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Tornado Deaths in the United States

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TORNADO DEATHS IN THE UNITED STATES [1]

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INTRODUCTION

The purpose of this paper is to analyze and present the temporal and areal distribution of tornado deaths in the United States. It is hoped that such information will be useful to tornado researchers and forecasters, to disaster agencies such as Civil Defense and the Red Cross, to business concerns such as insurance companies, and, more generally, to an increasingly interested and well-informed public.

In examining the results of the analysis, the reader undoubtedly will discern certain patterns in the hourly, monthly, seasonal, and areal distributions of tornado-death activity that apparently can be explained in terms of an obviously important variable, the temporal and areal changes in atmospheric conditions affecting the number, severity, and distribution of tornadoes.[2] Indeed, although the ultimate cause for the origin and development of these storms is too imperfectly understood at present to attempt a definitive meteorological explanation of the distributions, enough is known concerning the general physical characteristics of tornadoes and concerning general synoptic and dynamic conditions with which they are connected (see for example [3] [1, 6, 10, 12, 19, 21, 26, 27 and 35]) to infer general meteorological explanations. These will be left to the reader, however, as they are beyond the scope of this paper. For the present purpose it suffices to suggest briefly in the following sections a reasoned association of the outstanding contrasts in tornado-death activity with certain features of tornado frequencies and regional factors.

SCOPE AND SOURCES OF THE DATA

Data used cover the 38 years from 1916 to 1953. Thus the investigative period begins with the year the Weather Bureau commenced the systematic recording of tornado statistics; it concludes with the last calendar year for which information was available when the compilation was completed. The resulting span of years is long enough to provide data not only representative of the broader features of tornado-death distribution, but indicative of many details as well.

Basic source of information is the annual tornado summaries compiled by the Weather Bureau.[4] These summaries not only identify those storms officially recognized as having been death-dealing tornadoes, but they also specify the total number of deaths attributed to each such disturbance.[5] In relatively few instances, however, does this source indicate where along the path of

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[2] Population becomes a factor of minor significance, however, because of contrasts in population density and arrangement in the chief areas of tornado activity, as they shift from region to region during the year.

[3] Numbers in brackets identify references listed on p. 29.

[4] For 1916–1934, these summaries are to be found in the appropriate *Report of the Chief of the Weather Bureau.* For 1935–1949, they are published in the pertinent volume of the *United States Meteorological Yearbook.* Since 1950 they have appeared in the Annual issue, No. 13, of *Climatological Data, National Summary.*

[5] In this study, wherein storm-by-storm death totals are essentially the same as those previously compiled by the Weather Bureau, the definition of what constitutes a tornado death is precisely the same, namely, any death caused directly or indirectly by a tornado.

a given storm or at what time of day the individual deaths took place. It has, therefore, been necessary to supplement basic facts in the annual summaries with a very substantial amount of additional detail gathered from numerous official and unofficial sources.

Most important among supplementary sources are other Weather Bureau publications, particularly *Climatological Data, by Sections* and the *Monthly Weather Review.* Among unofficial sources, and second only to *Climatological Data, by Sections* in quantity and quality of information, are reports in regional newspapers. Disaster statistics of the American National Red Cross likewise provide some valuable data, particularly in more recent years.

THE BODY OF DATA

Though no attempt has been made to verify and correct storm-by-storm death totals as recorded in the annual summaries, there is a small discrepancy between figures used in this investigation and those previously published by the Weather Bureau for the same period of years (table 1). It will be observed that whereas the net difference is but 1 death, the absolute difference is 139.[6] An analysis of these changes reveals that 18 of the 139 consist of death reports believed to have been demonstrably erroneous, and that only the remaining 121 constitute a difference requiring further explanation. Of the latter, 51 were incapable of being located even within the county where they were presumed to have occurred and were, therefore, rejected.[7] The other 70 deaths, all of which were added, resulted from use of alternative storm totals larger than those officially adopted previously by the Weather Bureau. In the several cases involved, the alternative total was adopted primarily because it facilitated the spot location of deaths.[8] It should be emphasized, however, that no such changes were justified merely on the basis of cartographic convenience; it was also essential that data used in any revision come from a source judged to be reliable, and that the new total itself seem plausible.

