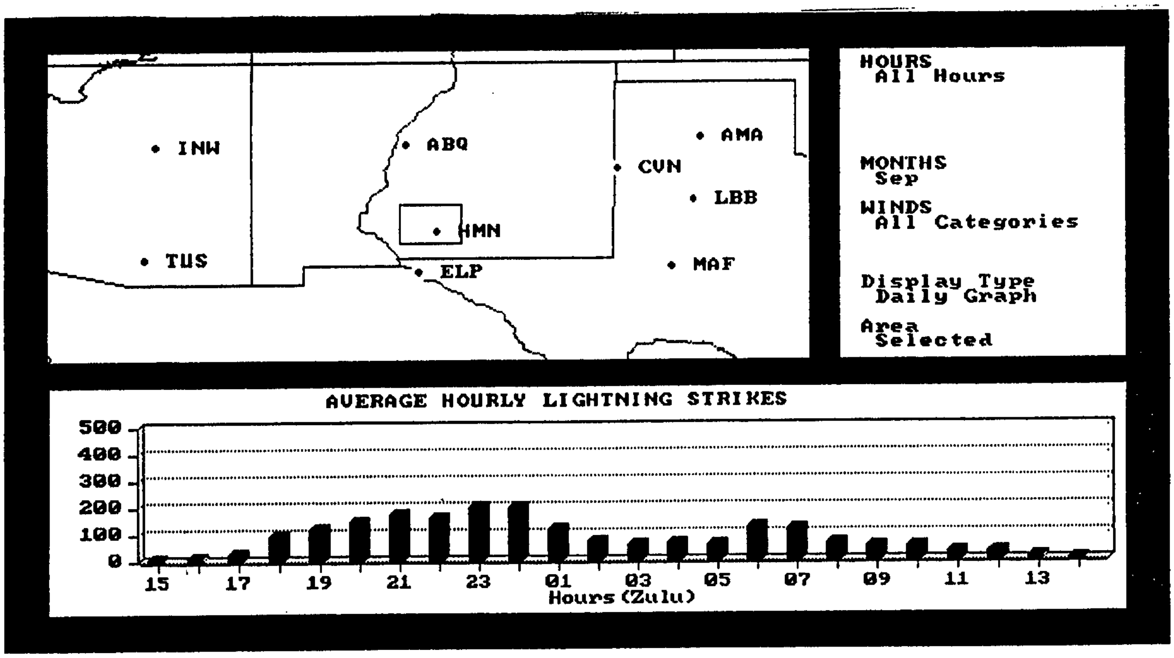

Figure 5. Diurnal variation in lightning strikes around Hollomon AFB, N.M. during September. Graph shows average hourly lightning strikes for all 700-mb wind directions within an area of about 3,600 square nautical miles centered on Holloman AFB (HMN).

Table 1. Monthly variations in average hourly lightning strikes by 700-mb wind directions for all hours around Holloman AFB, N.M. Area of analysis is the same as Figure 4.

Table of Average Hourly Lightning Strikes

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	0	0	1	0	1
APR	0	0	0	0	0	5	3	0	1	9
MAY	2	0	0	3	16	10	13	3	1	48
JUN	4	1	2	5	4	6	14	0	1	37
JUL	14	10	29	11	22	32	27	5	14	164
AUG	12	33	18	24	18	47	32	9	42	235
SEP	6	8	0	2	17	14	24	4	8	83
OCT	0	0	0	0	1	1	1	0	0	3
ALL	38	52	49	45	78	115	114	22	67	580

