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Lightning Strike Density for the Contiguous United States From Thunderstorm Duration Records

Prepared by D. R. MacGorman, M. W. Maier, W. D. Rust

National Oceanic and Atmospheric Administration

Prepared for
U.S. Nuclear Regulatory
Commission

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ABSTRACT

An improved lightning ground strike climatology has been obtained from thunderstorm duration data recorded by 450 air weather stations. From lightning strike location data collected in Florida and Oklahoma, it was found that strike density could be estimated from thunderstorm duration by the equation $N_s = 0.054H^{1.1}$, where N_s is the number of strikes per square kilometer and H is thunderstorm duration in hours. This relationship was applied to thunderstorm duration data from the aviation stations to obtain lightning strike density for the contiguous United States.

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1. INTRODUCTION

Designing for protection against lightning requires knowledge of the probability that lightning will strike a given location and of the probability that a given strike will cause a certain level of damage. There have been several studies of lightning current waveforms, which determine the probability that a particular structure will sustain a given severity of damage. A discussion of lightning current waveforms and lightning damage has been presented in a previous report (Ref. 7). The probability that lightning will strike a given location is provided by annual lightning ground strike densities, but direct climatological measurements of lightning strike densities are not yet available. The only data that have been readily available for the United States have been compilations of thunderstorm day, which is defined as the number of days during which thunder is heard at a given location. There have been several attempts to infer lightning strike probabilities from thunderstorm day statistics. As an indicator of strike probabilities, however, the thunderstorm day has a number of problems:

1. It takes no account of the duration of lightning activity, but equates days having a few minutes of lightning activity with days having long-lived storms.

2. It ignores the variability of lightning flash rates.

3. It ignores whether the lightning that occurred struck ground.

4. It includes lightning over an area that varies from day to day, depending on how far thunder can be heard and how diligently it is noted. The farthest lightning on a tabulated day could be anywhere from less than 1 km to more than 20 km from the station.

Of these problems, only the first can now be readily taken into account for a sufficient time and area to be widely useful in engineering design. The duration of thunderstorm activity is routinely recorded by aviation weather stations, but has not been tabulated in climatic data bases. It is the intent of this study to use thunderstorm duration data to produce a more accurate map of lightning ground strike density for the contiguous United States.

Our strategy to attain this objective included two initial tasks. The first was to collect lightning ground strike location data in two locales with different climatologies. We then performed a regression analysis on the data to find functions relating lightning ground strike density to both thunderstorm duration and thunderstorm day. As we expected, a better fit could be obtained with thunderstorm duration.

The second task was to compile a data base from a nationwide network of stations in order to determine thunderstorm duration statistics for the 48 contiguous states. Weather records from aviation stations were examined by the National Climatic Center, as discussed by Changery (Ref. 1), to compile start times (when thunder was first heard) and end times (when there had been no thunder heard for fifteen minutes). We analyzed these times to determine the mean annual thunderstorm duration at each station. These duration data were then combined with the relationship between lightning ground strike density and thunderstorm duration determined in the first task to produce a map of mean annual lightning strike density in the contiguous United States. The resulting map of lightning strike density, when combined with the earlier discussion of lightning currents by Maier and his colleagues (Ref. 7), should provide engineers with an improved data base to use in designing for reliable operation during thunderstorms.

2. DATA COLLECTION

2.1 Instrumentation

The equipment used to locate lightning ground strikes for our first task was a Lightning Location and Protection, Inc., system described in detail by Krider and his colleagues (Refs. 5 and 6). The configuration of the system we used consisted of two or three remote stations connected to a central processor. Each station analyzes electromagnetic waveforms to reject intracloud flashes and to determine directions to lightning ground strikes. Strike azimuths are transmitted to a central processor that locates strike points by triangulation and records the locations and various lightning parameters on a printer and on magnetic tape. Random errors in the determination of azimuths by each station appear to be ±1-2° based on studies of the repeatability of azimuths for multiple return strokes (i.e., multiple large current surges through the same channel). Systematic errors in azimuths caused by anomalies at a given site may be larger, but can be subtracted once they are determined.

During this project, the system was capable of detecting only lightning strikes that lowered negative charge to ground. Lightning strikes lowering positive charge are less frequent. Preliminary results from field programs subsequent to those in this project suggest that these positive ground flashes comprise anywhere from a few percent to a majority of ground strikes in a storm, with the most frequent value being roughly 5-10%.

2.2 Field Experiments

In order to test whether a mathematical function might be found to relate lightning strike density to thunderstorm duration across the contiguous United States, two sites having different climatologies were chosen for the field experiment. The formation of storms at the first site, in southern Florida, is dominated by dynamics associated with the sea breeze. Temperature differences between land and sea often aid the formation of zones of convergence, leading to the formation of storms. Storms are most frequent during the summer months. At the second site, in central Oklahoma, this coastal forcing mechanism for storms is absent. Instead, the formation of storms relies more heavily on large-scale mechanisms, such as frontal boundaries or mid-level cooling, to aid in the development of convection, especially during the spring. Furthermore, moisture is not as readily available, but must be transported several hundred kilometers from the Gulf of Mexico. Storms are most frequent in the spring, with a secondary maximum in the fall.

An additional consideration in the choice of these particular sites was the existence of substantial field programs that could provide radar data and other observations of value to this study. The lightning strike observations in Florida were a part of the Florida Area Cumulus Experiment. The observations in Oklahoma were in conjunction with the annual spring field program of the National Severe Storms Laboratory.

2.2.1 Florida Experiment

Our analysis for southern Florida used lightning strike data that were collected during the summer of 1978, from June 15 through September 1. There were two stations arranged as shown in Figure 1. Data were recorded for 220,000 flashes during 1,103 hours of observations. Site anomalies did not cause systematic errors in azimuth determinations that were large enough to be obvious in plots of the data, and lightning strike locations generally agreed well with the location of the radar echoes from storms. During the season, it was discovered that one antenna was not properly aligned, creating a directional error that was constant at all azimuths, but this error was corrected in our analysis.

2.2.2 Oklahoma Experiment

Lightning strike location data in Oklahoma were collected between April 1 and June 1 in 1980. There were three stations arranged as shown in Figure 2. During data collection, patterns appeared in the real-time plots of data from the station at Norman that are characteristic of appreciable systematic azimuthal errors near a baseline. Since the antenna for this station was on a large building, which can introduce azimuthally varying distortions into the measurement of direction to a lightning strike, these systematic errors were not surprising. To estimate the errors, we assumed that the other two stations had relatively small systematic errors, consistent with the more favorable appearance of the sites and with the lack of obvious systematic errors in real time plots of data from these two stations. By comparing the locations computed from these two stations with the azimuths determined by the station at Norman, we were able to compute corrections for all azimuths from Norman. When the azimuths were corrected in new calculations of strike locations, the characteristic pattern near baselines disappeared, suggesting that the corrections were reasonably accurate. Furthermore, the new strike locations agreed well with the location of radar echoes and with the location of a limited number of strikes recorded on video tape.

3. DATA ANALYSIS

3.1 Lightning Data Preparation

Before beginning the regression analysis, it was first necessary to correct the data as much as possible. The previous section on instrumentation briefly describes corrections that were made to the azimuth measurements of individual stations in Florida and Oklahoma. In addition, we attempted to correct the data for limitations in the lightning strike locating technique that we used. Two corrections were made.

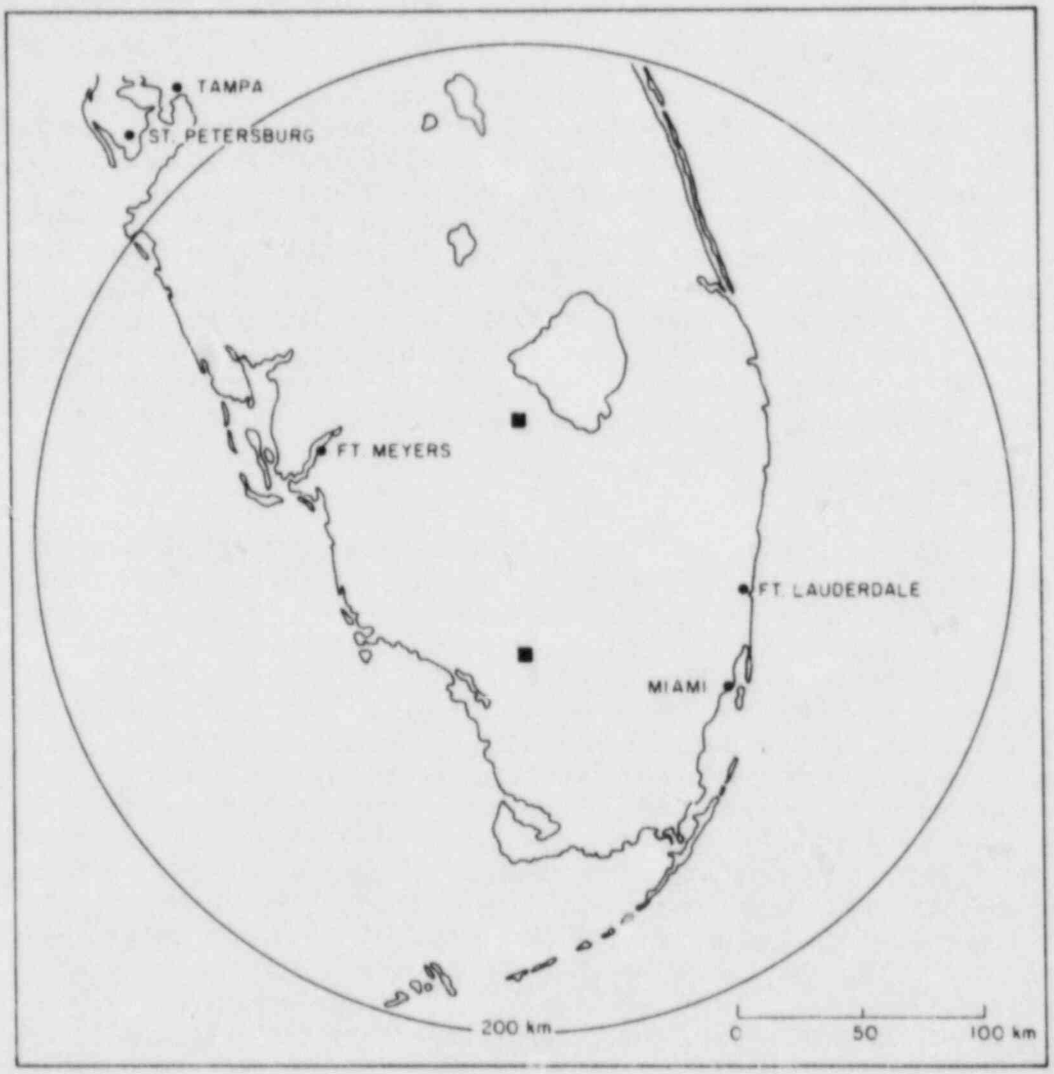

Figure 1. Location of lightning strike locating stations in Florida during 1978. The circle denotes the nominal range of the system.

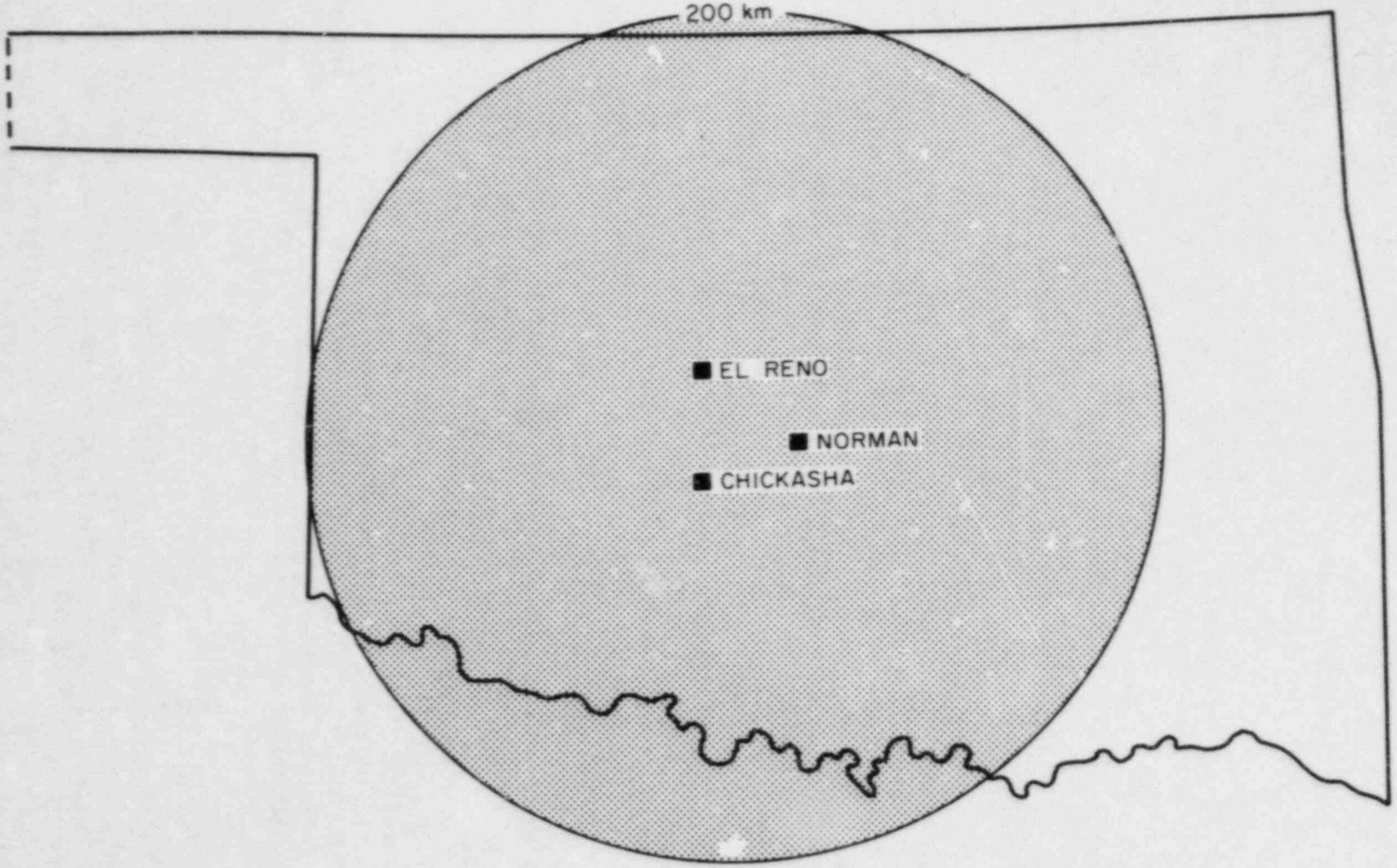

Figure 2. Location of lightning strike locating system in Oklahoma during 1980. The shaded circle indicates the nominal area of coverage of the system.