TABLE 1.—*Discrepancies between tornado deaths used in this study and previously published Weather Bureau figures for the same years*

	Number	Number	Percent of previous Weather Bureau total
Total used herein		8,742	100.01
Previous Weather Bureau total		8,741	100.00
Net difference		1	.01
Absolute difference		139	1.59
Of which the following were:			
Rejected as erroneous	18		
Rejected; could not locate accurately enough	51		
Additional deaths	70		
Total	139		

RELIABILITY OF THE DATA

Since death totals previously published by the Weather Bureau have been accepted as essentially complete and correct, it is appropriate to examine potential sources of error in their compilation, and to justify use of these storm-by-storm totals in this study. Although at first reflection, the death of a person might seem to be an incontrovertible and easily accountable statistic, it does not necessarily follow that the recording and summation of fatalities can be accomplished with unerring accuracy. For example, some victims die instantly whereas others linger for weeks. Duplication is another problem; the same person may be listed, sometimes in slightly different ways, both from his home town and from the place where he was killed, if not at home. The reconciliation of two overlap-

[6] The absolute difference is a numerical count of all deaths added to or subtracted from storm totals in the annual summaries.

[7] Most deaths, approximately 96 percent of the total, were located with definite reference to some place. Of those remaining, all but about 20 were placed with reference to the known path of a given tornado.

[8] It is worth pointing out that 48 of these 70 additional deaths resulted from use, for the tri-State tornado of March 18, 1925, of an alternative, larger total reported by two Weather Bureau meteorologists, who made an officially-sponsored one-week field investigation of the storm area. This more detailed compilation of fatalities was published by Root and Barron [25]. In view of the magnitude of the death total for this storm, more than 700 persons, it would indeed be a remarkable coincidence if either total were precisely correct. Moreover, there is some doubt that the smaller total, compiled by the American National Red Cross, and finally adopted by the Weather Bureau [33], possesses greater accuracy than the total used herein.

ping partial reports can be very unrewarding, and may admit of only an arbitrary decision. Then, too, complete and accurate death counts simply cannot be obtained from some remote areas, a situation especially common in the rural South a generation ago. Moreover, it is only in recent years that it is becoming possible to obtain reliable figures for number of Negroes killed in parts of the South. In the past, reports from these areas too frequently consisted of two lists, a detailed one of white casualties and a lump total or indefinite number for Negroes killed. These, then, are but a few examples of complications that conspire to make some death totals, particularly those involving numerous or widely scattered fatalities, approximations at best.

In spite of these and other potential causes of error, storm-by-storm death totals recorded in the annual tornado summaries published by the Weather Bureau seem to be remarkably complete and correct. The impression of correctness derives from repeated agreement between Weather Bureau totals and those reported by other apparently reliable sources, as revealed in the course of a thoroughgoing search for additional details of tornado-death occurrence. The completeness, at least of the roster of death-dealing tornadoes, is suggested by the pattern of annual tornado-death-day totals during the 38-year period (chart 14).[9] It will be observed that in spite of a progressive rise in number of tornadoes reported and in number of tornado days, there is no significant change in the number of tornado-death days. Thus, although many tornadoes have, in the past, obviously been unreported, and although the number of tornadoes reported has increased remarkably in recent years in response to concerted efforts to detect their occurrence, there has been no corresponding increase in the number of tornado-death days. It would appear, then, that throughout the 38-year period death-dealing tornadoes have always attracted sufficient attention to become a matter of record.

TREATMENT OF DATA

Since this paper attempts, above all else, to present to readers a vivid and reasoned picture of where and when tornado fatalities occur in the United States, emphasis is placed on a relatively few, simple features of tornado-death distribution. Moreover, the analysis of them is essentially tangible and statistically unsophisticated. Numerical counts and frequency distributions are the tools most frequently employed. Use of the latter is further encouraged by the sporadic manner in which tornado deaths occur. Under such circumstances some other statistical concepts commonly used, such as the mean, have very limited utility.

In analyzing the temporal distribution of tornado deaths, with the exception of their hourly occurrence, four phenomena are selected, namely, tornado deaths, tornado-death days, days with 25 or more deaths, and days with 100 or more deaths. That tornado deaths should be chosen is implicit in the title of this study. The concept of the tornado-death day is introduced to differentiate those comparatively few days on which deaths are caused by tornadoes from the large majority of all days when no such fatalities take place. The separate analysis of days with 25 or more deaths and 100 or more deaths carries this selective technique a step farther; it focuses special attention on the still fewer disastrous days which make a contribution to the death total out of all proportion to their limited frequency. Choice of the number 25 was determined chiefly by the fact that there is a distinct break in frequency of days with 25 or more deaths, on the one hand, and those with fewer than 25 on the other.[10] It also happens, incidentally, that days with 25 or more deaths constitute almost exactly the upper 10 percent of all tornado-death days, based on number of persons killed. Then, too, 25 tornado deaths on one day is certainly a total large enough to merit classification as "disastrous" or some other special appelation. The number 100 was chosen as a minimum total to define days marked by what might be called extraordinary high death totals, because some round number of approximately this minimum size was needed, and because the best break in the array of

[9] A tornado-death day may be regarded as a 24-hour period, between an instant after midnight on one day and midnight the same day, during which one or more deaths occurred and/or during which one or more persons received tornado-induced injuries that subsequently proved fatal. Unless specified otherwise, directly or by the context, the area involved in each instance is understood to be the entire United States.