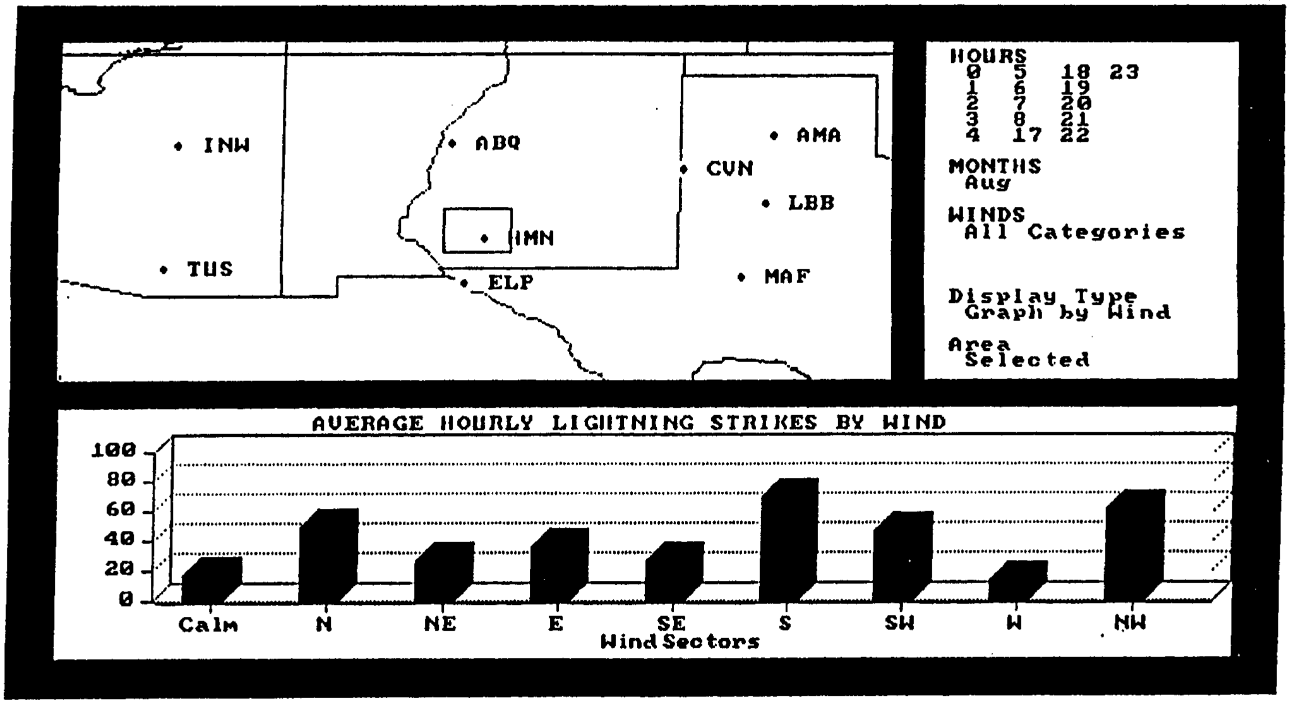

Figure 6. Variations in average hourly lightning strikes by 700-mb wind directions from 1700Z (1000MST) to 0800Z (0100MST) during August around the Holloman AFB, N.M. Area of analysis is the same as in Figure 4.