The first correction addressed the problem of detection efficiency. To determine this correction, two approaches were taken. First, all-sky video recordings of lightning strikes were made at several locations in Florida and Oklahoma. Records from the lightning strike locating system were then searched to see what percentage of the strikes recorded on video were detected by the locating system: 70-85% was typical at ranges within 100 km. Second, we developed an analysis using the lightning location data alone to estimate how rapidly detection efficiency decreased at longer ranges. In this analysis, we plotted peak amplitude, normalized to remove dependence on range, versus the range of the strike point for a large ensemble of lightning strikes. As range increased, there were increasingly larger amplitudes below which no strikes were observed because of the threshold of the locating system. By assuming that the distribution at 50 km was the actual distribution, we could then determine what part of the distribution was missing at longer ranges and so estimate a detection efficiency.

The resulting plot of detection efficiency versus range is shown in Figure 3 for both the Florida network with 2 stations separated by 96 km and the Oklahoma network with 3 stations separated by approximately 50 km. The decrease in detection efficiency at short ranges is due to saturation of station electronics by local lightning. The better detection efficiency in Florida relative to Oklahoma at ranges beyond 300 km may be due to better propagation of electromagnetic waves over sea water compared with propagation over land, as discussed by Weidman and Krider (Ref. 10). The triangles indicate detection efficiency estimated from video recordings of lightning strikes. The wide variation in efficiencies from the video recordings could be caused simply by the smallness of the sample size. The curves shown in Figure 3 were used to estimate how much to increase the number of lightning strikes at ranges beyond 50 km.

The second correction concerned multiple strike points for a single lightning flash. It is possible for a single lightning flash to strike ground at more than one point. Since we are more interested in the number of strikes per square kilometer than in the number of flashes striking ground, it is desirable to correct for instances when the locating system finds one strike point for a flash, but more than one exists. Accordingly, the above-mentioned all-sky video records were analyzed by Maier (Ref. 8) to determine what fraction of cloud-to-ground lightning flashes have two strike points close together. It was found that the mean number of strike points per ground flash was 1.39, and the number of strikes in our data base was increased accordingly.

3.2 Regression Analysis

There were no thunderstorm day or thunderstorm duration data collected for many of the regions and time periods in which lightning strike locations were determined. Therefore, to obtain an adequate data base for determining relationships between lightning density and the two measurements of thunderstorm activity, it was necessary to simulate what a weather station would report, given the lightning strike records. Grid points on a 200 x 200 km grid with 25 km spacing were chosen as model stations at each of the two sites.

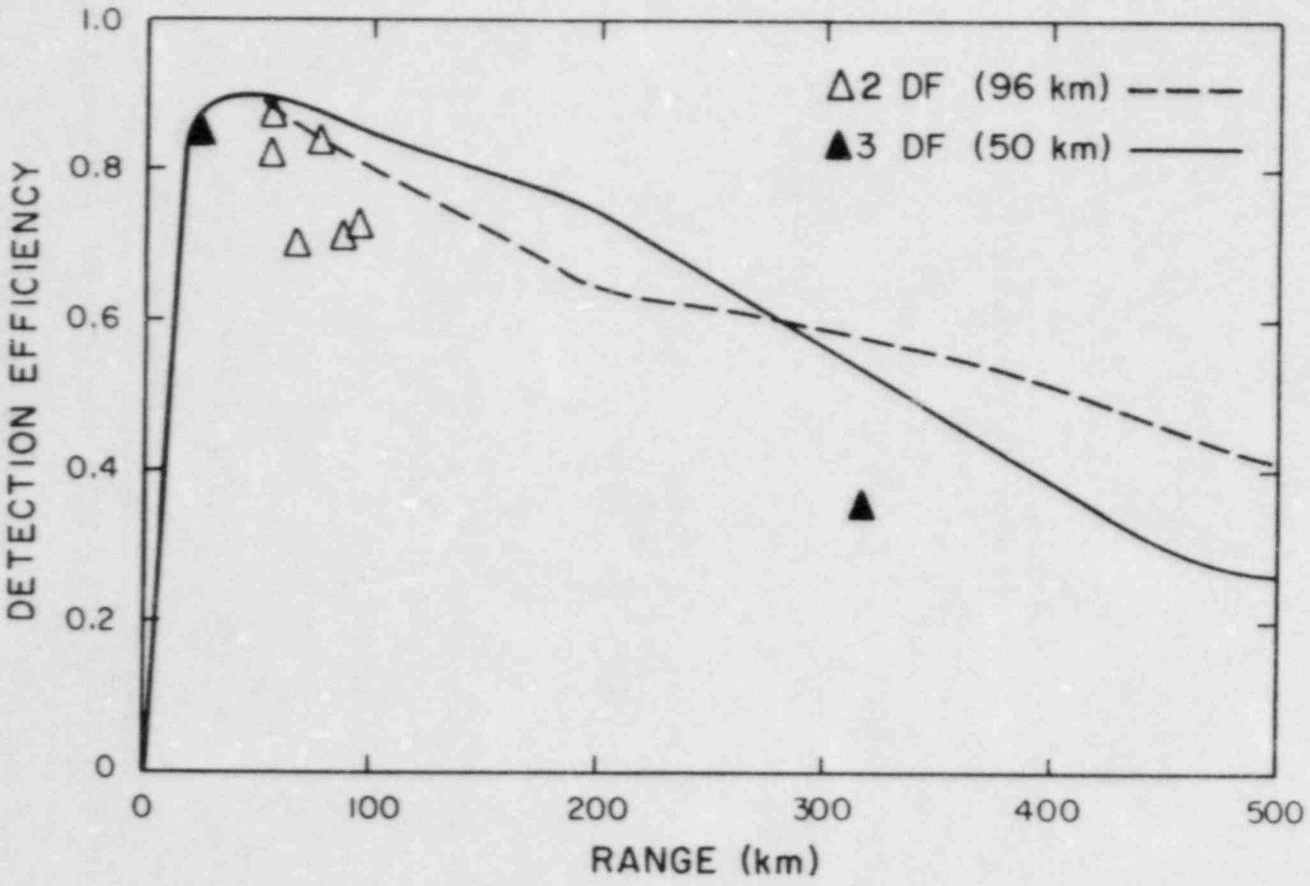

Figure 3. Estimated detection efficiency for the lightning ground strike locating system as a function of range.

Since the weather stations base their observations on thunder detection, this analysis required that we first estimate an average range from a lightning flash over which thunder would be heard. Therefore, we simulated what each model station would report, based on the measured lightning strike locations, if the average distance over which thunder was detected were 8 km, 10 km, 12 km, etc. At selected model stations, these simulated reports were then compared with actual reports from weather stations near Oklahoma City and Tulsa in Oklahoma; Palm Beach, Ft. Meyers, and Miami in Florida. It was found that the simulated and actual reports matched best when it was assumed that the average range over which thunder could be detected was 14 km. (One should be cautious in ascribing much significance to this range of detection, since the actual durations recorded probably were lengthened relative to the simulated durations by including intracloud as well as cloud-to-ground lightning.)

Using 14 km as the range of detection for thunder, we compiled simulated records of thunderstorm day and thunderstorm duration at all the model weather stations. Each station, then, had a lightning strike density, a number of thunderstorm days, and a number of thunderstorm hours. Regression analyses were performed with these data to fit a function of the form

$$N_s = AT^B \qquad (3\text{-}1)$$

where N_s is the number of strikes per square kilometer, T is the number of thunderstorm days or thunderstorm hours and A and B are to be determined. For thunderstorm day, the resulting function is

$$N_s = 0.01D^{1.62} \qquad (3\text{-}2)$$

in Florida, with a correlation coefficient of 0.56, and

$$N_s = 0.14D^{1.03} \qquad (3\text{-}3)$$

in Oklahoma, with a correlation coefficient of 0.52. Figure 4 shows a plot of the data from each station and the curves that we fit to the Florida and Oklahoma data for thunderstorm day.

For thunderstorm duration in hours, the functions that were obtained are

$$N_s = 0.03H^{1.22} \qquad (3\text{-}4)$$

in Florida, with a correlation coefficient of 0.67, and

$$N_s = 0.09H^{0.98} \qquad (3\text{-}5)$$

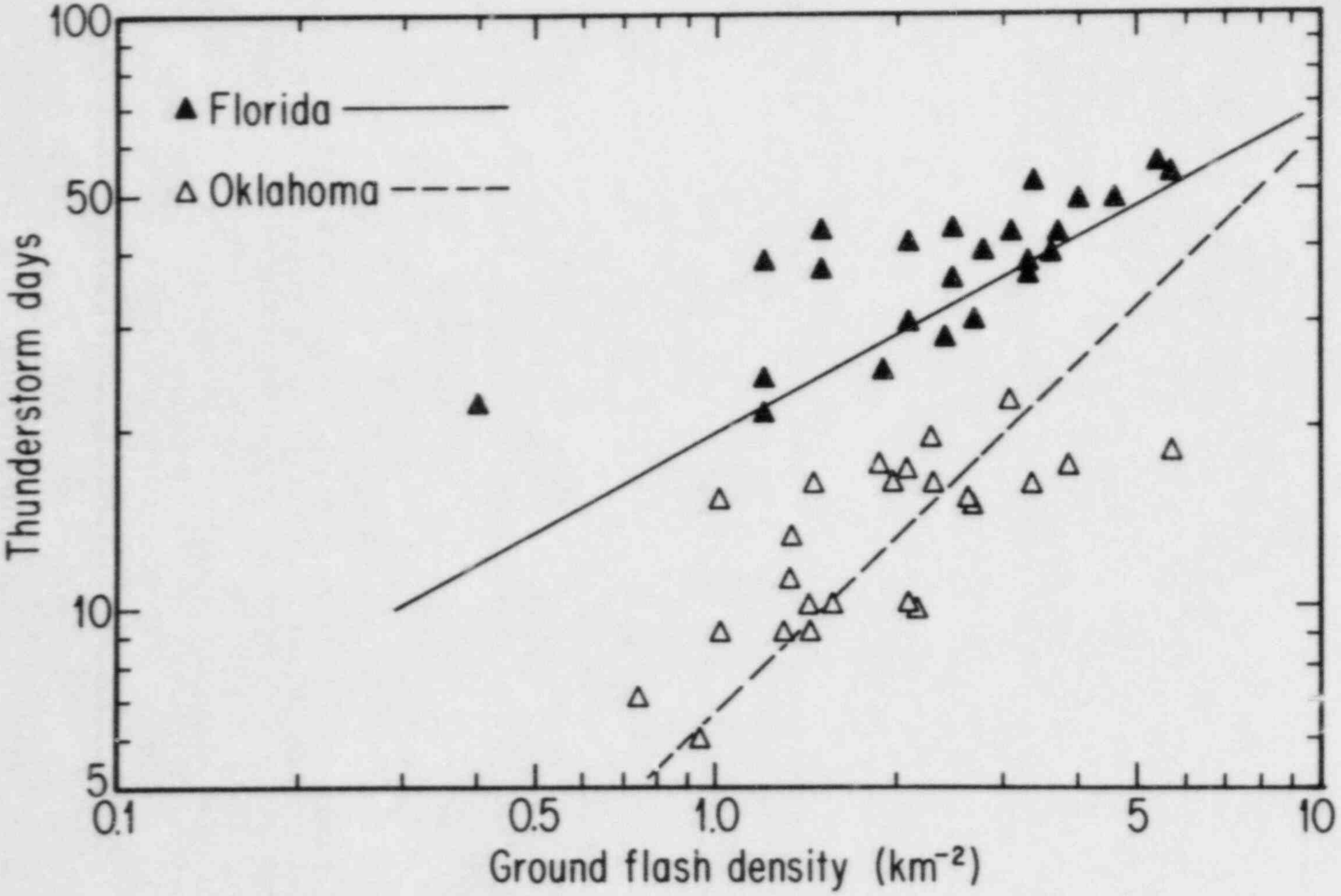

Figure 4. Regression analysis for thunderstorm day.

in Oklahoma, with a correlation coefficient of 0.71. Figure 5 shows a plot of the data and of the regression curves for thunderstorm duration. In both Florida and Oklahoma, the regression on thunderstorm duration has a higher correlation coefficient than the regression on thunderstorm day, implying that thunderstorm duration is better correlated with lightning strike densities.

The last step in this part of the analysis was to obtain a function, similar to the above, that describes the relationship between thunderstorm duration and lightning density for the combined Florida and Oklahoma data sets. In this combining of the data sets, data were included from earlier studies that compiled thunderstorm duration statistics in Florida, one at Tampa (Ref. 3) and one at Pittsfield (Ref. 4). A line was then drawn that appeared to give a reasonable fit to all of the data. The resulting line, shown in Figure 5, is described by

$$N_s = 0.054H^{1.10} \qquad (3\text{-}6)$$

An exponent for H of nearly 1 agrees well with studies in Europe discussed by Prentice (Ref. 9). Note that, for a given value of thunderstorm duration, there is often a spread of a factor of 2 to 3 in the corresponding values of ground flash density and there is an apparent trend for the largest values of flash density to be in Oklahoma.

3.3 Aviation Station Data

Analysis for the second task, to compile thunderstorm duration statistics nationwide, was based on data from aviation weather station records. As noted previously, aviation stations routinely record times when the first thunder from a storm is heard and when fifteen minutes have elapsed since the last thunder. Changery (Ref. 1) compiled these start and stop times for 450 stations nationwide. Most stations had recorded data continually for 30 years, but all had a period of record of at least eight years.

The distribution of the stations, shown in Figure 6, was somewhat denser in the eastern half of the country than in the western half. There are some areas in the western states where stations are sparse enough that significant variations in the lightning data may have been missed. This is particularly true near mountainous regions where topographic effects will cause significant weather variations over relatively short distances. Changery (Ref. 1) attempted to compensate for station sparsity by including supplemental stations with records covering a shorter period and by subjectively adjusting the data in mountainous regions to account for the effects of topography. This compensation has not been made in our study.