[10] Frequencies of days with less than 25 deaths were, with but 1 exception, 3 or more; days with 25 or more deaths occurred, with 2 exceptions, only once or twice.

daily death totals was between 96 deaths (1 day) and 112 deaths (1 day).

Hourly distribution of tornado deaths is also analyzed by means of the frequency distribution. In this instance, however, the number of deaths is too small to justify breaking down the hourly intervals by months or by years.

Analysis of the areal distribution of tornado deaths is organized primarily on the basis of tornado-death regions.[11] Though boundaries are sometimes diffuse and arbitrarily placed, particularly where data are scanty, obvious contrasts in tornado-death attributes in various parts of the country suggest at once the utility of regional organization. Moreover, this approach lends itself particularly well to a comparative examination of tornado-death characteristics, one of the most interesting and effective means of demonstrating their areal distribution. Though the area and extent of regions thus delimited are not to be regarded as definitively settled, they do represent broad-scale contrasts in tornado-death characteristics of a rather enduring nature, since contrasts on which they are based depend on significant areal differences in physical and cultural factors which control the occurrence of tornado fatalities.

[11] A tornado-death region may be regarded as any part of the earth's surface within which tornado-death characteristics are (a) relatively homogeneous, and (b) sufficiently distinctive to impart to that area a tornado-death attribute which justifies setting it apart from contiguous, contrasted areas.

CHAPTER I

TEMPORAL DISTRIBUTION OF TORNADO DEATHS

Tornado deaths occur on relatively few days during the year. Of the total of 8,742 fatalities from 1916 through 1953, the 8,734 fatalities capable of being assigned to some specific calendar day took place on but 669 days, a little less than five percent of all days during the period covered by the investigation (table 2).[1] Tornado-death days thus averaged less than 18 per year. It will also be noted that during the same period, the average annual number of tornado deaths was approximately 230 persons. Though it will be shown subsequently that the latter figure fluctuates greatly from year to year, these annual means serve to convey a general impression of the frequency of days on which people are killed by tornadoes and the order of magnitude of the resulting deaths.

TABLE 2.—*General summary: number of tornado-death days and tornado deaths, 1916–53*

Tornado-death days		Tornado deaths	
Number	669	Number	8,742
Percent of all days	4.8	Annual average	230.1
Average per year	17.6		

MONTHLY VARIATION IN NUMBER OF DEATHS

Among the 12 months of the year, there was a large and systematic variation in number of tornado fatalities. Even a casual inspection of the record reveals that most deaths took place from March through June (fig. 1). Indeed, nearly 83 percent of the total occurred in these 4 months, the other 8 months accounting for only about 17 percent (table 3).

TABLE 3.—*Tornado deaths by seasons, 1916–53*

Season	Tornado deaths	
	Number	Percent of total
March–June	7,245	82.9
July–February	1,497	17.1

MARCH THROUGH JUNE

Days with 25 or more deaths, though limited in number, play an especially significant role in the accumulation of tornado fatalities in the United States. For the 38 years covered in this study, more than two-thirds of all deaths occurred on 66 such days (table 4). It is therefore interesting to determine to what extent these high-total days contributed to the exceptionally numerous fatalities from March through June.

Table 4 reveals that 52 of these 66 high-total days occurred from March through June, and that these 52 days accounted for approximately 75 percent of that 4-month death total. In contrast, comparable figures for the other 8 months were 14 days and slightly over 39 percent of the fatalities. Furthermore, between March and June, days with 25 or more deaths averaged 104 fatalities; similar days in the other 8 months averaged just under 42.

TABLE 4.—*Days with 25 or more deaths vs. days with fewer than 25 deaths, by seasons, 1916–53*

Months	Days with 25 or more deaths				Days with fewer than 25 deaths		
	Number	Number of deaths	Percent of season total	Average number deaths per such day	Number	Number of deaths	Average number deaths per such day
Mar.-June	52	5,406	74.8	104	391	1,831	4.7
July-Feb.	14	587	39.2	41.9	212	910	4.3
All months	66	5,993	68.6	90.8	603	2,741	4.5

[1] Eight deaths, whose place, month, and year of occurrence were known, could not be assigned to a specific calendar day. Therefore data concerning daily tornado-death totals and frequencies, and most other tornado-death-day information are based on these 8,734 fatalities. On the other hand, data relating to monthly and annual occurrence of tornado deaths are based on all 8,742 fatalities.