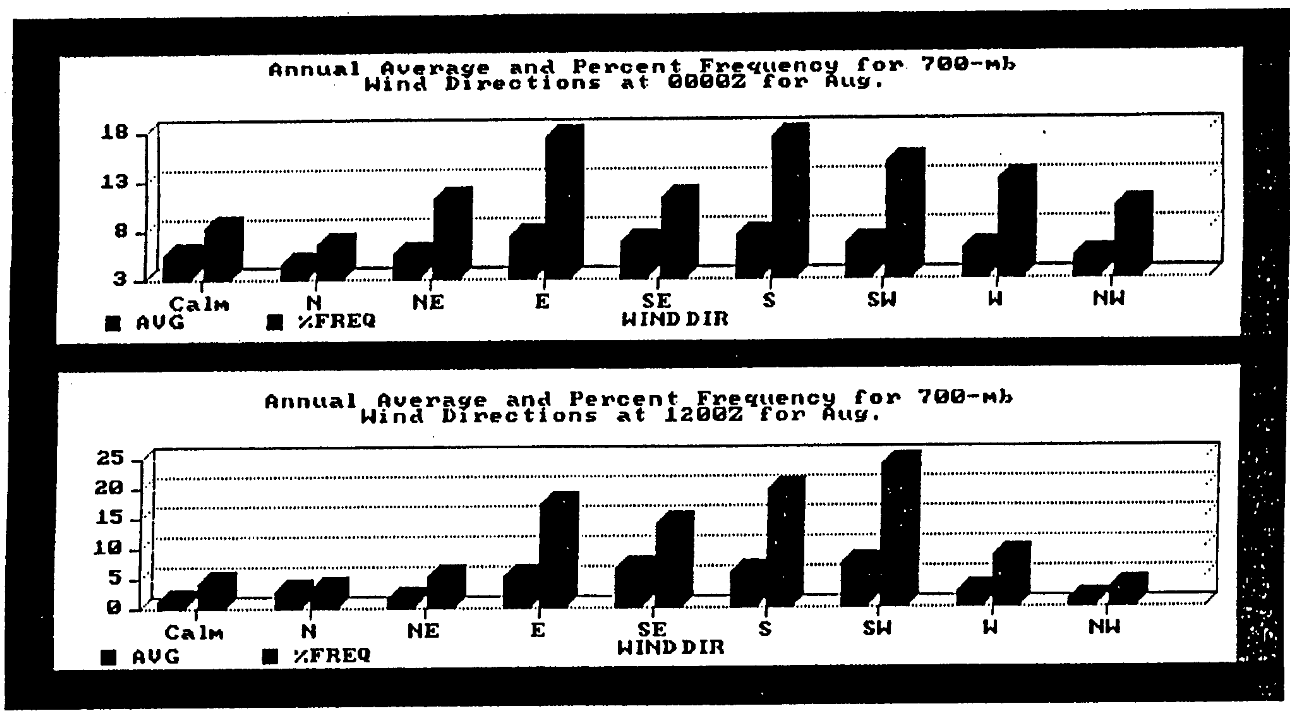

Figure 7. Frequency distributions of 700-mb wind directions for 0000Z (1700MST) and 1200Z (0500MST) during August in the Holloman AFB, N.M., area. Based on data from El Paso, Texas.

4.5 Regional Lightning-Strike Patterns. Isopleth analyses of the average hourly lightning strikes were examined to compare lightning-strike patterns to known thunderstorm patterns. Bartlett (1943) observed that on a typical summer day at Holloman AFB thunderstorms developed first over the mountains. An example is shown in the lightning-strike pattern in Figure 8 for August at 1900Z (1200 MST) with 700-mb winds from the south. The contours show an area of strikes over the Sacramento Mountains to the north and east of Holloman AFB. Bartlett (1943) also observed that thunderstorms that developed to the south of Holloman AFB often moved over Holloman if the lower tropospheric winds were from the southeast through southwest. Continuing from Figure 8, the lightning-strike pattern in Figure 9 for August at 2000Z (1300 MST), also with 700-mb winds from the south, shows an area of strikes just to the southwest of Holloman AFB. Then by 2100Z (1400 MST), as seen in Figure 10, the area of strikes is over Holloman AFB. In a later study by Gudencge, et al. (1954), it was noted that summertime thunderstorms usually developed over the mountains to the west of Holloman AFB when lower tropospheric winds were from the southwest. An example is shown in Figure 11 for September at 0000Z (1700 MST) with 700-mb winds from the southwest. An area of lightning strikes is over the northwestern part of Holloman AFB. The lightning presumably originated with thunderstorm development over the mountains to the southwest through west, although no strikes were evident in the 2300Z (1600 MST) isopleth analysis. Later at 0100Z (1800 MST), as shown in Figure 12, an area of lightning strikes appears to the north of Holloman AFB. Apparently it is the same area of strikes as seen in Figure 11, but moved northeastward by the southwest 700-mb winds. As a final example of similarities between patterns in thunderstorm climatology and this lightning-strike climatology, refer to Figures 13 and 14. Figure 13 from Changery (1981) shows the mean number of thunderstorms over the southwestern United States during August. By comparison, Figure 14 shows contours of the average hourly lightning strikes in the Holloman AFB analysis area for August for all hours and 700-mb wind directions. It can readily be seen that the lightning-strike pattern closely resembles the thunderstorm pattern.