We analyzed the data base of start and stop times compiled by Changery to determine the mean annual number of thunderstorm days and thunderstorm hours at each station. A table giving these data and the period of record for all 450 stations is included in the Appendix. We also

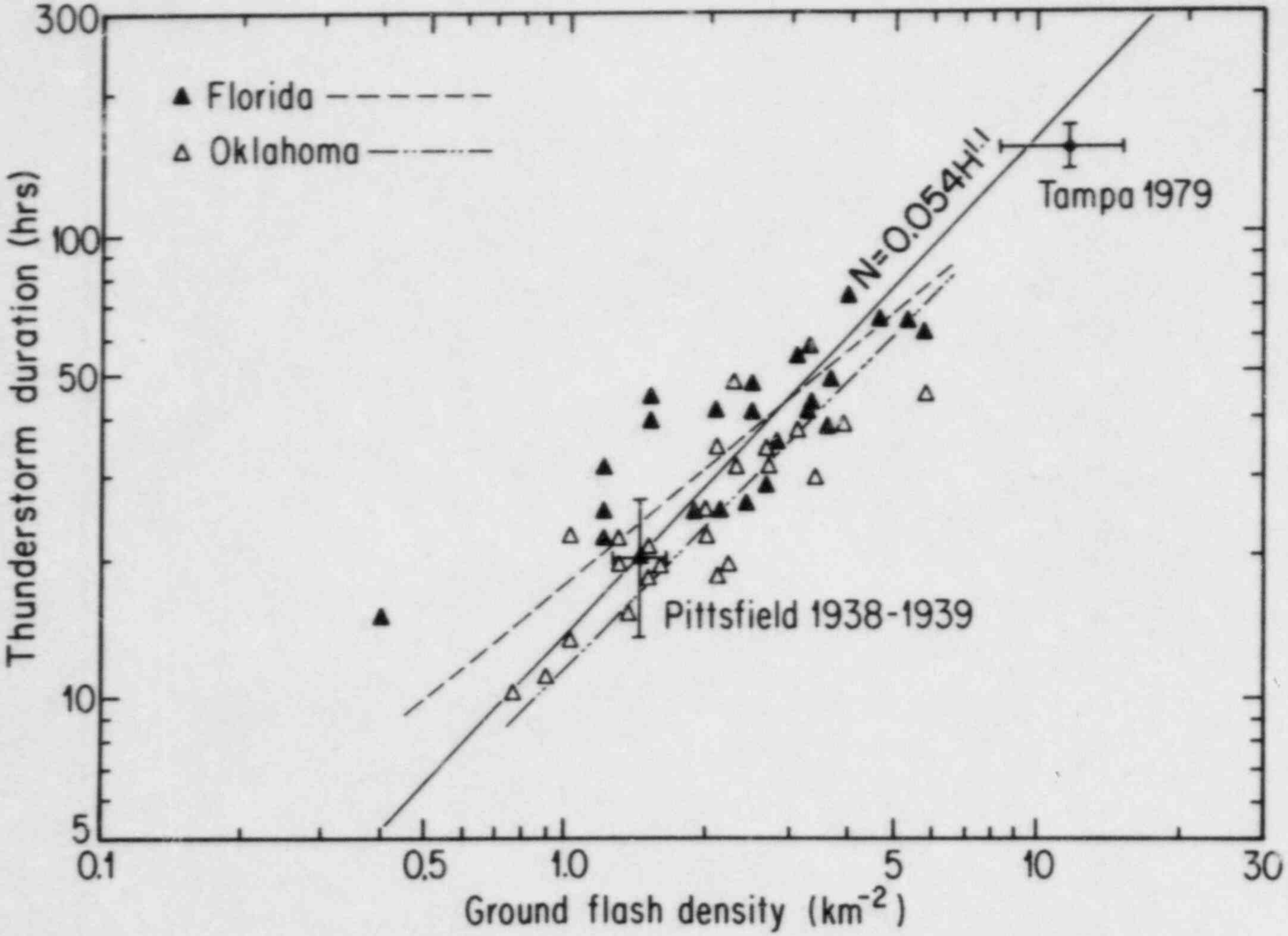

Figure 5. Regression analysis for thunderstorm duration.

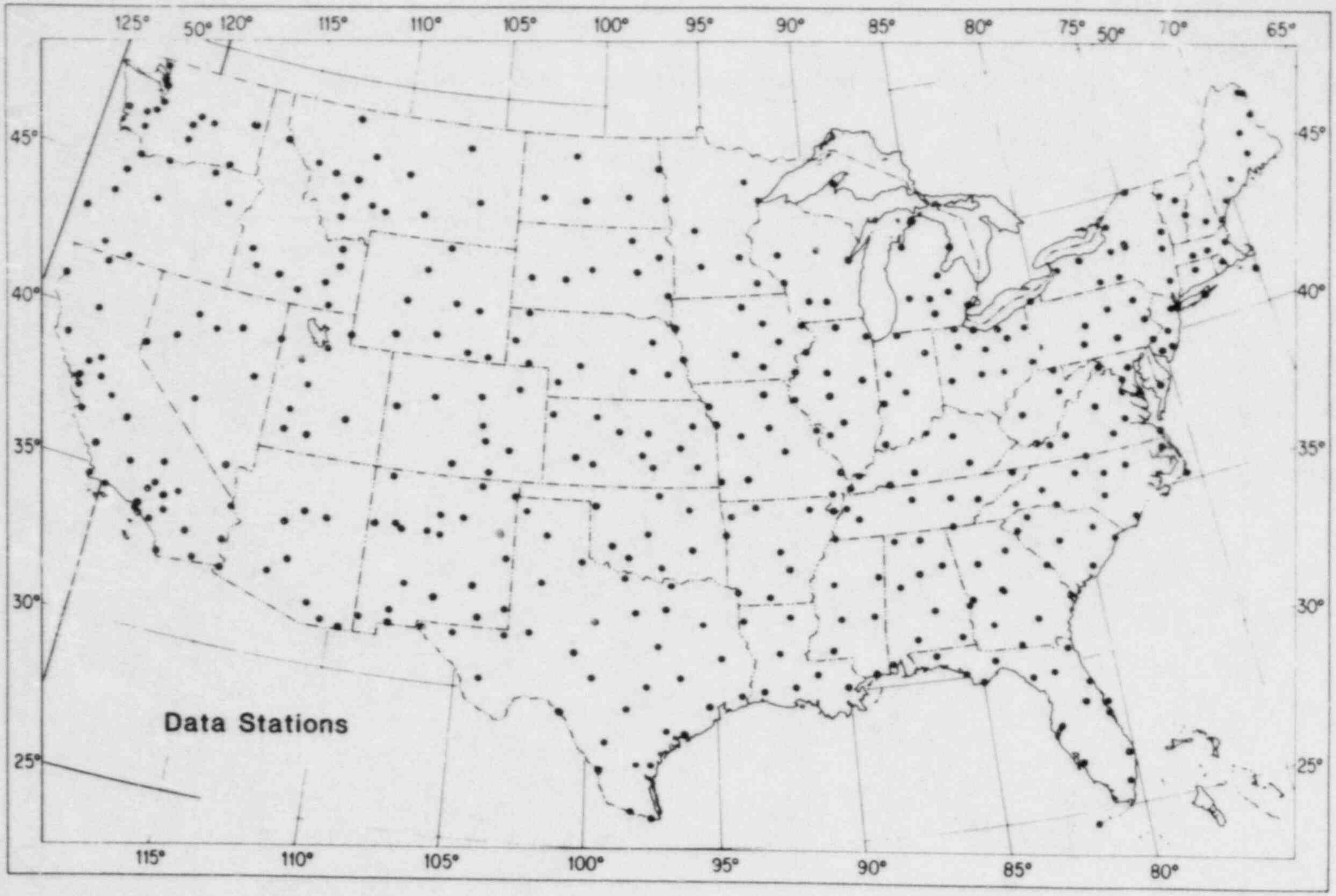

Figure 6. Map of analyzed aviation weather stations.

produced contoured maps of thunderstorm day and duration; Figure 7 shows mean annual thunderstorm days, and Figure 8 shows mean annual thunderstorm duration in hours. While the contour map of thunderstorm duration has many features similar to the map of thunderstorm day, it also has significant differences: values of thunderstorm duration fall faster as one moves westward through the western states, and there are larger relative maxima in north central Arizona, northeastern New Mexico, southeastern Texas, and from eastern Kansas and western Missouri through eastern Arkansas. These differences are caused in part by regional variations in the mean duration of thunderstorm events (the mean start to stop time), shown in Figure 9, and in part by variations in the mean number of storms (see Appendix).

3.4 Lightning Ground Strike Density

Once the two initial tasks were completed, the determination of lightning ground strike density was straight forward. We simply took the mean annual thunderstorm duration at each station and calculated a lightning ground strike density from Equation 3-6. The resulting mean annual lightning ground strike densities are shown plotted as contours on a map of the contiguous United States in Figure 10.

To get an idea of the year-to-year variability in the calculated lightning ground strike density, we examined the data from Tampa, Florida, in greater detail. Shown in Figure 11 are the calculated values of annual ground strike density for each of the thirty years of record. The standard deviation in this case is approximately 5 km^{-2}, or 40% of the mean, and the maximum strike density is almost twice the mean. The trend for ground strike density to increase until 1971 at Tampa is only regional. Decreasing and level trends are observed at other stations during this interval. An analysis of regional trends in thunderstorm day statistics is presented by Changnon and Hsu (Ref. 2).

The effect that this variability would have had on observation intervals shorter than 30 years is shown in Figure 12. For a given number of sequential years of observation, there are a number of sets that can be derived from the thirty years of record, and for each of these sets a mean annual strike density can be calculated. Since, for example, there are 27 possible combinations of three sequential years in the 30 year total, we can obtain 27 values for mean annual lightning strike density. At each number of sequential years on the abscissa the solid curve shows the total spread in values, and the dashed curve shows the minimum spread from 50% of the possible time periods. In one year of observation, for example, the value of flash density could have been anywhere from 0.4 to twice the 30 year average, while in six years, it could have been half to 1.5 of the 30 year average.

3.5 Peak Current

To determine the probability that there will be a lightning strike having an electric current with a certain amplitude, duration, and rise time, one needs to combine the estimates of lightning strike density from this study with information on lightning current characteristics. A previous report discusses these characteristics in some detail (Ref. 7).

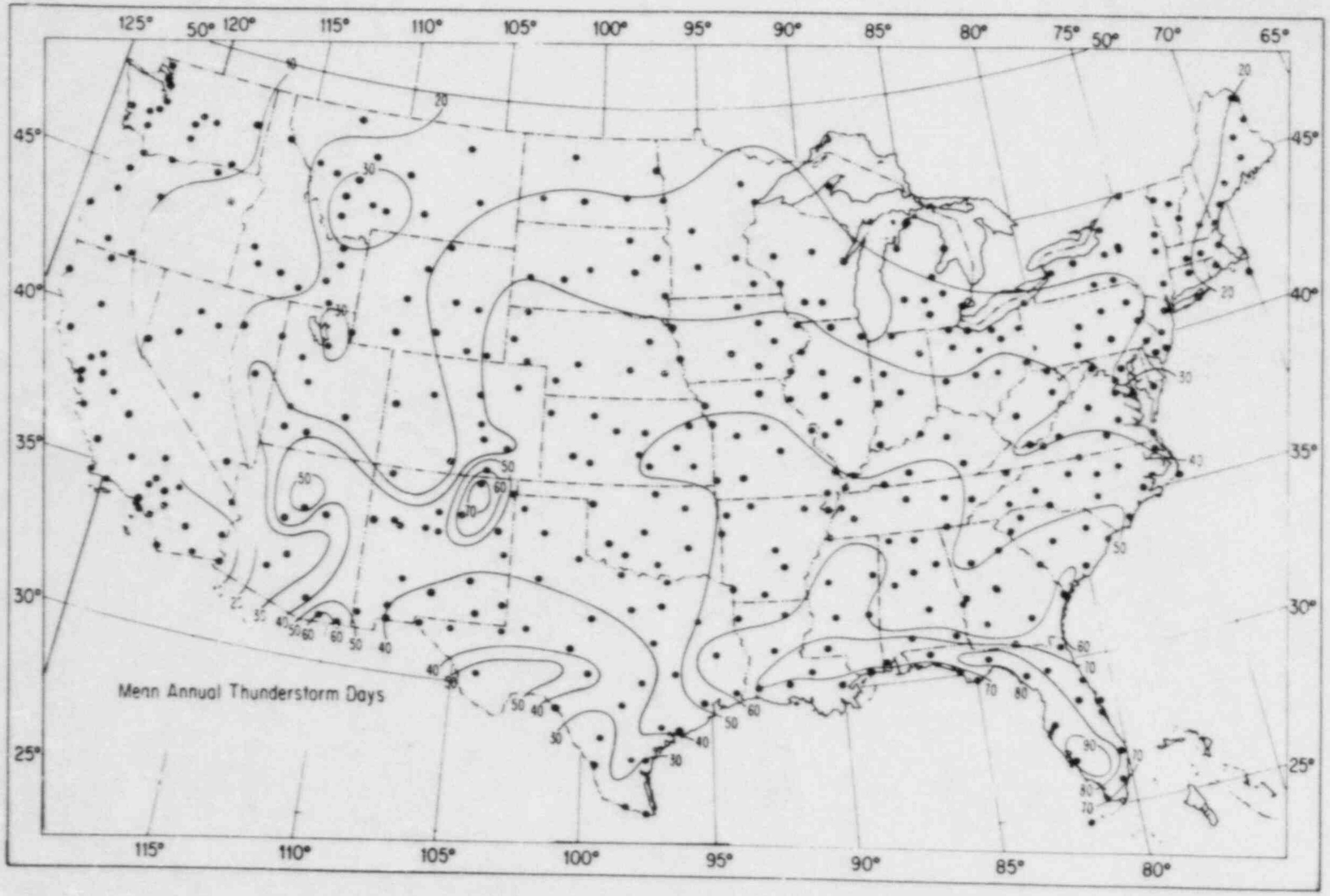

Figure 7. Contour map of mean annual thunderstorm day.