TABLE 5.—*Days with 100 or more deaths, by months, 1916–53*

Month	Number of days	Deaths	
		Number	Percent
March	5	1,601	67.9
April	6	1,084	48.4
May	4	595	36.8
June	2	294	28.7
March–June	17	3,574	49.4

On the other hand, there was very little difference in average number of persons killed on days with less than 25 deaths, whether in March–June or July–February. It is therefore apparent that the remarkable disparity between the total number of deaths in each of these two periods resulted chiefly from the greater frequency and more deadly nature of high-total death days from March through June.

The size of the daily death average, 104 persons, on the 52 high-total days in months from March through June prompts further anlaysis. It is apparent that days having 100 or more fatalities must have played an important role in the accumulation of deaths in 1 or more of these 4 months.

During the 38-year period there were 17 exceptional days on which tornadoes claimed 100 or more lives, and all 17 occurred in March, April, May, or June (table 5).[2] Moreover, these relatively few days accounted for virtually half of all deaths in these four months.

There was, however, a considerable contrast in the significance of these exceptional days in the accumulation of deaths within individual months. Thus more than two-thirds of all deaths in March took place on just five such days; in April nearly half on six days. On the other hand, four days with more than 100 deaths accounted for less than two-fifths of the May total, and two such days for less than one-third of all fatalities in June.[3]

[2] For all years of record there is at least one exception, possibly two, to this pattern established in more recent years. On February 19, 1884, an historic series of tornadoes killed several hundred persons in Alabama, Georgia, and the Carolinas. Authorities differ on the number of deaths caused by these storms; Brooks [3] says about 1,200, Finley [8] "about 800", the Weather Bureau [34], 420 persons. The other possible exception is July 26, 1875, when, according to Weather Bureau [34] records, a storm thought to have been a tornado struck Erie, Pa., and killed 134 persons.

[3] If days with 90 to 99 deaths were also included, figures for June, the only month with daily totals in this interval, would rise to a more impressive 4 days with 480 deaths, comprising approximately 47 percent of the monthly total. It is apparent that with respect to days having exceptionally high tornado casualties June is not to be regarded too lightly.

TABLE 6.—*Number of tornado deaths on individual days having 100 or more deaths, 1916–53*

Date	Number of deaths	Date	Number of deaths
Mar. 18, 1925	788	May 27, 1917	151
Mar. 21, 1932	317	Mar. 28, 1920	148
Apr. 5, 1936	248	Mar. 16, 1942	147
Apr. 20, 1920	216	June 8, 1953	142
May 9, 1927	206	Apr. 12, 1945	135
Apr. 6, 1936	204	May 11, 1953	125
Mar. 21, 1952	201	May 26, 1917	113
Apr. 9, 1947	169	Apr. 30, 1924	112
June 23, 1944	152		

An examination of individual days having 100 or more deaths reveals additional interesting detail (table 6). It will be observed that the four days having highest totals occurred in March or April, as did seven of the first eight such days. Moreover, with the single exception of May 9, 1927, days on which substantially more than 150 persons were killed also took place in March or April.[4]

Unquestionably, tornado-death activity is highest in this country between March and June. However, observations comparing the level of death activity in each of the four months need to be expressed more guardedly. Yet there is every indication that the peak is reached early in the season, probably in March, and that although the level remains fairly high through June, there is a progressive decline after the early season maximum.

The high death totals from March through June are to be attributed primarily to the great frequency and unusual severity of tornadoes during these months. That tornadoes are more frequent at this time of year is borne out by monthly totals of all such storms reported in the United States from 1916 through 1953 (table 7).[5] That they produce more severe effects as well, is already suggested strongly by the unusual frequency and deadliness of early-season tornado-death strikes. It is also substantiated by numerous published ac-

[4] For all years of record there are two departures from this pattern: February 19, 1884, previously noted, and May 27, 1896, when according to Weather Bureau [34] figures the St. Louis tornado claimed 306 lives.

[5] Though the roster of death-dealing tornadoes is believed to be substantially complete, it should be understood that the same is not true of the roster of all tornadoes, at least not during most years covered by this investigation. Furthermore, because of more complete records for certain States, like Kansas and Iowa, which lie within the chief areas of tornado activity from May to October, it is probable that the record of all tornadoes is biased in favor of more nearly complete totals for the months indicated. It is believed, however, that the magnitude of such bias is insufficient to invalidate the broad generalizations employed herein.