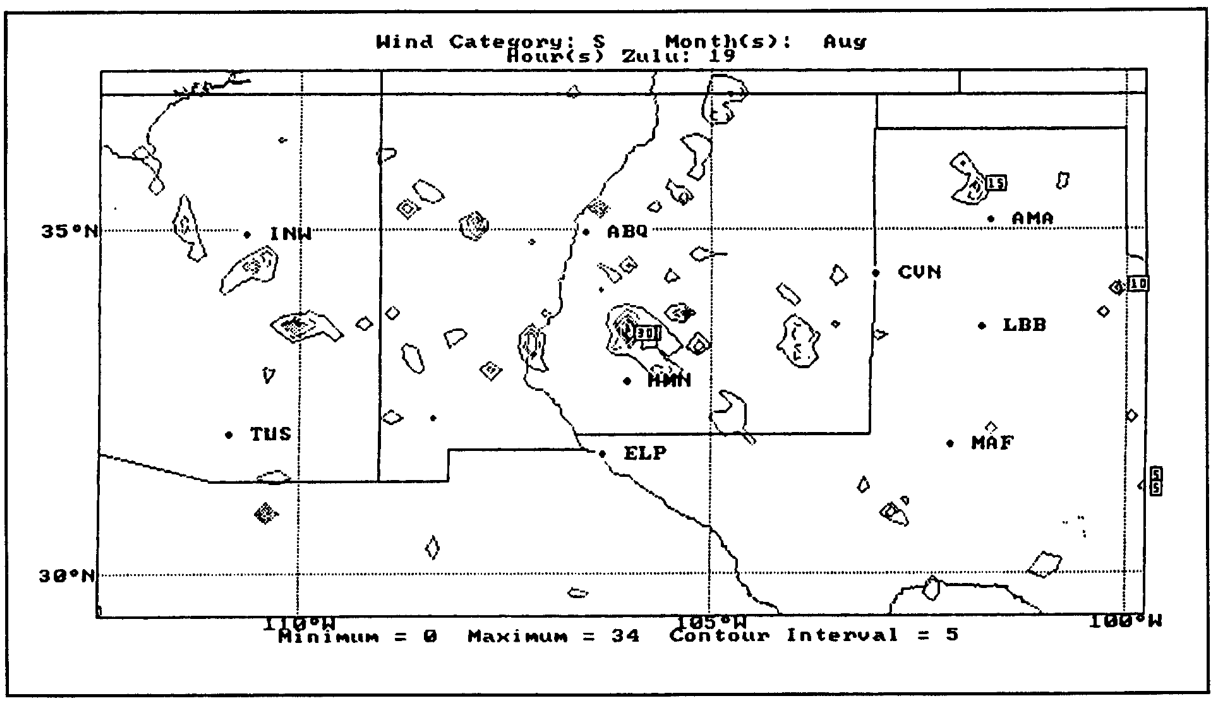

Figure 8. Isopleth analysis of the average hourly lightning strikes with 700-mb winds from the south at 1900Z (1200MST) in August. Area of analysis is as in Figure 1.