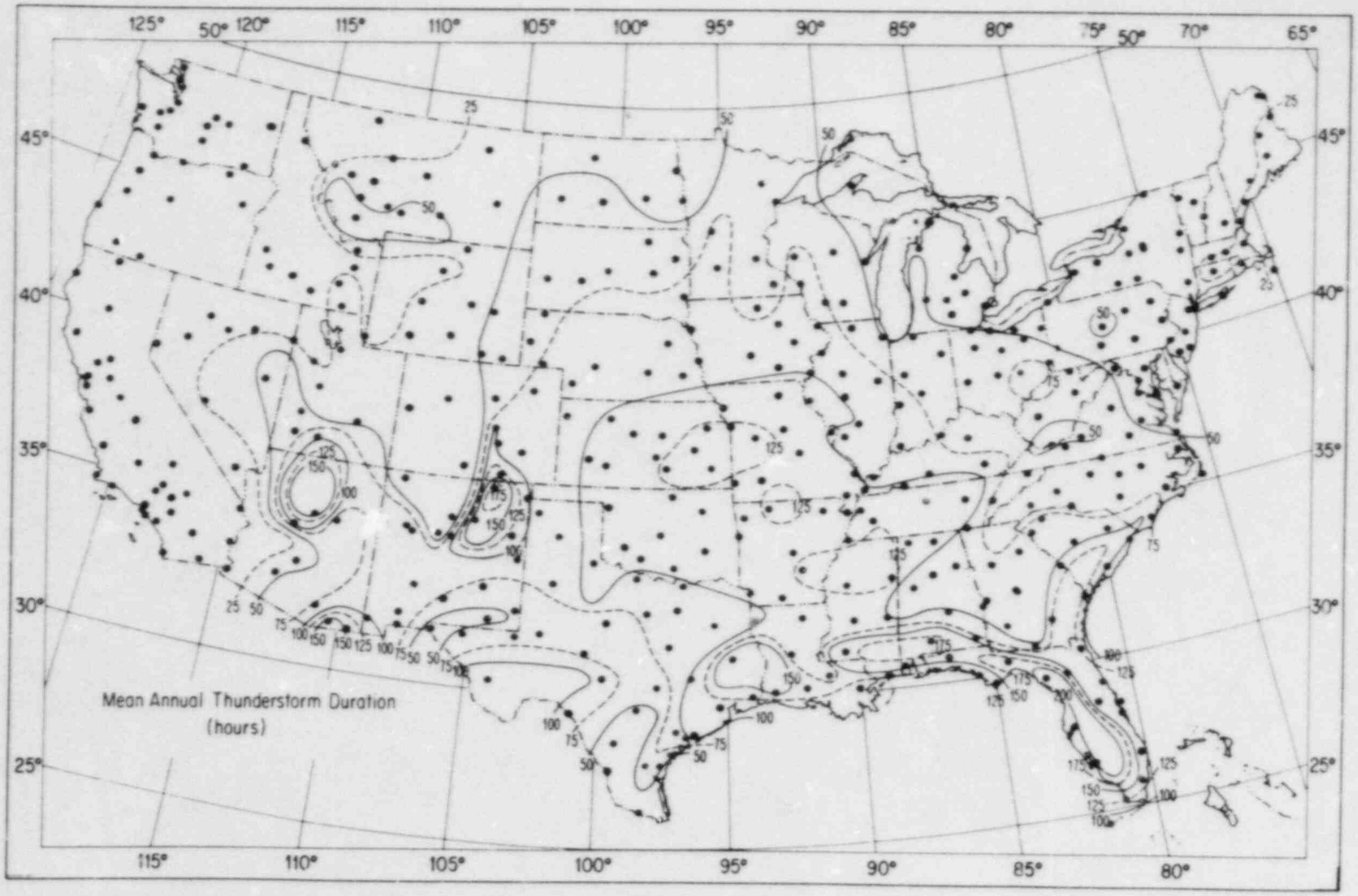

Figure 8. Contour map of mean annual thunderstorm duration.

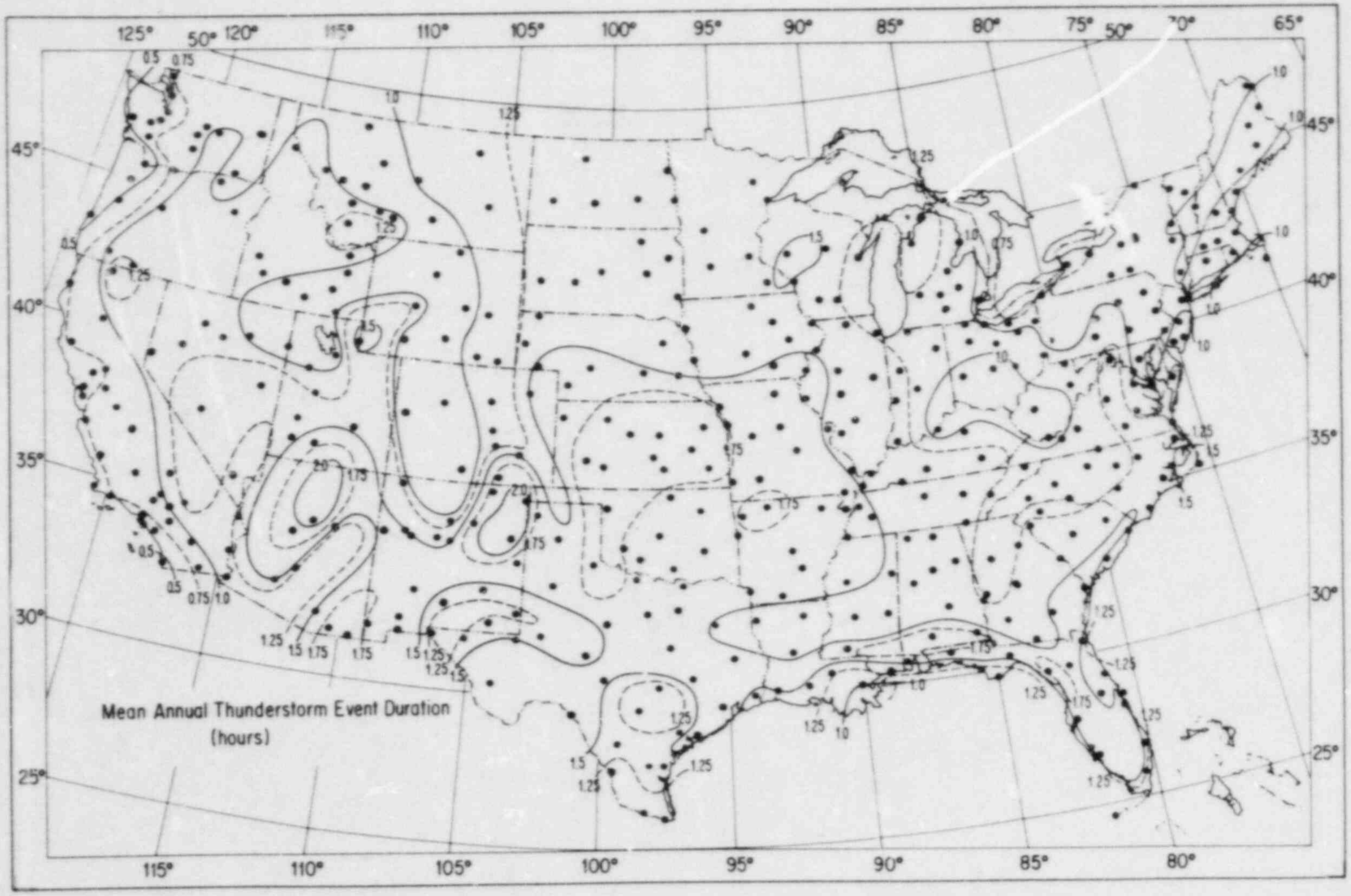

Figure 9. Contour map of mean thunderstorm event duration.

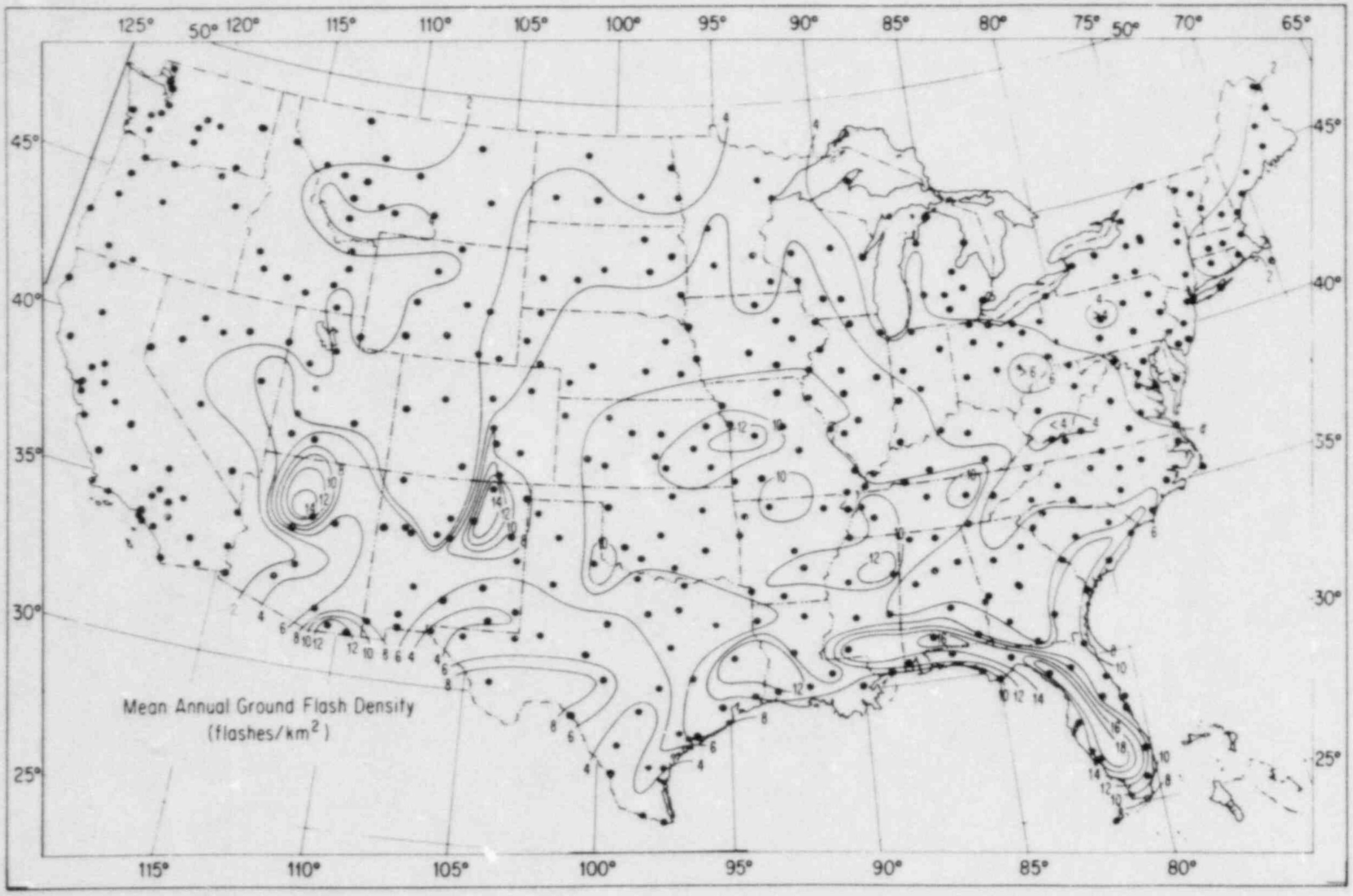

Figure 10. Contour map of mean annual lightning strike density.

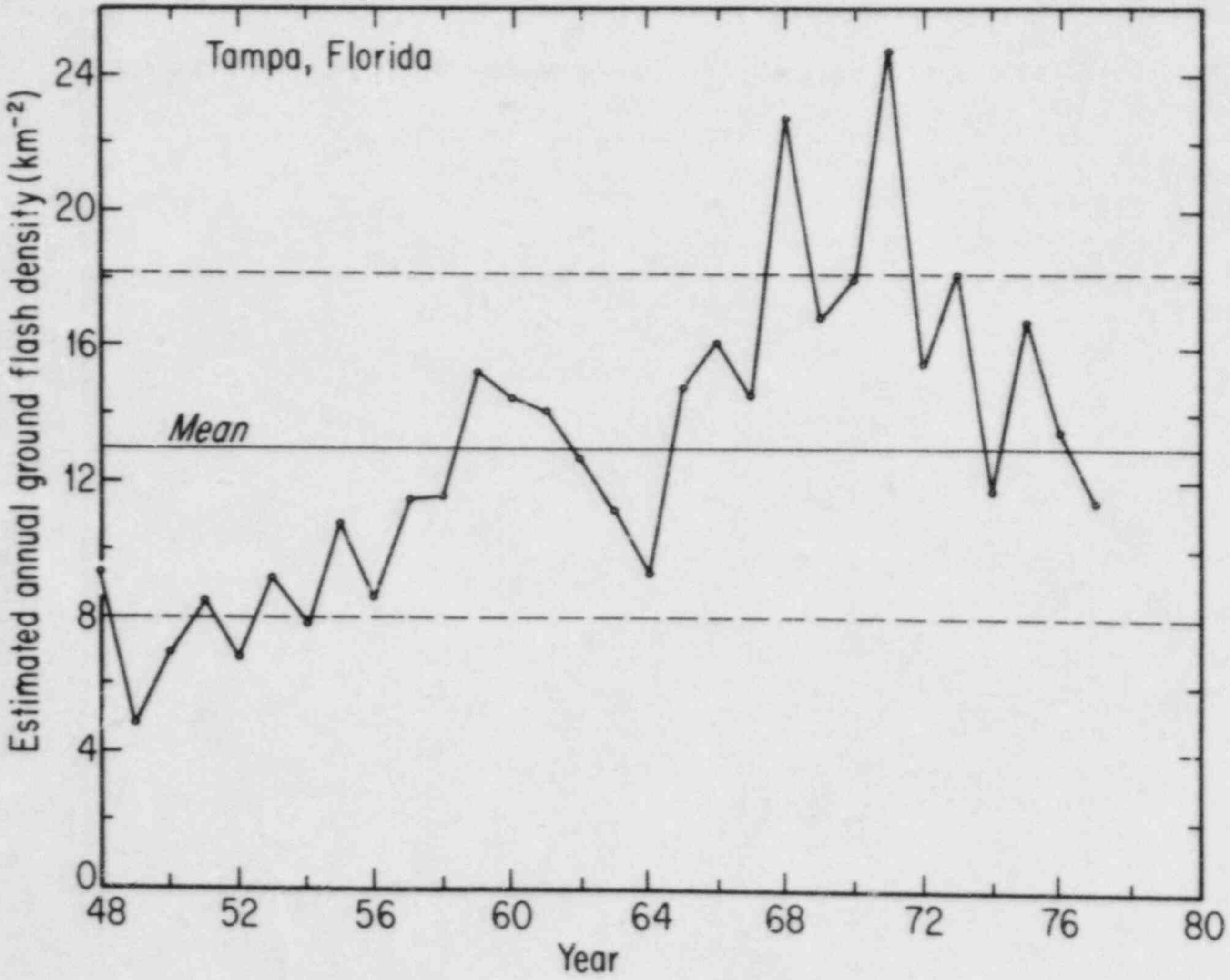

Figure 11. Estimated annual lightning strike density at Tampa, Florida, for a 30 year period. Dashed lines denote the standard deviation.