TABLE 7.—*Tornadoes reported in the United States, 1916–53, by months (compiled from official Weather Bureau figures)*

Month	Number	Month	Number
Mar	610	July	427
Apr	836	Aug	273
May	1,144	Sept	259
June	917	Oct	144
		Nov	166
		Dec	116
		Jan	145
		Feb	167

counts of the utter devastation caused by vortices during these months.

Though gradually decreasing severity and, finally, frequency of tornado activity seem unquestionably to be the most important factors accounting for trends in tornado-death activity from March through June, regional contrasts in other factors certainly contribute in a minor way to the changes noted. Most obvious is the contrast between the dispersed rural settlement typical of the Midwest, where tornado activity is centered by May and June, and the more clustered pattern of population in similar areas in the Southeast, where it is centered in March and April. Other factors of lesser significance will be enumerated and discussed briefly in connection with the four tornado-death regions.

JULY THROUGH FEBRUARY

Though there were detailed contrasts in the tornado-death attributes of individual months from July through February, there was one characteristic common to all, namely, the relatively small proportion of all deaths compared with that for the other 4 months (fig. 1). In these remaining 8 months, deaths were most numerous in February, which, in spite of fewer calendar days, contributed between 3 and 4 percent of all fatalities for the 38-year period (table 8). Comparable figures for the other 7 months ranged down to 1 percent in July.

Not only in number but also in structure, deaths in these remaining 8 months differ widely from those in the period from March through June. It will be recalled that the number of high-total days in these 8 months was but 14, less than one-third as many as in the other 4 (table 4). Furthermore the average number of deaths per such day in July–February was less than half that for March–June. Then, too, the absolute daily maximum in

TABLE 8.—*Tornado deaths and tornado-death days, by months, 1916–53*

Month	Deaths		Number of death days	Average number of deaths per death day	1-day death maximum
	Number	Percent of total			
Jan	242	2.8	32	7.6	59
Feb	304	3.5	33	9.2	41
Mar	2,361	27.0	88	26.8	788
Apr	2,238	25.7	126	17.8	248
May	1,620	18.5	131	12.4	206
June	1,026	11.7	98	10.5	152
July	88	1.0	34	2.6	10
Aug	108	1.2	27	4.0	36
Sept	216	2.5	22	9.8	81
Oct	121	1.4	20	6.1	29
Nov	232	2.6	29	8.0	76
Dec	186	2.1	29	6.4	38
All months	8,742	100.0	669	13.1	788

each of these 8 months was less than 100 deaths; for 5 of them it was under 50 (table 8).

Within individual months the number of cases as well as deaths involved is so limited that it may not be representative of long-term trends. However, for the period studied, July had not only fewest deaths, but also the lowest death-day average, less than 3 persons, and the lowest daily maximum, 10. Though the number of death days declined in

FIGURE 1.—Tornado deaths and tornado-death days, expressed as percent of all tornado deaths and tornado-death days, respectively, for the years 1916–1953.

TABLE 9.—*High-total vs. low-total death days, by months, 1916–53*

Month	Days with 25 or more deaths			Days with fewer than 25 deaths		
	Number of days	Number of deaths	Percent of monthly death total	Number of days	Number of deaths	Average number deaths per such day
Jan	2	89	36.8	30	153	5.1
Feb	5	170	55.9	28	134	4.8
Mar	12	1,901	80.5	76	457	6.0
Apr	16	1,641	73.3	110	597	5.4
May	15	1,131	69.8	116	486	4.2
June	9	733	71.5	89	291	3.3
July	0	0	0.0	34	88	2.6
Aug	1	36	33.4	26	72	2.8
Sept	3	149	69.0	19	67	3.5
Oct	1	29	24.0	19	92	4.8
Nov	1	76	32.8	28	156	5.6
Dec	1	38	20.4	28	148	5.3
All months	66	5,993	68.6	603	2,741	4.5

August and still further in September, each of these latter months registered an increase in total deaths and in the 1-day maximum. In September the margin of increase was especially noteworthy. October experienced still fewer death days, and the increase in other phases of death activity noted in August and September was emphatically reversed. On the other hand, figures expressing all phases of tornado-death activity increased again in November, when they almost matched those in September. Following another slight decline in December, there was a general increase in most aspects of death activity thereafter.