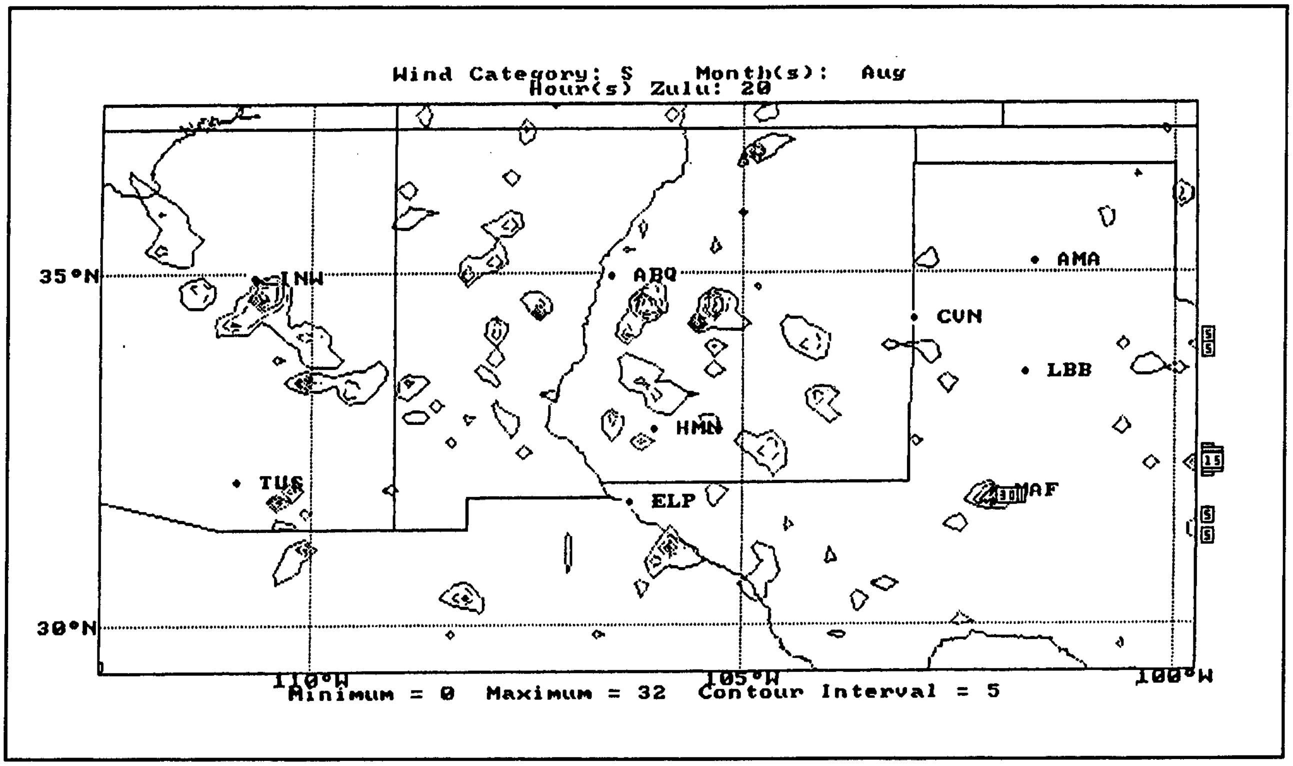

Figure 9. Isopleth analysis of the average hourly lightning strikes with 700-mb winds from the south at 2000Z (1300MST) in August. Area of analysis is as in Figure 1.

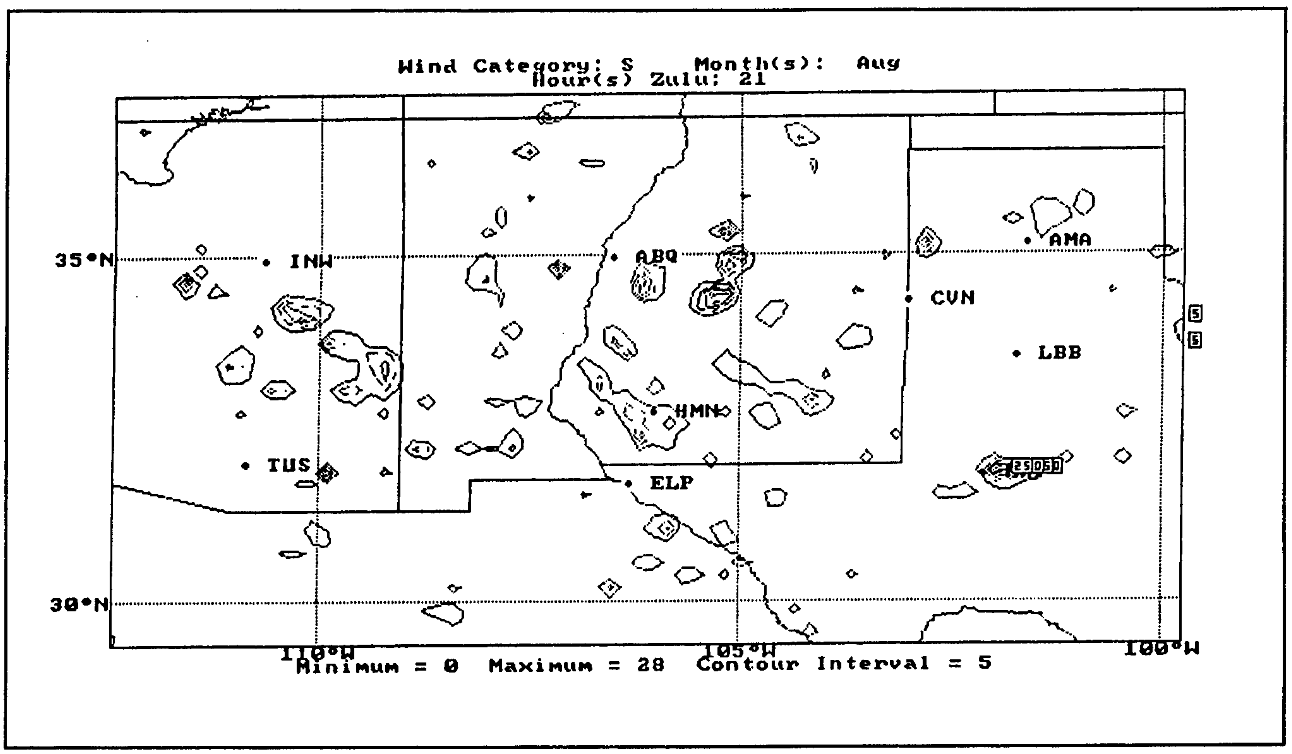

Figure 10. Isopleth analysis of the average hourly lightning strikes with 700-mb winds from the south at 2100Z (1400MST) in August. Area of analysis is as in Figure 1.