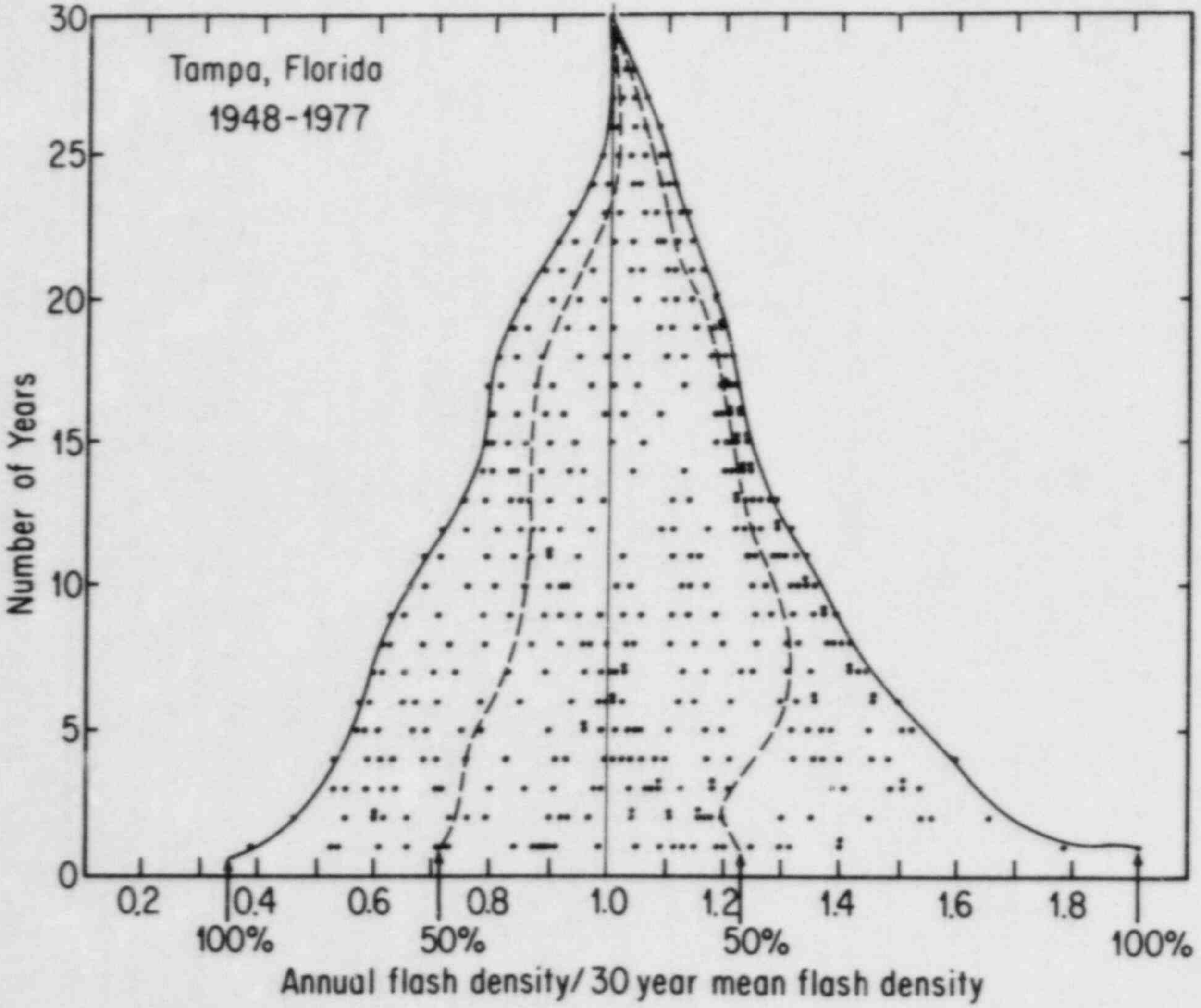

Figure 12. Variations in mean annual strike density for different periods of record at Tampa, Florida.

Figure 13 shows the cumulative probability distribution of peak electric fields and currents that we have estimated from the lightning strike locating system in Florida and Oklahoma. To minimize the effects of distance, caused by smaller signals falling below the threshold of the system, flashes were included in this analysis only if the strike point was within 50 km of one of the stations in the system. There were 7,650 flashes from Florida and 6,866 from Oklahoma. The peak fields, normalized to a range of 100 km, were 7.5 V/m and 5.4 V/m, respectively, with corresponding median peak currents of 38 kA and 27 kA.

Peak currents for the distribution were estimated from the measured peak electric fields by modeling the return stroke current surge in a lightning channel to ground, as described by Uman and others (Ref. 11). These calculated peak currents will vary, depending on the value of the return stroke velocity used in the model. For example, if one assumes that the velocity is 6×10^7 m s^{-1} instead of 1×10^8 m s^{-1}, the median peak current will be 62 kA instead of 38 kA in the Florida data and 45 kA instead of 27 kA in the Oklahoma data. Although the peak fields that were measured in Oklahoma are somewhat smaller than those in Forida, it is possible that there were compensating differences in return stroke velocities between the two locales.

4. CONCLUSION

The distributions of peak currents in Figure 13 agree fairly well with distributions found in other studies, some of which are plotted in Figure 14. These distributions can be combined with lightning strike density statistics to estimate the lightning hazard for a facility. For example, to estimate the probability in Oklahoma City that a facility 300 m on a side would be struck by lightning with a peak current of 200 kA or more, one looks at Figures 13 and 14 to find that approximately 1% of all lightning strikes have currents this large. Since Oklahoma City was estimated to have 9 strikes per square kilometer, the facility would be struck an average of 0.8 times in a year and would be struck with at least 200 kA once in approximately 125 years. Because of the various uncertainties in estimating lightning strike density, we recommend that engineering standards be based on a higher frequency, perhaps one 200 kA strike in 40-50 years.

The lightning strike density estimates shown in Figure 12 are an improvement on previous estimates in that they are based on thunderstorm duration instead of thunderstorm day. While this reduces the number of uncertainties, there still is no direct, long-term measurement of lightning strike density, and the limitations of our study should be kept in mind when using the data:

1. The relationship between thunderstorm duration and lightning strike density is based on a relatively small data base. Data were collected from only two locations. In each location, data were analyzed for only one year and for only the season of the year when thunderstorms were most frequent.

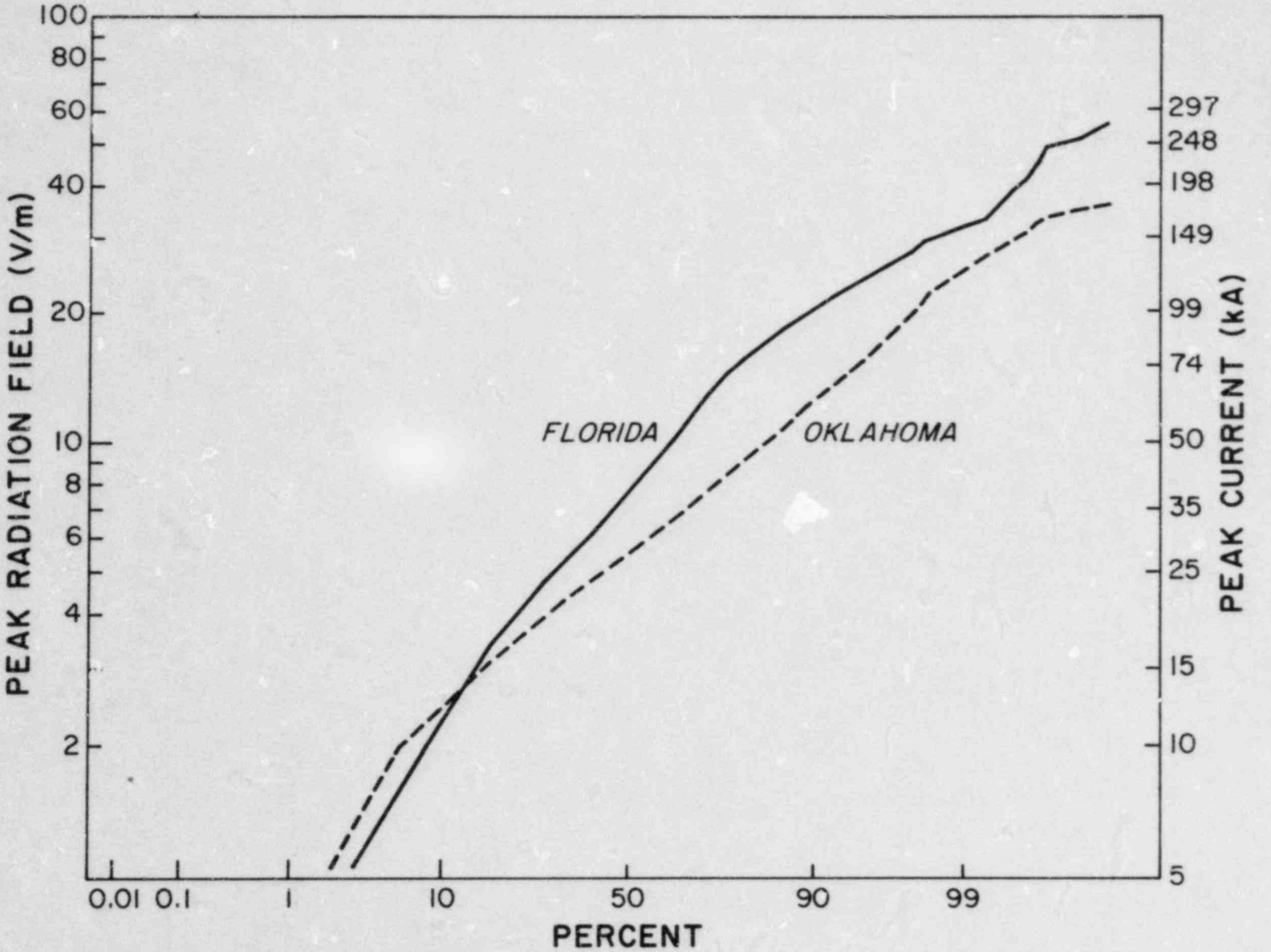

Figure 13. Cumulative probability distribution for peak electric fields and currents in Florida and Oklahoma.

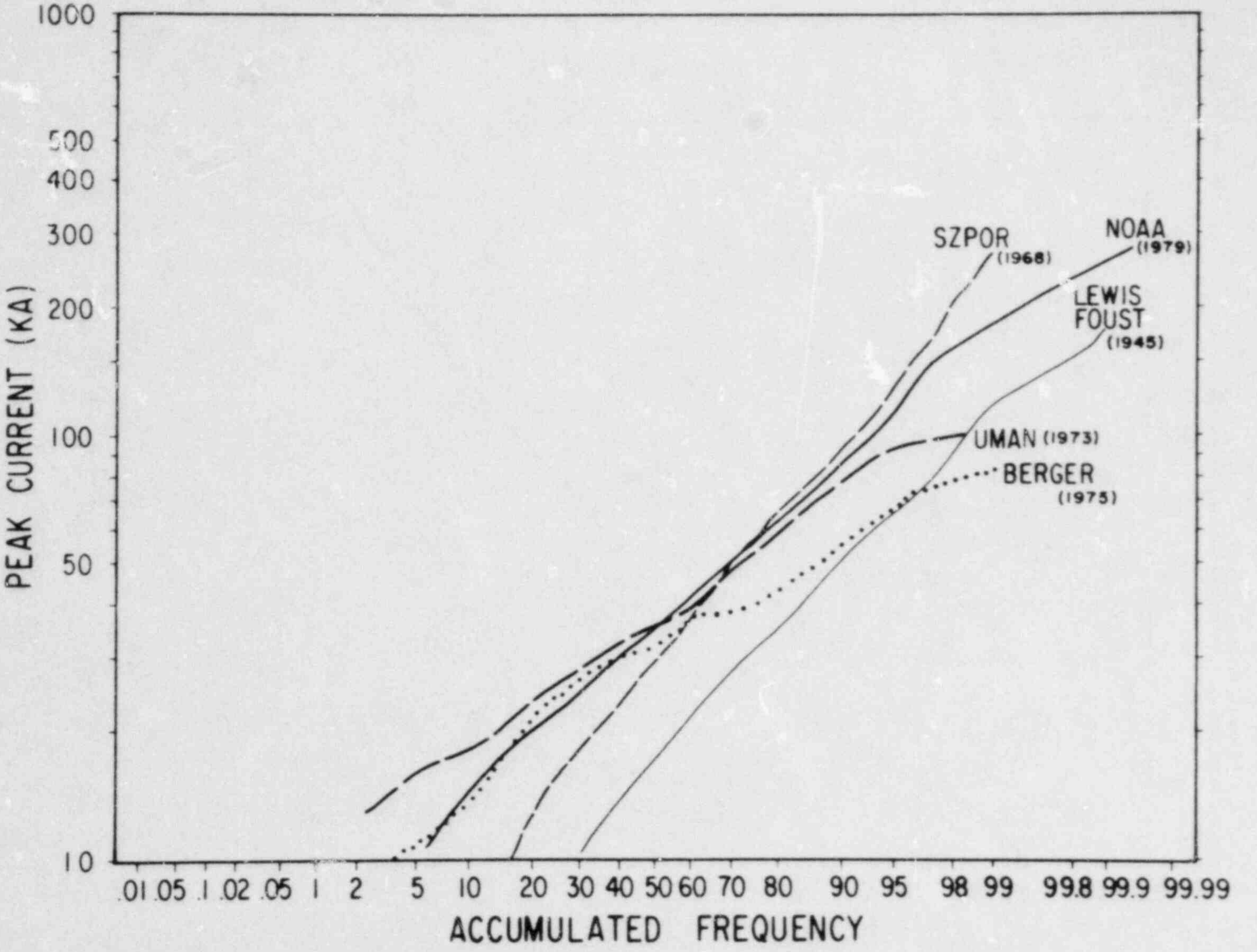

Figure 14. Cumulative probabiltiy distribution for peak electric currents from other studies (Refs. 7, 11, 12, 13, and 14) (taken from Ref. 7).

2. Lightning flashes that lower positive charge to ground were not detected by the locating system used in this project. Omission of this class of ground flashes has three implications. First, equation 3-6 should be revised to give a somewhat higher lightning strike density for a given thunderstorm duration. The scanty data now available suggest that the densities should be increased approximately 10%. Second, studies of the peak electric current in lightning channels to ground may be biased. There is some evidence, such as a study by Brook and his colleagues (Ref. 16), that positive ground flashes tend to have larger currents than negative ground flahses, so present estimates of the probability that a flash will have a large peak current may be too low. Third, the duration of current in the channel to ground tends to be longer for positive ground flashes, and the action integral will also tend to be larger, resulting in greater damage in some circumstances.

3. There are regions in the United States, particularly in western states and mountainous regions, where the density of air weather stations available probably is insufficient to determine all major features in the distribution of thunderstorm duration. Changery (Ref. 1) discusses this and attempts to compensate for it. With this compensation, his contours of thunderstorm events show some features not present in the contours of thunderstorm duration in this study.

4. As discussed in the introduction section, thunderstorm duration has shortcomings as an indicator of lightning ground strike activity. It does not distinguish between lightning that stays within the cloud and lightning that strikes ground or between storms having different lightning flash rates. Also, at a given location, the area over which thunder can be heard and flashes counted varies considerably, typically by a factor of four or more.

5. RECOMMENDATIONS:

There are two options we would like to suggest for improving estimates of lightning ground strike density to use in the engineering design of facilities. The option that is simpler and would yield results more quickly is to broaden the lightning strike data base from which the relationship between thunderstorm duration and lightning strike density is obtained. The data base should be broadened to include positive ground flashes, storms thoughout the year in Oklahoma or Florida or both, and storms from other regions of the United States, such as the western or northeastern states. Lightning strike locating systems are already operating in each of these two regions.