In spite of the small body of data, a few cautious generalizations may be made concerning the monthly trend of tornado deaths for July-February, at least for the 38 years covered in this study. Most certain of all is the indication that tornado-death activity experiences a precipitous drop soon after the arrival of summer, probably reaching a minimum in July. There is also a relatively abrupt change between February and March. However, between July and February the general increase seems to be unsteady, with, perhaps, a secondary minimum in October.

The low death totals from July through February obviously result from fewer tornadoes and less violent effects than in the remaining 4 months of the year. The precipitous drop in tornado deaths and the substantial decrease in number of all tornadoes from June to July coincides with the arrival of summer. Though tornadoes are more numerous in July than in any month until March, it is not at all certain that the same is true of their severity.

The general, if somewhat irregular, increase in number of tornado deaths after July probably corresponds at first to a gradual increase in the incidence of severe tornadoes, because the number of vortices reported does not reach a minimum until December (table 7).

TABLE 10.—*Days in September having 25 or more tornado deaths, 1916–53*

Date	Number of deaths
Sept. 21, 1924	36
Sept. 29, 1927	81
Sept. 29, 1938	32

In view of the small sample, one can scarcely say that there is evidence of much change in the severity of tornadoes in August. However, by September there is a substantial increase in the number of fatalities, an increase that results chiefly from a sharp jump in deaths on high-total days (table 9). It is certainly interesting, and it may be significant, to note that between 1916 and 1953 all such high-total days occurred late in the month, when summer is essentially over (table 10). Indeed, there is just one instance between July 1 and September 20 in the 38-year period studied when as many as 25 deaths took place on one day.[6]

The secondary death minimum in October is probably no accident. It will be recalled that there is a sharp drop in number of all tornadoes reported in October, which has fewer than any month save December (table 7). Moreover, no month has fewer tornado-death days than October (table 8).

The decrease in number of tornado deaths again in December is neither as abrupt nor as suggestive of a long-term trend as that in October. Yet it coincides with the lowest monthly total of all tornadoes reported. One probable factor is the ever smaller area subject to tornadoes with the arrival of winter.

The increase of tornado deaths in January and again in February corresponds with similar increases in the number of all tornadoes reported. The increase in number of tornado deaths, however, results chiefly from an increase in number of high-total days and in deaths on such days (table 9). It seems likely therefore that the incidence of severe tornadoes increases in January; it certainly does in February. However, the abrupt increase in number of all tornadoes, as well as in severity of tornadoes, is reserved until the approach of spring, in March.

[6] On August 21, 1918, 36 persons lost their lives when a tornado struck Tyler, Minn.

MONTHLY SHIFTS IN AREAL DISTRIBUTION OF DEATHS

Not only number but also areal distribution of tornado deaths varies from month to month. In a general way, monthly changes in the distribution of deaths are reflected in corresponding shifts in the geographical center of deaths. For the 38 years studied, the center moved from east-central Mississippi in February, to central Iowa in July and August (chart 1).[7] In fall and winter months, it returned southward, and, in general, eastward to reach Mississippi again in January.

MARCH THROUGH JUNE

During March and April, a large majority of all fatalities took place between the latitudes of southern Illinois and south-central Mississippi, and between the meridians of west-central Texas and east-central South Carolina (charts 4 and 5).[8] In March, however, deaths in this general area were concentrated in the central and east-central portion. On the contrary, in April they were more widespread, longitudinally speaking, with marked increases in Oklahoma, Texas, and western Arkansas, as well as in eastern Georgia and South Carolina.

In May deaths were more widely dispersed, having reached northwestward to the Dakotas, and Wyoming, and westward to New Mexico (chart 6). The northwestward movement was attended by a notable increase in the number of deaths in Iowa, Missouri, Kansas, and Nebraska. At the same time, there was a marked decrease in tornado-death activity in the Southeast, in States from Mississippi to South Carolina.

Positive changes in June included a farther northwestward penetration to Idaho and Montana, and a spreading northeastward to Massachusetts (chart 7). On the negative side, there was a virtual cessation of tornado-death activity in the Southeast and a marked decline in Louisiana and Texas as well. Most striking change compared with May was the appearance of a few exceptionally large death groups in the northeastern quarter of the country.

The four exceptionally large death groups in Michigan, Ohio, West Virginia, and Massachusetts in June immediately suggest the probable importance of large and locally dense population. Indirectly but unmistakably they also testify to the violence of the storms that caused them; a death group of this size always represents the work of a mighty storm. That catastrophes of comparable magnitude seem not to be typical of tornado-death activity farther west in these same latitudes, as far as the Rockies, may be explained, aside from meteorological considerations, by the larger and more clustered population of many areas in the East.