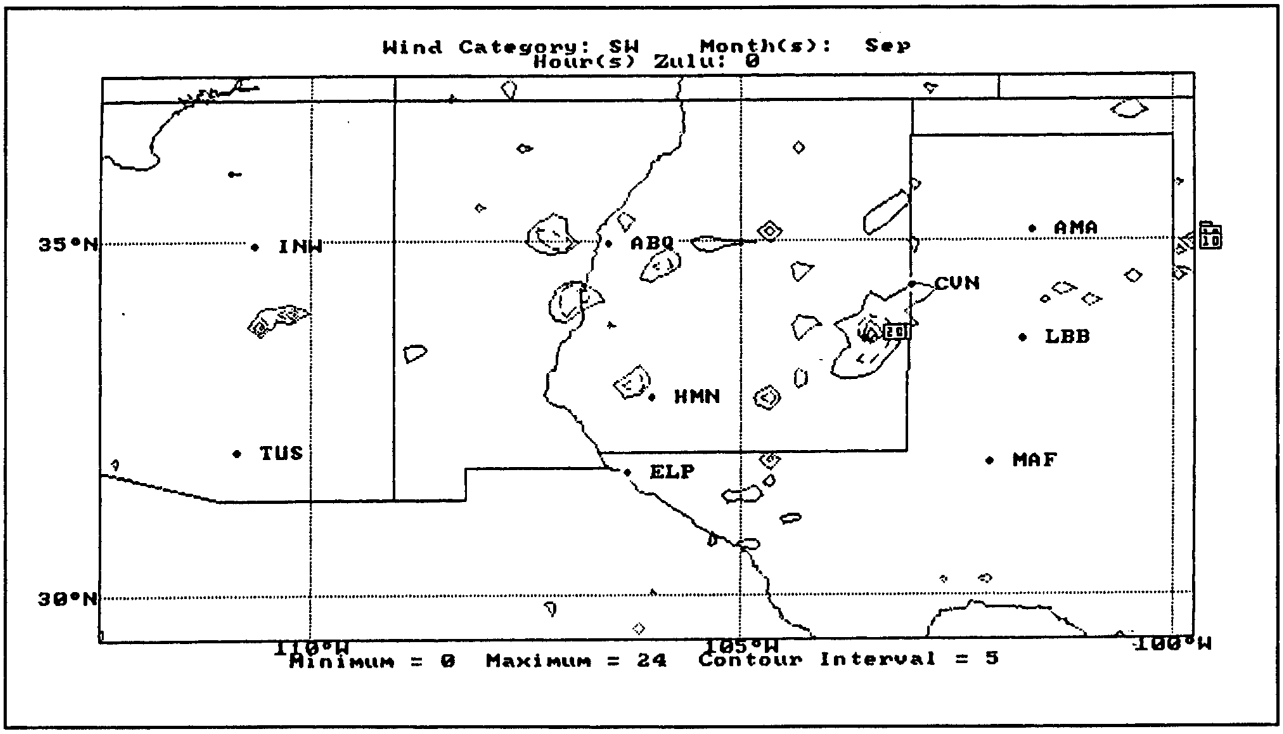

Figure 11. Isopleth analysis of the average hourly lightning strikes with 700-mb winds from the southwest at 0000Z (1700MST) in September. Area of analysis is as in Figure 1.