Direct measurements of lightning strike density would provide much better climatological estimates than are possible with the first option. The second option we would suggest, therefore, is to begin gathering direct measurements of lightning ground strike data with the goal of developing a data base suitable for lightning strike climatology. Since the middle 1970's, when the present study began, a number of lightning locating networks have been installed. Much of Alaska and the contiguous United States is now within the observational area of these networks, although the detection efficiency and location accuracy of the different networks may vary significantly. It should be possible for the several federal organizations that have demonstrated interest in these systems to cooperate in improving coverage of the United States and in operating the systems as efficiently as possible. Widespread collection of lightning strike data would improve the data base available for design engineers and could also aid in storm hazard warnings if the data are monitored in real time.

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APPENDIX

Table of Aviation Weather Station Data

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
ALABAMA									
Anniston	33 35	85 51	30	55(7)	76(14)	102(24)	144	60	1.3
Birmingham	33 34	86 45	30	57(10)	84(18)	80(21)	128	42	1.0
Dothan	31 14	85 26	30	59(9)	73(14)	110(30)	162	63	1.5
Evergreen	31 25	87 02	20	73(10)	97(18)	182(50)	298	119	1.9
Huntsville	34 42	86 35	19	54(9)	78(13)	101(20)	134	61	1.3
Mobile	30 41	88 15	30	77(11)	105(23)	153(36)	251	101	1.5
Montgomery	32 18	86 24	30	58(11)	78(15)	101(26)	158	64	1.3
Muscle Shoals	34 45	87 37	30	58(8)	73(12)	99(16)	130	73	1.4
Tuscaloosa	33 14	87 37	30	52(8)	66(11)	82(21)	143	53	1.2
ARIZONA									
Douglas	31 27	109 36	27	52(9)	69(14)	126(28)	180	78	1.8
Flagstaff	35 08	111 40	16	53(8)	70(8)	165(40)	233	100	2.4
Fort Huachuca	31 35	110 20	16	60(6)	93(14)	169(38)	249	120	1.8
Gila Bend	32 53	112 43	19	22(8)	28(12)	46(22)	97	19	1.6
Phoenix	33 26	112 01	30	21(5)	25(6)	27(7)	39	12	1.1
Prescott	34 39	112 26	30	45(7)	64(11)	122(28)	185	79	1.9
Tucson	32 07	110 56	30	38(8)	52(12)	75(23)	116	18	1.5
Winslow	35 01	110 44	30	35(7)	49(10)	58(18)	94	25	1.2
Yuma	32 40	114 36	30	7(3)	8(4)	9(5)	23	0	1.1
ARKANSAS									
El Dorado	33 13	92 48	28	55(9)	72(15)	112(28)	160	66	1.5
Fayetteville	36 00	94 10	28	50(8)	67(13)	111(32)	216	60	1.7
Fort Smith	35 20	94 22	30	53(10)	73(16)	114(34)	186	56	1.6
Harrison	36 16	93 09	21	56(10)	76(13)	137(33)	182	80	1.8
Little Rock	34 50	92 15	30	54(10)	74(17)	104(30)	175	61	1.4
Pine Bluff	34 10	91 56	25	59(10)	77(14)	126(33)	205	82	1.6
Texarkana	33 27	94 00	30	55(9)	74(17)	118(36)	217	70	1.6
Walnut Ridge	36 08	90 56	19	51(7)	70(15)	114(34)	198	55	1.6

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
CALIFORNIA									
Arcata	40 59	124 06	27	5(3)	5(3)	4(4)	16	0	0.8
Bakersfield	35 25	119 03	30	3(2)	3(3)	3(3)	8	0	0.9
Blythe	33 37	114 43	29	8(2)	9(4)	11(5)	24	2	1.2
Burbank	34 12	118 22	30	3(2)	3(3)	2(2)	9	0	0.7
Castle AFB (Merced)	37 22	120 34	30	5(3)	6(4)	4(5)	20	0	0.8
Daggett	34 52	116 47	29	12(5)	14(7)	21(11)	45	5	1.5
Edwards AFB (Muroc)	34 55	117 54	29	5(4)	6(5)	6(6)	23	0	1.0
El Toro MCAS	33 40	117 44	29	4(2)	4(3)	3(3)	11	0	0.8
Fresno	36 46	119 43	30	5(3)	6(3)	5(3)	13	0	0.8
George AFB (Victorville)	34 35	117 23	27	9(5)	10(6)	11(9)	31	0	1.1
Imperial	32 50	115 34	17	4(2)	5(2)	4(2)	8	0	0.9
Long Beach	33 49	118 09	30	3(2)	3(3)	2(2)	6	0	0.6
Los Angeles	33 56	118 23	29	4(2)	4(3)	3(4)	22	0	0.8
Moffett Field NAS (Sunnyvale)	37 25	122 03	30	3(3)	3(3)	2(3)	17	0	0.8
Montague	41 47	122 28	23	8(3)	9(4)	13(8)	31	4	1.4
Needles	34 46	114 37	30	13(4)	15(5)	22(8)	38	7	1.4
Norton AFB (San Bernardino)	34 06	117 15	30	7(4)	8(5)	7(5)	18	0	0.8
Oakland	37 44	122 12	30	2(2)	2(2)	1(1)	4	0	0.5
Palmdale	34 38	118 05	26	5(4)	6(5)	6(6)	19	0	1.0
Paso Robles	35 40	120 38	24	2(2)	2(3)	2(3)	12	0	1.0
Red Bluff	40 09	122 15	30	9(4)	11(4)	11(6)	26	2	1.0
Sacramento	38 31	121 30	29	5(2)	5(3)	5(3)	13	0	0.8
Salinas	36 40	121 36	29	2(1)	2(2)	2(2)	8	0	0.8
San Clemente Island	33 01	118 35	14	2(2)	2(2)	1(1)	5	0	0.7
San Diego	32 44	117 10	30	2(2)	2(2)	1(1)	4	0	0.5
Santa Barbara	34 26	119 50	30	2(2)	3(2)	2(3)	15	0	0.9
Stockton	37 54	121 15	30	3(2)	3(2)	2(2)	6	0	0.7
Thermal	33 38	116 10	27	7(2)	8(3)	8(4)	19	2	1.0
Travis AFB (Fairfield)	38 16	121 56	30	4(2)	4(3)	3(4)	16	0	0.7
Ukiah	39 08	123 12	28	2(2)	2(2)	2(3)	13	0	1.0
Vandenburg AFB	34 23	120 34	16	3(2)	3(5)	2(3)	11	0	0.6

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
COLORADO									
Akron	40 07	103 10	30	45(9)	56(14)	90(31)	153	52	1.6
Colorado Springs	38 49	104 43	29	59(9)	86(16)	95(21)	134	59	1.1
Denver	39 45	104 52	30	39(8)	49(11)	47(18)	94	25	1.0
Eagle	39 39	106 55	30	30(8)	35(11)	37(19)	93	13	1.0
Grand Junction	39 07	108 32	30	33(8)	47(16)	38(17)	92	14	0.8
La Junta	38 03	103 31	30	35(8)	41(11)	58(20)	95	19	1.4
Pueblo	38 17	104 31	30	35(13)	41(16)	46(20)	73	20	1.1
Trinidad	37 15	104 20	29	54(13)	67(18)	117(37)	182	44	1.8
CONNECTICUT									
Hartford	41 56	72 42	30	22(4)	27(6)	22(8)	46	10	0.8
DELAWARE									
Dover AFB	39 08	75 28	23	30(7)	42(11)	45(18)	79	12	1.1
Wilmington	39 40	75 36	30	29(5)	38(7)	34(9)	55	19	0.9
DISTRICT OF COLUMBIA									
Washington	38 51	77 02	30	29(6)	38(10)	28(10)	58	9	0.8
FLORIDA									
Cape Canaveral	28 28	80 33	13	70(10)	93(16)	136(31)	191	80	1.5
Crestview	30 47	86 31	30	76(10)	96(17)	161(28)	210	86	1.7
Cross City	29 38	83 06	19	85(10)	120(17)	221(42)	305	147	1.8
Daytona Beach	29 11	81 03	30	78(13)	108(21)	143(30)	204	83	1.3
Fort Myers	26 35	81 52	29	93(11)	126(18)	212(48)	313	118	1.7
Gainesville	29 41	82 16	17	79(12)	99(13)	152(25)	203	112	1.5
Jacksonville	30 30	81 42	30	62(12)	83(18)	103(42)	195	51	1.2
Key West	24 35	81 42	30	62(9)	91(17)	95(23)	148	43	1.0
MacDill AFB (Tampa)	27 51	82 30	30	82(13)	116(30)	150(48)	272	62	1.3

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
FLORIDA, (continued)									
Melbourne	28 06	80 38	30	67(14)	82(26)	112(48)	209	37	1.4
Miami	25 48	80 16	30	72(14)	107(22)	126(41)	229	47	1.2
Orlando	28 33	81 20	30	78(10)	99(16)	127(30)	196	80	1.3
Pensacola	30 21	87 19	29	65(12)	93(20)	128(34)	208	59	1.4
Tallahassee	30 23	84 22	30	83(9)	113(15)	178(27)	234	119	1.6
Tyndall AFB (Panama City)	30 04	85 35	29	64(9)	93(16)	112(24)	156	73	1.2
Vero Beach	27 39	80 25	30	75(10)	99(14)	142(29)	205	94	1.4
West Palm Beach	26 41	80 06	29	78(12)	113(17)	138(29)	224	78	1.2
GEORGIA									
Albany	31 32	84 11	30	55(10)	71(16)	92(34)	161	35	1.3
Alma	31 32	82 31	24	59(9)	73(15)	128(37)	216	81	1.7
Athens	33 57	83 19	22	52(7)	71(12)	87(16)	122	55	1.2
Atlanta	33 39	84 25	30	46(7)	61(10)	57(12)	79	30	0.9
Augusta	33 22	81 58	30	55(8)	76(13)	101(26)	155	44	1.3
Brunswick	31 09	81 23	30	57(8)	72(11)	122(25)	174	72	1.7
Columbus	32 31	84 56	20	55(10)	73(11)	84(16)	116	57	1.1
Fort Benning	32 21	85 00	28	58(11)	77(17)	95(30)	161	40	1.2
Macon	32 42	83 39	30	56(9)	75(15)	96(23)	168	60	1.3
Robins AFB	32 38	83 36	30	54(9)	68(13)	90(27)	164	53	1.3
Savannah	32 08	81 12	30	63(9)	84(12)	130(28)	190	80	1.5
Valdosta	30 47	83 17	27	62(9)	70(18)	89(30)	165	46	1.3
IDAHO									
Burley	42 32	113 47	30	19(5)	23(9)	21(10)	50	4	0.9
Dubois	44 10	112 13	23	30(8)	40(13)	42(16)	75	18	1.0
Gooding	42 55	114 46	18	14(5)	17(6)	16(8)	29	7	1.0
Idaho Falls	43 31	112 04	30	22(6)	26(9)	22(10)	42	4	0.9
Malad City	42 10	112 19	24	29(8)	38(12)	39(20)	114	12	1.0
Mountain Home AFB	43 03	115 52	27	14(7)	16(10)	13(10)	36	1	0.8
Mullan Pass	47 27	115 40	31	16(5)	20(7)	20(11)	54	4	1.0
Pocatello	42 55	112 36	30	23(7)	30(11)	26(11)	48	4	0.9

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
ILLINOIS									
Chanute AFB	40 18	88 09	15	42(8)	61(15)	79(27)	142	40	1.3
Chicago (Midway)	41 47	87 45	30	38(10)	54(16)	45(15)	77	20	0.8
Moline	41 27	90 31	30	44(7)	67(13)	84(20)	126	48	1.3
Peoria	40 40	89 41	30	45(6)	66(10)	89(21)	135	51	1.3
Quincy	39 56	91 12	30	48(7)	71(12)	119(33)	211	55	1.7
Rockford	42 12	89 06	30	39(8)	55(13)	65(20)	111	29	1.2
Scott AFB (Belleville)	38 33	89 51	30	47(7)	66(12)	80(25)	131	25	1.2
Springfield	39 50	89 40	30	45(10)	65(15)	88(24)	120	58	1.3
Vandalia	38 59	89 10	21	49(6)	67(9)	114(22)	156	79	1.7
INDIANA									
Fort Wayne	41 00	85 13	30	39(6)	55(11)	56(17)	90	29	1.0
Indianapolis	39 44	86 17	30	42(8)	59(13)	58(13)	80	33	1.0
Lafayette	40 25	86 56	30	39(8)	55(12)	67(16)	99	33	1.2
South Bend	41 42	86 19	30	40(6)	58(10)	65(16)	117	33	1.1
Terre Haute	39 27	87 18	29	44(8)	62(12)	78(18)	107	45	1.3
IOWA									
Burlington	40 47	91 07	30	45(8)	65(13)	104(26)	180	63	1.6
Cedar Rapids	41 53	91 42	25	41(6)	57(10)	84(21)	133	53	1.5
Des Moines	41 32	93 39	26	46(7)	66(12)	94(23)	139	66	1.4
Dubuque	42 24	90 42	27	42(7)	39(12)	43(18)	110	18	1.1
Mason City	43 09	93 20	30	34(6)	44(9)	62(16)	104	33	1.4
Ottumwa	41 06	92 27	30	44(7)	61(12)	95(21)	165	66	1.5
Sioux City	42 23	96 22	30	41(8)	56(12)	77(20)	125	29	1.4
Waterloo	42 33	92 24	22	40(6)	57(10)	74(16)	108	56	1.3
KANSAS									
Chanute	37 40	95 29	30	51(9)	73(17)	130(42)	223	55	1.8
Dodge City	37 46	99 58	30	47(8)	62(13)	112(29)	196	69	1.8
Emporia	38 20	96 12	27	50(8)	72(14)	139(37)	269	93	1.9
Garden City	37 56	100 43	30	43(8)	54(12)	103(34)	212	53	1.9
Goodland	39 22	101 42	30	46(9)	60(14)	88(27)	160	43	1.5