JULY THROUGH FEBRUARY

Broadly speaking, the areal distribution of deaths in July, August, and September displayed more similarities than differences. Though widespread, a majority of them were concentrated in the North Central States, both east and west of the Mississippi River (charts 8, 9, and 10). In July the extent of death distribution was not unlike that of June, but the number of deaths represented was less than one-tenth as many. Most conspicuous, in contrast to June, was the complete absence of any large death groups. In August and Sep-

[7] The manner in which the center of deaths is calculated for each month and for all months is similar to that described by Murphy and Spittal [22]. A pair of axes, consisting in this case of a conveniently situated meridian and parallel, were drawn on a piece of tracing paper. The latter was then placed on the dot map (charts 2–13) for the particular month being analyzed, in such a manner that the axes on the tracing paper coincided with their counterparts on the map. In order to adjust the position of the parallel so as to have it pass through the actual center of gravity of deaths for that month, the distance of the center of each dot, cluster of dots, or circle on the map north of the assumed position of the parallel was measured, and then multiplied by the number of deaths represented. Products thus obtained for all deaths north of the assumed position of the parallel were added. Next, distances were measured and products computed and added for all dots and circles south of the assumed position of the parallel. The smaller of these two sums was then subtracted from the larger, and the difference divided by the number of deaths represented on the map in question. The resulting quotient indicated the number of units distance the assumed position of the parallel had to be moved north or south, as the case may have been, so as to pass through the center of gravity of deaths for the month under consideration. The initial, assumed position of the meridian was adjusted in a similar manner so that it, too, passed through the center of gravity for that month. The intersection of the relocated axes represented the sought-for death center for the month or period being considered.

[8] The size of circles used to represent 10 or more deaths is graduated so that the area covered by a given circle is in proportion to the number of deaths being represented. Scale of the circles is based on the area covered by one dot, which represents one death.

Table 11.—*All tornado strikes of record accounting for 25 or more deaths between July 1 and Sept. 21 (compiled from official Weather Bureau figures)*

Date	Number deaths	Place
July 26, 1875	134	Erie, Pa.
Aug. 9, 1878	30	Wallingford, Conn.
Aug. 21, 1883	31	Rochester, Minn.
Aug. 21, 1918	36	Tyler, Minn.

tember, a few apparently significant deaths appeared in the Southeast, particularly along the Atlantic slope from Florida northward.

The geographical distribution of all recorded death strikes accounting for 25 or more fatalities between July 1 and September 21, is interesting and suggestive (table 11); all 4 such death strikes took place near the northern limit of tornado-death activity.

The appearance, in August and September of tornado deaths along the Atlantic Seaboard and Gulf Coast is related in part to the onset of the hurricane season. Though at least a few death-dealing tornadoes have been associated with tropical storms, the contribution of such vortices to death totals, even in an absolute sense, is exceedingly small.[9]

October and November were clearly transition months (charts 11 and 12). In October there was a marked southward shift in the center of death activity; in November the most conspicuous development was a concentration of deaths in lower Mississippi Valley States and those adjacent to them. Most notable exception to the latter generalization was 17 deaths in Charles County, Maryland in November. Incidentally, these deaths did not happen in connection with a tropical storm (see Brooks [4]).

By December the transition period was essentially completed, and from then through February there were few important changes in the areal pattern of deaths (charts 13, 2, and 3). In general, the distribution of deaths in December was localized in the immediate vicinity of the lower Mississippi River Valley. During January and February deaths were somewhat more widespread, there having been a small but emphatic shift eastward in the center of death activity in each of these two months.

It is interesting to note that the few deaths outside the South from December through February all took place in central United States. That such tornadoes are rare as far north as Illinois in December is noted by Fulks and Smith [11] in their analysis of the tornadoes of December 2, 1950. Three of the latter four storms were in Illinois, and 2 of the 3 accounted for 3 of the 4 December deaths in that State.

FLUCTUATIONS AND TREND IN ANNUAL TORNADO-DEATH TOTALS

The number of tornado fatalities varies markedly from year to year as well as from month to month. During the period covered by this investigation the annual total fluctuated between a low of 29 in 1937 and a high of 842 in 1925 (chart 14, table 12). On the other hand, fluctuation in the annual number of tornado-death days varied much less, from 10 in 1916 and 1919 to a high of 28 in 1953 (chart 14, table 12). In 29 of the 38 years, however, the annual total fluctuated only between 13 and 22. There was, moreover, no necessarily direct relationship between number of tornado-death days and number of deaths. In the year 1928, for example, 91 deaths were spread over 27 days, whereas in the previous year 532 deaths occurred on only 21 days. Even more striking in this respect was 1925, a year in which 842 fatalities took place on just 15 days. In general, nevertheless, years with highest death totals also had somewhat more death days (table 13). It is also apparent from data in this table, however, that the great preponderance of deaths in high-total years resulted more importantly from larger death-day totals than from the moderate excess of death days themselves.