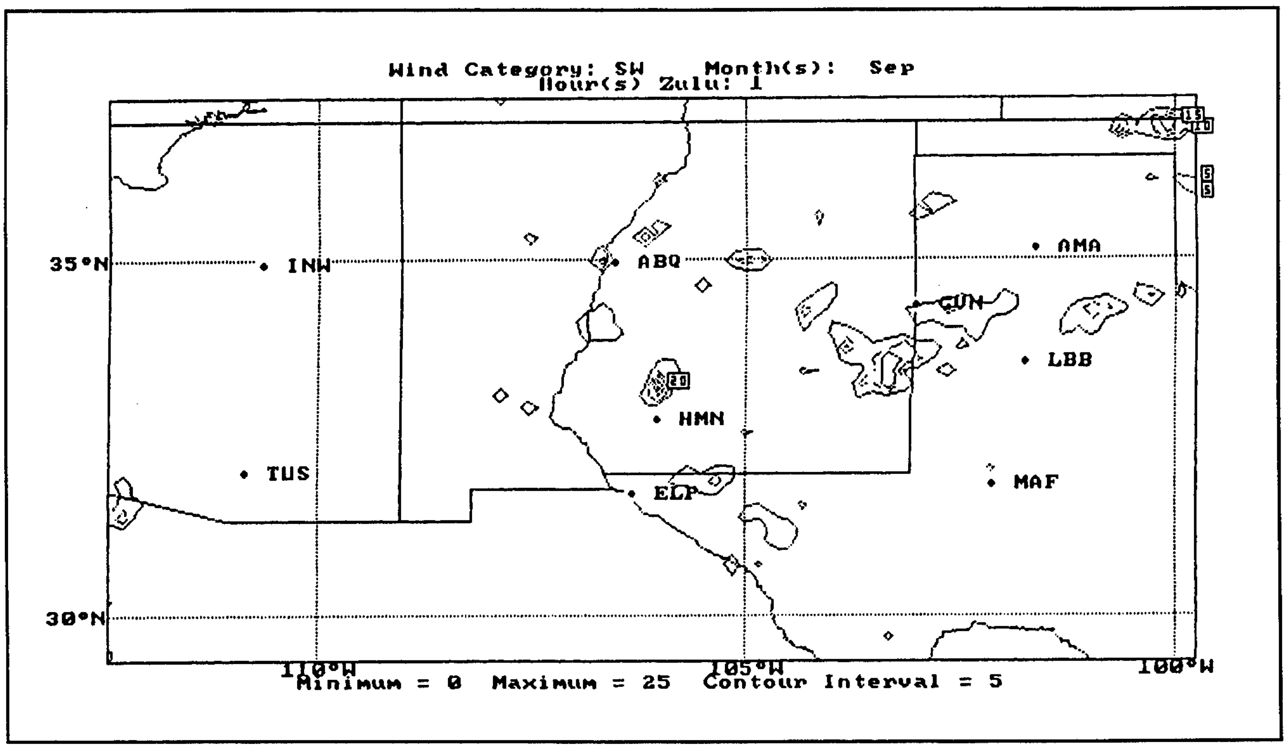

Figure 12. Isopleth analysis of the average hourly lightning strikes with 700-mb winds from the southwest at 0100Z (1800MST) in September. Area of analysis is as in Figure 1.

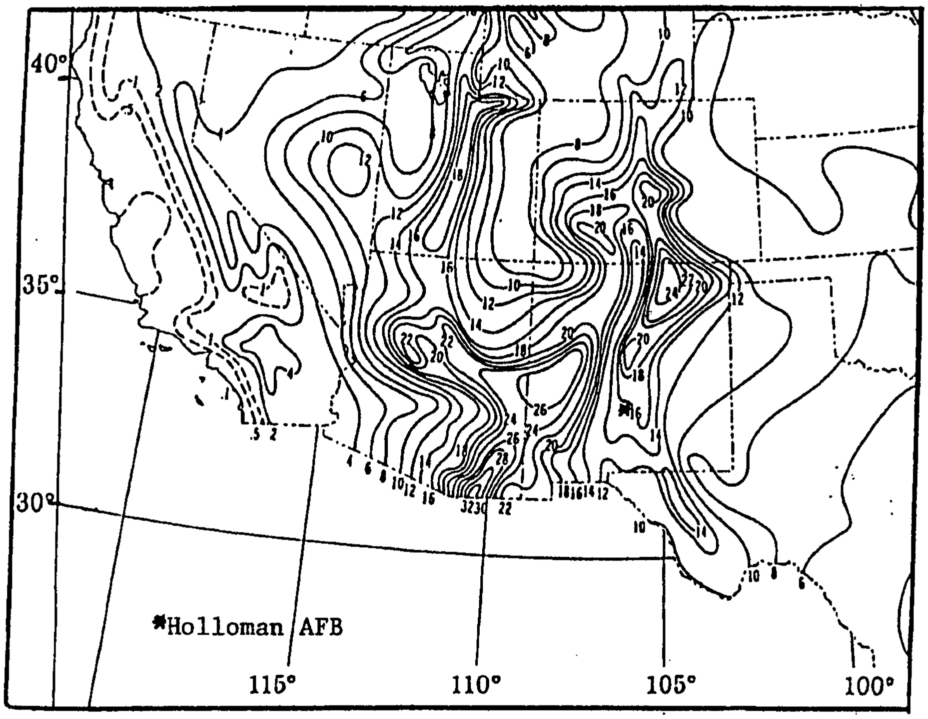

Figure 13. Analysis of the mean number of thunderstorms during August over the southwestern United States. Adapted from Changery (1981).