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
				KANSAS, (continued)					
Hill City	39 23	99 50	23	46(10)	60(14)	115(41)	248	52	1.9
Hutchinson	38 04	97 52	28	41(9)	55(16)	85(35)	205	33	1.5
Russell	38 52	98 49	28	45(9)	58(13)	110(28)	220	69	1.9
Salina	38 48	97 39	26	45(7)	59(10)	109(22)	156	68	1.8
Topeka	39 04	95 38	30	52(9)	75(12)	138(31)	232	97	1.9
Wichita	37 37	97 16	30	50(8)	71(14)	127(36)	197	68	1.8
				KENTUCKY					
Bowling Green	36 58	86 26	30	51(6)	73(10)	94(17)	129	67	1.3
Fort Campbell	36 40	87 30	27	54(10)	78(16)	103(26)	167	54	1.3
Lexington	38 02	84 36	30	45(7)	67(13)	68(22)	126	34	1.0
London	36 58	84 08	28	49(6)	69(10)	91(20)	139	55	1.3
Louisville	38 11	85 44	30	44(8)	63(13)	51(15)	89	25	0.8
Paducah	37 04	88 46	28	48(7)	67(12)	88(24)	143	56	1.3
				LOUISIANA					
Alexandria	31 19	92 32	24	64(13)	84(21)	115(34)	167	57	1.4
Baton Rouge	30 32	91 09	30	70(11)	92(17)	111(29)	180	60	1.2
Lafayette	30 12	91 59	30	68(9)	88(13)	126(30)	178	66	1.4
Lake Charles	30 07	93 13	30	70(13)	104(23)	155(53)	261	85	1.5
Monroe	32 31	92 03	30	59(12)	80(18)	114(39)	207	58	1.4
New Orleans	30 02	90 02	30	68(12)	91(21)	92(39)	167	21	1.0
Shreveport	32 28	93 49	30	53(9)	69(14)	94(22)	138	59	1.4
				MAINE					
Augusta	44 19	69 48	30	19(4)	25(5)	25(9)	47	11	1.0
Caribou	46 52	68 01	24	20(4)	27(7)	28(9)	45	9	1.0
Houlton	46 08	67 47	30	16(5)	21(7)	20(8)	40	5	1.0
Loring AFB (Limestone)	46 57	67 53	27	18(5)	25(9)	21(10)	38	7	0.9
Millenocket	45 39	68 41	29	17(4)	22(5)	24(8)	41	9	1.1
Old Town (Bangor)	44 48	68 49	30	17(3)	20(5)	21(7)	36	10	1.0
Portland	43 39	70 19	30	17(4)	20(4)	16(5)	26	4	0.8

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
MARYLAND									
Baltimore	39 11	76 40	24	27(6)	35(9)	29(9)	44	10	0.8
Patuxent River NAS	38 17	76 25	30	32(6)	42(10)	43(13)	69	12	1.0
Salisbury	38 20	75 30	29	31(6)	39(9)	46(14)	71	24	1.2
MASSACHUSETTS									
Boston	42 22	71 02	29	18(4)	22(5)	16(7)	35	5	0.7
Nantucket	41 15	70 04	30	17(5)	20(7)	20(8)	39	8	1.0
Otis AFB (Falmouth)	41 39	70 31	29	15(5)	18(5)	16(8)	35	4	0.9
Westover AFB (Chicopee Falls)	42 12	72 32	28	24(5)	30(8)	30(11)	57	14	1.0
Worcester	42 16	71 52	30	20(4)	26(6)	25(8)	41	12	0.9
MICHIGAN									
Detroit	42 25	83 01	30	31(6)	41(10)	33(12)	78	[illegible]	0.8
Flint	42 58	83 44	30	32(6)	45(11)	45(12)	80	25	1.0
Grand Rapids	42 53	85 31	30	34(7)	49(12)	44(12)	73	26	0.9
Houghton	47 10	88 30	30	25(5)	34(8)	42(17)	81	20	1.2
Jackson	42 16	84 28	30	33(6)	44(10)	42(11)	74	24	1.0
Lansing	42 47	84 36	23	33(8)	45(12)	39(13)	81	15	0.9
Muskegon	43 10	86 14	23	35(6)	47(9)	57(14)	80	27	1.2
Pellston	45 34	84 48	30	27(5)	36(8)	44(13)	70	26	1.2
Saginaw	43 32	84 05	30	28(5)	37(8)	39(12)	71	21	1.1
Sault Ste. Marie	46 28	84 22	30	27(6)	38(10)	42(12)	68	23	1.1
Traverse City	44 44	85 35	30	29(5)	37(8)	45(12)	72	23	1.2
MINNESOTA									
Alexandria	45 52	95 23	30	36(6)	50(9)	76(18)	104	39	1.5
Duluth	46 50	92 11	30	32(6)	47(9)	58(21)	112	26	1.2
International Falls	48 34	93 23	30	30(7)	42(11)	62(16)	92	35	1.5
Minneapolis	44 53	93 13	30	34(8)	46(13)	56(22)	100	14	1.2
Redwood Falls	44 33	95 05	28	37(7)	51(13)	75(22)	118	28	1.5
Rochester	43 55	92 30	30	38(7)	54(12)	68(20)	105	26	1.3

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
				MISSISSIPPI					
Columbus	33 38	88 27	19	66(12)	97(19)	147(45)	237	67	1.5
Greenwood	33 30	90 05	30	61(11)	81(18)	136(40)	232	67	1.7
Jackson	32 19	90 05	30	65(11)	87(17)	112(23)	160	58	1.3
Keesler AFB (Biloxi)	30 24	88 55	22	68(11)	98(21)	142(33)	237	95	1.4
McComb	31 11	90 28	29	76(13)	102(22)	169(44)	286	103	1.7
Meridian	32 20	88 45	30	58(9)	79(14)	99(26)	156	57	1.3
				MISSOURI					
Cape Girardeau	37 14	89 35	17	51(8)	72(13)	101(22)	136	70	1.4
Columbia	38 49	92 13	30	51(9)	75(16)	118(31)	196	69	1.6
Joplin	37 10	94 30	30	48(9)	65(13)	104(23)	171	57	1.6
Kansas City	39 07	94 35	30	47(9)	70(15)	88(29)	180	32	1.2
Kirksville	40 06	92 33	30	48(7)	71(13)	113(26)	185	67	1.6
Malden	36 36	89 59	18	53(13)	71(20)	118(47)	218	49	1.7
Saint Joseph	39 46	94 55	30	48(11)	67(20)	118(43)	208	17	1.7
Saint Louis	38 45	90 23	30	42(6)	59(11)	62(16)	97	21	1.1
Springfield	37 14	93 23	30	54(11)	80(18)	119(32)	198	49	1.5
Vichy	38 08	91 46	30	49(8)	67(14)	109(35)	176	55	1.6
Whiteman AFB (Knobnoster)	38 44	93 34	23	55(10)	85(20)	146(51)	264	70	1.7
				MONTANA					
Billings	45 48	108 32	30	27(6)	34(9)	23(8)	36	10	0.7
Bozeman	45 47	111 09	30	29(7)	38(12)	32(16)	72	10	0.8
Butte	45 57	112 30	30	34(9)	49(15)	44(19)	81	16	0.9
Cut Bank	48 36	112 22	30	17(6)	22(8)	20(10)	42	3	0.9
Dillon	45 15	112 33	30	36(9)	52(18)	68(30)	132	27	1.3
Drummond	46 37	113 12	25	29(6)	40(10)	43(12)	66	23	1.1
Glasgow	48 13	106 37	23	26(6)	32(8)	38(15)	78	17	1.2
Great Falls	47 29	111 21	30	23(5)	31(9)	22(8)	42	7	0.7
Helena	46 36	112 00	30	31(8)	45(11)	41(16)	76	14	0.9
Lewiston	47 03	109 27	30	28(8)	36(12)	39(18)	94	14	1.1
Livingston	45 40	110 32	30	38(8)	55(13)	58(17)	97	29	1.1
Miles City	46 26	105 52	30	27(7)	33(9)	38(15)	76	13	1.1
Missoula	46 55	114 05	30	23(6)	32(10)	25(10)	57	9	0.8

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
NEBRASKA									
Chadron	42 50	103 50	30	40(7)	50(11)	66(15)	108	41	1.3
Grand Island	40 58	98 19	30	44(8)	61(12)	87(20)	125	48	1.4
Imperial	40 31	101 37	21	40(8)	50(13)	74(27)	139	37	1.5
Lincoln	40 51	96 45	30	46(8)	63(13)	96(23)	151	48	1.5
Norfolk	41 59	97 26	30	44(9)	40(14)	54(27)	124	23	1.4
North Platte	41 08	100 41	30	44(8)	59(13)	89(28)	166	51	1.5
Omaha	41 18	95 54	30	45(7)	63(11)	82(16)	112	50	1.3
Scottsbluff	41 52	103 36	30	42(9)	55(13)	67(20)	104	33	1.2
Sidney	41 08	103 02	30	47(6)	58(10)	92(15)	120	47	1.6
NEVADA									
Battle Mountain	40 37	116 52	18	17(6)	21(8)	20(7)	29	7	1.0
Elko	40 50	115 47	30	21(6)	25(8)	21(9)	44	3	0.8
Ely	39 17	114 51	25	31(9)	44(14)	61(21)	103	21	1.4
Las Vegas	36 05	115 10	30	15(4)	19(6)	17(8)	39	4	0.9
Lovelok	40 04	118 33	30	11(5)	12(6)	14(9)	41	1	1.1
Reno	39 30	119 47	30	13(6)	17(7)	19(10)	38	3	1.1
Tonopah	38 04	117 05	26	16(4)	19(7)	26(11)	47	11	1.4
Winnemucca	40 54	117 48	28	14(6)	19(8)	19(11)	41	1	1.0
NEW HAMPSHIRE									
Concord	43 12	71 31	30	19(4)	23(5)	22(6)	31	9	0.9
Lebanon	43 38	72 19	30	21(3)	27(6)	29(8)	47	13	1.1
Pease AFB (Portsmouth)	43 05	70 49	19	19(4)	25(6)	20(6)	34	11	0.8
NEW JERSEY									
Atlantic City	39 27	74 35	30	25(4)	32(7)	32(11)	65	14	1.0
Fort Dix	40 00	74 36	29	29(6)	41(11)	40(13)	73	9	1.0
Millville	39 22	75 04	26	25(5)	31(7)	35(12)	55	15	1.1
Newark	40 42	74 10	30	24(4)	29(7)	22(8)	52	8	0.8

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
NEW MEXICO									
Albuquerque	35 03	106 37	30	38(6)	47(10)	38(10)	65	19	0.8
Cannon AFB (Clovis)	34 23	103 19	19	45(11)	59(16)	94(26)	154	57	1.6
Carlsbad	32 20	104 16	29	30(12)	36(17)	46(29)	137	9	1.3
Columbus	31 49	107 38	26	39(13)	50(18)	84(36)	146	9	1.7
Deming	32 15	107 42	16	45(9)	59(13)	88(28)	143	42	1.5
Farmington	36 45	108 14	25	26(8)	32(12)	32(15)	62	6	1.0
Grants	35 10	107 54	14	47(7)	62(13)	84(33)	177	53	1.4
Hobbs	32 41	103 12	29	34(9)	42(14)	53(19)	112	21	1.2
Holloman AFB (Alamogordo)	35 51	106 05	30	43(11)	56(16)	73(27)	135	26	1.3
Las Vegas	35 39	105 09	30	63(11)	83(18)	161(36)	220	97	1.9
Otto	35 05	106 01	18	49(10)	65(18)	102(41)	203	51	1.6
Raton	36 45	104 30	12	77(10)	110(24)	191(50)	293	119	1.7
Rodeo	31 56	108 59	21	43(17)	60(28)	90(49)	170	12	1.5
Roswell	33 24	104 32	21	38(11)	49(17)	64(30)	151	37	1.3
Santa Fe	35 37	106 05	30	42(9)	50(15)	49(23)	127	18	1.0
Truth or Consequences	33 14	107 16	26	42(9)	52(13)	82(35)	191	36	1.6
Tucumcari	35 11	103 36	30	45(9)	56(13)	114(29)	183	58	2.0
Zuni	35 06	108 48	24	46(9)	57(13)	85(27)	151	34	1.5
NEW YORK									
Albany	42 45	73 48	30	25(5)	32(7)	27(8)	42	11	0.9
Binghamton	42 13	75 59	30	30(4)	41(8)	34(12)	61	10	0.8
Buffalo	42 56	78 44	30	29(6)	39(10)	28(8)	50	12	0.7
Elmira	42 10	76 54	30	29(4)	31(9)	28(10)	48	10	0.9
Glens Falls	43 21	73 37	30	25(5)	31(8)	30(12)	63	11	1.0
Griffiss AFB (Rome)	43 14	75 25	30	33(6)	47(13)	46(19)	73	15	1.0
Massena	44 56	74 51	30	23(5)	30(7)	25(9)	47	8	0.9
New York (LaGuardia)	40 46	73 52	30	23(4)	30(5)	23(7)	36	10	0.8
Poughkeepsie	41 38	73 53	30	24(4)	30(6)	34(9)	56	20	1.1
Rochester	43 07	77 40	30	28(5)	36(8)	30(11)	50	15	0.8
Suffolk Co. AFB (Westhampton)	40 49	72 38	18	21(4)	28(6)	28(8)	45	14	1.0
Syracuse	43 07	76 07	30	29(5)	36(8)	27(8)	45	10	0.8
Utica	43 09	75 23	30	26(5)	35(8)	31(13)	61	12	0.9
Watertown	44 00	76 01	28	24(4)	30(6)	26(8)	47	12	0.9

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				NORTH CAROLINA					
Asheville	35 26	82 32	30	47(7)	63(12)	71(20)	129	36	1.1
Hatteras	35 16	75 33	30	44(8)	60(13)	94(26)	147	54	1.6
Charlotte	35 14	80 56	30	40(9)	52(12)	47(22)	105	15	0.9
Cherry Point MCAS	34 54	76 53	30	44(7)	59(11)	70(19)	109	30	1.2
Elizabeth City	36 16	76 11	21	39(7)	50(11)	68(25)	126	31	1.4
Greensboro	36 05	79 57	30	42(7)	56(11)	63(15)	88	36	1.1
Hickory	35 44	81 23	30	44(7)	55(9)	64(16)	96	30	1.2
Pope AFB	35 11	79 01	30	43(8)	59(12)	68(18)	113	35	1.2
Raleigh	35 52	78 47	30	44(7)	62(13)	68(16)	99	34	1.1
Rocky Mount	35 58	77 48	29	38(7)	49(9)	57(14)	91	33	1.2
Wilmington	34 16	77 55	30	46(7)	62(11)	74(19)	109	38	1.2
				NORTH DAKOTA					
Bismark	46 46	100 45	30	31(7)	38(9)	53(17)	94	18	1.4
Dickinson	46 47	102 48	30	32(6)	42(8)	62(18)	96	13	1.5
Fargo	46 54	96 48	30	30(4)	37(7)	44(12)	74	21	1.2
Grand Forks	47 57	97 11	30	25(5)	31(9)	40(15)	81	18	1.3
Jamestown	46 55	98 41	30	27(5)	36(8)	46(12)	78	22	1.3
Minot	48 16	101 17	30	26(6)	33(7)	44(18)	88	11	1.4
				OHIO					
Akron	40 55	81 26	30	39(7)	52(12)	52(15)	82	25	1.0
Cincinnati/Covington, KY	39 04	84 40	30	40(8)	52(12)	41(12)	62	23	0.8
Cleveland	41 24	81 51	30	34(6)	48(10)	35(12)	72	14	0.7
Columbus	40 00	82 53	30	41(7)	60(12)	52(12)	74	30	0.9
Dayton	39 54	84 13	30	38(6)	56(12)	51(12)	75	31	0.9
Findlay	41 01	83 40	30	37(6)	51(10)	50(12)	82	29	1.0
Mansfield	40 49	82 31	24	37(5)	51(9)	54(15)	87	30	1.1
Toledo	41 36	83 48	30	38(6)	[illegible](11)	53(14)	84	26	1.0
Youngstown	41 16	80 40	30	35(7)	45(10)	39(15)	78	19	0.9
Zanesville	39 57	81 54	30	45(7)	63(12)	79(17)	119	56	1.2