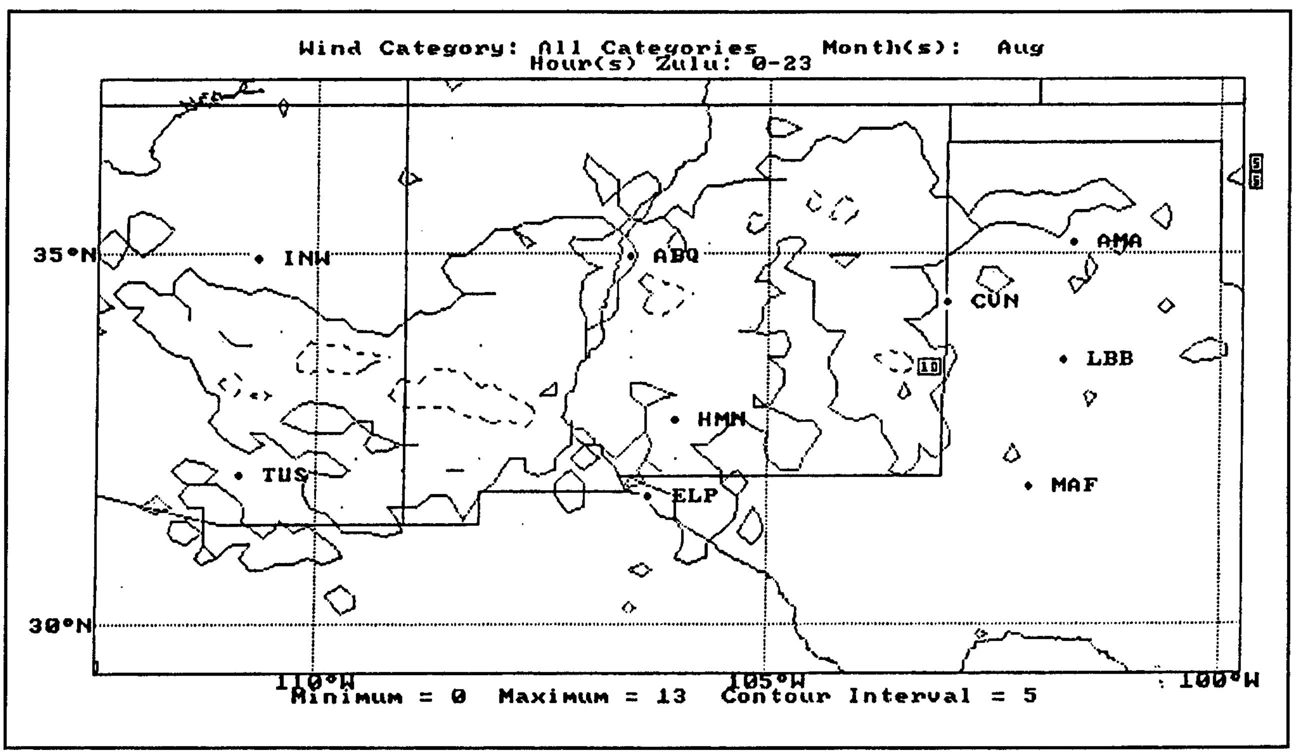

Figure 14. Isopleth analysis of the average hourly lightning strikes with 700-mb wind directions and all hours during August. Area of analysis is as in Figure 1.

Chapter 5

SUMMARY

5.1 Discussion. The CG lightning-strike climatology stratified by 700-mb wind directions was developed to help weather forecasters more accurately predict thunderstorms in the vicinity of Holloman AFB. Despite limitations in the lightning-strike and upper-air data used, it was shown by comparison to known temporal and spatial variations in summertime thunderstorms that the lightning-strike climatology adequately depicts several of the variations. The wind stratification appeared 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 what was presented in this report.

5.2 Recommendation. AFCCC recommends use of the lightning climatology as another tool to predict thunderstorms at Holloman 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
BOXNUM	Grid box number
C	Calm
CG	Cloud-to-ground (lightning)
DATSAV	AFCCC's database of surface and upper-air data
DB2	AFCCC's relational database
E	East
EGA	Enhanced Graphics Adapters
F-117A	Air Force Stealth aircraft
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
MST	Mountain Standard Time
N	North
NE	Northeast
NLDN	National Lightning Detection Network
NW	Northwest
POF	Percent occurrence frequency
S	South
SE	Southeast
SIDEBOX	Number of grid boxes in east-west direction
SOCS	Surface Observation Climatic Summaries
SW	Southwest
W	West
x	Grid-point Cartesian coordinate
y	Grid-point Cartesian coordinate
Z	Zulu (Greenwich Mean Time)