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				OKLAHOMA					
Ardmore	34 18	97 01	30	46(7)	62(12)	103(24)	151	67	1.7
Fort Sill (Lawton)	34 39	98 24	29	45(9)	62(15)	110(27)	161	68	1.8
Gage	36 18	99 46	30	45(8)	62(13)	114(25)	165	69	1.9
Hobart	35 00	99 03	29	44(9)	59(14)	97(26)	133	40	1.6
McAlister	34 53	95 47	24	49(8)	66(14)	108(31)	208	66	1.6
Oklahoma City	35 24	97 36	30	46(6)	64(9)	108(22)	151	74	1.7
Ponca City	36 44	97 06	30	48(7)	65(12)	112(26)	175	72	1.7
Tulsa	36 12	95 54	30	47(9)	67(16)	98(25)	152	58	1.5
				OREGON					
Astoria	46 09	123 53	25	8(3)	8(5)	4(3)	11	1	0.5
Baker	44 50	117 49	30	16(7)	20(9)	21(11)	49	2	1.1
Eugene	44 07	123 13	30	4(4)	5(4)	3(3)	10	0	0.6
Klamath Falls	42 10	121 44	30	11(5)	13(7)	15(10)	37	0	1.1
Medford	42 22	122 52	8	7(2)	9(4)	10(4)	14	2	1.1
North Bend	43 25	124 15	30	7(4)	8(4)	4(3)	9	0	0.5
Pendelton	45 41	118 51	30	9(4)	11(6)	8(6)	23	1	0.7
Portland	45 36	122 36	30	7(3)	7(3)	3(2)	8	0	0.4
Redmond	44 16	121 09	30	10(5)	12(7)	13(9)	35	1	1.0
Salem	44 55	123 01	30	5(3)	6(3)	3(2)	8	0	0.5
				PENNSYLVANIA					
Allentown	40 39	75 26	30	31(5)	43(7)	40(11)	68	23	0.9
Altoona	40 18	78 19	30	31(7)	41(12)	44(15)	82	20	1.1
Erie	42 05	80 11	30	34(11)	43(16)	40(17)	64	16	0.9
Harrisburg	40 13	76 51	25	31(6)	34(11)	30(9)	46	18	0.9
Philadelphia	39 53	75 15	30	25(5)	30(9)	22(8)	41	7	0.7
Philipsburg	40 53	78 05	30	35(6)	48(10)	60(20)	118	30	1.2
Pittsburg	40 30	80 13	30	36(6)	47(10)	38(11)	74	22	0.8
Wilkes-Barre	41 20	75 44	30	30(6)	41(10)	35(11)	61	13	0.9
Williamsport	41 15	76 55	30	34(6)	43(12)	38(13)	68	21	0.9

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RHODE ISLAND									
Providence	41 44	71 26	30	19(4)	24(7)	18(6)	33	8	0.8
SOUTH CAROLINA									
Anderson	34 30	82 43	29	49(8)	63(11)	86(23)	134	48	1.4
Charleston	32 54	80 02	30	55(11)	77(16)	91(29)	147	45	1.2
Columbia	33 57	81 07	30	52(11)	76(18)	97(29)	159	31	1.3
Florence	34 11	79 43	30	50(9)	68(15)	89(23)	150	50	1.3
Greenville	34 54	82 13	30	46(7)	61(11)	63(12)	98	42	1.0
Myrtle Beach	33 41	78 56	24	53(9)	75(14)	113(29)	177	62	1.5
SOUTH DAKOTA									
Aberdeen	45 27	98 26	30	31(6)	41(8)	55(14)	94	23	1.3
Huron	44 23	98 13	30	37(7)	50(12)	65(18)	101	28	1.3
Philip	44 03	101 36	21	38(7)	51(10)	73(16)	107	49	1.4
Pierre	44 23	100 17	30	32(6)	42(9)	51(12)	76	21	1.2
Rapid City	44 09	103 04	30	40(8)	54(13)	72(19)	111	25	1.3
Sioux Falls	43 34	96 44	30	39(7)	55(12)	85(19)	129	36	1.5
Watertown	44 55	97 09	30	31(6)	39(9)	62(21)	97	14	1.6
TENNESSEE									
Bristol	36 29	82 24	30	44(6)	59(9)	58(12)	81	38	1.0
Chattanooga	35 02	85 12	29	53(7)	76(12)	91(17)	134	63	1.2
Crossville	35 57	85 05	23	59(8)	84(13)	127(29)	197	82	1.5
Dyersburg	36 01	89 24	13	56(11)	79(20)	121(37)	200	68	1.5
Jackson	35 36	88 55	29	57(9)	79(13)	122(25)	190	81	1.5
Knoxville	35 49	83 59	30	45(6)	62(10)	59(14)	97	32	1.0
Memphis	35 03	89 59	30	51(8)	75(15)	85(18)	115	57	1.1
Nashville	36 07	86 41	30	53(7)	75(12)	89(15)	127	62	1.2

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					TEXAS				
Abilene	32 26	99 41	30	39(7)	50(11)	73(18)	103	26	1.5
Alice	27 44	98 02	30	35(8)	43(11)	58(17)	111	30	1.4
Amarillo	35 14	101 42	30	46(9)	62(16)	87(26)	157	35	1.4
Austin	30 18	97 42	30	38(7)	50(11)	58(17)	92	17	1.1
Brownsville	25 54	97 26	30	23(7)	29(9)	32(12)	62	13	1.1
Childress	34 26	100 17	29	47(8)	63(11)	121(25)	178	61	1.9
College Station	30 35	96 22	30	48(8)	61(12)	101(28)	168	42	1.7
Corpus Christi	27 46	97 30	30	27(7)	36(9)	46(18)	107	24	1.3
Cotulla	28 27	99 13	28	27(6)	33(8)	47(15)	86	27	1.4
Dalhart	36 01	102 33	29	43(8)	56(14)	89(26)	159	43	1.6
Dallas	32 51	96 51	29	37(7)	50(11)	63(17)	97	37	1.3
Del Rio	29 22	100 55	14	33(7)	44(9)	70(18)	111	39	1.6
El Paso	31 48	106 24	30	33(8)	39(9)	37(13)	59	21	0.9
Galveston	29 16	94 51	24	49(10)	68(17)	103(35)	181	47	1.5
Houston	29 39	95 17	30	55(10)	77(13)	94(24)	145	53	1.2
Junction	30 30	99 46	22	46(9)	64(14)	97(26)	160	56	1.5
Laredo	27 32	99 28	23	26(7)	35(12)	42(20)	117	15	1.2
Lubbock	33 39	101 49	30	42(10)	54(15)	87(28)	172	38	1.6
Lufkin	31 14	94 45	29	66(13)	89(20)	158(39)	249	98	1.8
Marfa	30 15	103 53	9	53(16)	65(24)	114(52)	185	57	1.7
McAllen	26 11	98 14	16	26(6)	30(8)	37(10)	54	21	1.2
Midland	31 56	102 12	30	34(9)	44(14)	56(24)	123	13	1.3
Mineral Wells	32 47	98 04	25	43(7)	57(11)	95(23)	147	48	1.7
Palacois	28 43	96 15	28	46(9)	63(13)	106(34)	172	58	1.7
Port Arthur	29 57	94 01	30	64(11)	90(20)	128(33)	220	77	1.4
Salt Flat	31 45	105 05	16	37(10)	46(13)	59(26)	124	20	1.3
San Angelo	31 22	100 30	30	35(6)	45(9)	64(19)	120	34	1.4
San Antonio	29 32	98 28	30	33(7)	44(10)	48(15)	90	28	1.1
Tyler	32 22	95 24	30	43(9)	54(14)	78(28)	147	43	1.4
Victoria	28 51	96 55	23	47(11)	66(18)	86(26)	154	43	1.3
Waco	31 37	97 13	30	42(7)	55(12)	90(23)	151	53	1.6
Wichita Falls	33 58	98 29	30	44(7)	62(12)	94(23)	154	39	1.5
Wink	31 47	103 12	30	35(7)	43(11)	66(17)	113	33	1.5

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
UTAH									
Bryce Canyon	37 42	112 09	26	38(10)	52(14)	90(36)	184	42	1.7
Cedar City	37 42	113 06	29	31(8)	43(12)	64(30)	163	31	1.5
Delta	39 23	112 31	26	23(6)	30(10)	30(13)	60	10	1.0
Hanksville	38 25	110 42	19	28(9)	36(14)	48(23)	101	12	1.3
Michaels AFB (Dugway Proving Ground)	40 11	112 56	14	18(6)	22(9)	21(11)	43	6	0.9
Milford	38 26	113 01	16	28(9)	36(11)	47(21)	83	13	1.3
Salt Lake City	40 46	111 58	30	34(7)	47(11)	43(17)	87	15	0.9
Wendover	40 44	114 02	23	20(10)	25(14)	23(14)	55	5	0.9
VERMONT									
Burlington	44 28	73 09	30	24(6)	33(10)	30(14)	59	10	0.9
Montpelier	44 12	72 34	30	21(4)	26(8)	22(9)	38	6	0.9
VIRGINIA									
Blackstone	37 05	77 57	17	40(8)	53(13)	70(23)	110	18	1.3
Charlottesville	38 08	78 27	16	34(6)	43(11)	51(21)	106	22	1.2
Danville	36 34	79 20	24	39(8)	49(12)	54(16)	83	27	1.1
Norfolk	36 57	76 17	30	30(6)	39(7)	43(13)	70	17	1.1
Pulaski	37 05	80 47	21	41(6)	55(9)	64(15)	97	25	1.2
Quantico	38 30	77 18	22	30(7)	37(11)	40(19)	87	14	1.1
Richmond	37 30	77 20	30	35(8)	47(12)	46(17)	77	13	1.0
Roanoke	37 19	79 58	30	37(7)	49(12)	48(14)	81	25	1.0
WASHINGTON									
Bellingham	48 48	122 32	30	4(3)	4(3)	3(4)	16	0	0.8
Ellensburg	47 02	120 31	22	9(5)	11(7)	14(11)	49	1	1.2
Ephrata	47 18	119 32	30	6(3)	7(5)	7(5)	23	0	1.0
Fairchild AFB (Spokane)	47 38	117 39	30	11(4)	12(6)	10(5)	29	3	0.8
Hoquiam	46 58	123 53	24	5(2)	5(3)	3(3)	11	0	0.7
McChord	47 09	122 29	30	6(3)	7(4)	4(3)	9	0	0.5
Olympia	46 58	122 54	30	4(3)	5(4)	3(3)	12	0	0.6
Seattle	47 27	122 18	30	7(3)	6(3)	2(2)	6	0	0.4

STATION	LAT	LONG	LENGTH OF RECORD(yr)	MEAN ANNUAL THUNDERSTORM DAYS	MEAN ANNUAL THUNDERSTORM EVENTS	MEAN ANNUAL THUNDERSTORM DURATION(h)	MAXIMUM ANNUAL THUNDERSTORM DURATION(h)	MINIMUM ANNUAL THUNDERSTORM DURATION(h)	MEAN THUNDERSTORM EVENT DURATION(h)
WASHINGTON, (continued)									
Spokane	47 38	117 32	30	10(4)	12(6)	10(7)	39	1	0.8
Tatoosh Island	47 57	124 33	30	6(3)	6(4)	3(3)	10	0	0.5
The Dalles	45 37	121 09	26	3(2)	3(3)	3(4)	15	0	0.8
Toledo	46 29	122 48	23	4(2)	4(2)	3(4)	17	0	0.8
Walla Walla	46 06	118 17	30	8(4)	9(5)	6(5)	21	0	0.7
Wenatchee	47 24	120 12	18	5(3)	5(4)	4(4)	13	0	0.8
Whidbey Island	48 21	122 40	30	3(2)	3(2)	3(4)	18	0	0.9
Yakima	46 34	120 32	30	6(4)	8(6)	7(6)	23	0	0.9
WEST VIRGINIA									
Bluefield	37 18	81 13	18	33(6)	41(10)	38(10)	64	24	0.9
Charleston	38 22	81 36	27	41(8)	60(12)	54(14)	80	30	0.9
Elkins	38 53	79 51	21	43(9)	66(17)	69(23)	115	28	1.0
Huntington	38 22	82 33	30	42(6)	59(11)	55(14)	82	29	0.9
Martinsburg	39 24	77 59	30	32(7)	40(9)	50(16)	76	19	1.3
Morgantown	39 38	79 55	30	41(8)	55(13)	56(18)	103	28	1.0
Parkersburg	39 21	81 26	29	45(8)	65(12)	74(17)	128	43	1.1
Wheeling	40 11	80 39	29	38(8)	51(12)	58(20)	100	26	1.1
WISCONSIN									
Eau Claire	44 52	91 29	28	37(7)	52(12)	87(26)	127	23	1.7
Green Bay	44 29	88 08	28	33(7)	48(11)	49(15)	77	13	1.0
La Crosse	43 52	91 15	30	36(8)	52(12)	73(24)	139	30	1.4
Lone Rock	43 12	90 11	30	39(6)	56(10)	79(18)	118	45	1.4
Madison	43 08	89 20	30	38(7)	54(12)	57(15)	80	21	1.1
Milwaukee	42 57	87 54	30	33(7)	45(12)	42(12)	72	21	0.9
Wausau	44 55	89 37	28	36(7)	49(11)	69(22)	117	25	1.4

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					WYOMING				
Casper	42 55	106 28	30	35(8)	45(11)	42(12)	74	17	0.9
Cheyenne	41 09	104 49	30	49(10)	67(16)	69(19)	99	35	1.0
Douglas	42 45	105 22	19	37(9)	48(12)	51(21)	95	19	1.1
Evanston	41 20	111 00	16	25(6)	12(7)	18(11)	42	3	1.5
Lander	42 49	108 44	28	30(8)	40(11)	44(18)	101	19	1.1
Laramie	41 19	105 41	30	37(7)	46(10)	55(18)	97	30	1.2
Rawlins	41 48	107 12	26	27(7)	32(9)	28(11)	64	15	0.9
Rock Springs	41 36	109 04	30	27(9)	34(13)	31(12)	52	11	0.9
Sheridan	44 46	106 58	30	34(9)	46(15)	45(19)	92	17	1.0
Worland	43 58	107 58	17	16(6)	18(7)	14(9)	38	4	0.8

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An improved lightning ground strike climatology has been obtained from thunderstorm duration data recorded by 450 air weather stations. From lightning strike location data collected in Florida and Oklahoma, it was found that strike density could be estimated from thunderstorm duration by the equation $N_s = 0.054H^{1.1}$, where N_s is the number of strikes per square kilometer and H is thunderstorm duration in hours. This relationship was applied to thunderstorm duration data from the aviation stations to obtain lightning strike density for the contiguous United States.

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FROM THUNDERSTORM DURATION RECORDS