This latter situation is one reminiscent of a similar relationship between high monthly death totals and high-total death days. It is, therefore, appropriate to examine in greater detail the monthly structure of death distribution within individual years. Chart 15 reveals that between 1916 and 1953 each of 13 years had more than the average annual number of fatalities for the period as a whole. In each of these 13 years it is also evident that there were one or more months with an unusually large number, say 100 or more, of deaths. Moreover, in every one of these 13 cases,

[9] The tornadoes which claimed 32 lives at Charleston, S. C., in September 1938 were not associated with a hurricane.

Table 12.—*Tornado deaths, tornado-death days, tornadoes and tornado days: annual totals 1916–53 (tornadoes and tornado days compiled from official Weather Bureau figures)*

Year	Number of tornado deaths	Number of tornado-death days	Number of all tornadoes	Number of all tornado days
1916	150	10	90	36
1917	520	22	121	38
1918	135	16	81	45
1919	206	10	65	35
1920	479	14	87	49
1921	198	15	106	55
1922	137	23	108	65
1923	107	16	102	59
1924	373	27	130	58
1925	842	15	119	64
1926	144	14	111	56
1927	532	21	164	63
1928	91	27	203	79
1929	269	21	197	73
1930	175	16	192	72
1931	36	13	94	57
1932	394	14	152	67
1933	361	26	260	96
1934	47	13	147	77
1935	70	21	182	77
1936	551	17	159	73
1937	29	13	148	76
1938	183	18	220	78
1939	86	22	155	75
1940	65	11	128	65
1941	52	13	118	57
1942	379	21	170	68
1943	58	18	155	63
1944	275	18	173	67
1945	210	18	126	68
1946	77	16	109	66
1947	313	22	171	80
1948	140	19	190	74
1949	211	23	262	84
1950	70	13	210	92
1951	34	14	300	119
1952	229	11	270	104
1953	514	28	532	151
Total	8,742	669	6,307	2,681

Table 13.—*Number of tornado deaths, number of tornado-death days, and average number of deaths per death day in high-death-total years vs. low-death-total years, 1916–53*

	Number of deaths	Number of tornado-death days	Average number of deaths per tornado-death day
19 years with highest death totals	7,039	361	19.5
19 years with lowest death totals	1,703	308	5.6

the months having more than 100 deaths occurred in the period from March through June. Incidentally, most, though not all, high-total months thus involved included days on which tornado fatalities exceeded 100 persons (table 6). In contrast, it is interesting to note that out of 7 years in which the month of maximum deaths did not fall between March and June, only 1 (1926) had an annual total of over 100 deaths.

Considering the 38-year period as a whole, the trend in number of deaths has been downward.

Table 14.—*Tornado deaths and tornado-death days, first 19 years vs. the second 19 years, 1916–53*

Years	All death days		Days with 25 or more deaths		Days with fewer than 25 deaths
	Number	Percent of 38-year total	Number	Average number deaths per day	Average number deaths per day
1916–34	333	59.4	38	96.4	5.2
1935–53	336	40.6	28	83.2	3.9

Thus, half the 8,742 deaths had accumulated by September 1931, in the 16th year of the investigative period; it required slightly more than 22 years to amass the other half (chart 15). Stated in a different way, nearly 60 percent of all deaths occurred in the first 19 years and only slightly over 40 percent in the second 19 years (table 14).

That this difference was not due to the occurrence of a larger number of tornado-death days in the first 19 years is demonstrated by the remarkably even division in number of death days between the two periods (table 14). In fact the second 19 years had three more. Rather, the difference in question resulted from a larger number of deaths per death day in the first 19 years, both on days with 25 or more deaths and on those with less than 25 deaths. This higher average number of fatalities per death day during the first 19 years was also reflected in the more frequent occurrence of days having 25 or more deaths.

The decrease in deaths during the second 19 years could have been caused by reduced tornadic activity, by less violent tornadoes, by tornadoes striking in less densely settled areas, by better tornado detection and warning services, or by a whole host of chance circumstances which virtually defy analysis and testing. It will presently be shown that the most plausible explanation for the modest decline in annual number of tornado deaths is the use of improved tornado detection and warning services by a better-informed public.

There is, for example, no evidence to suggest that tornadoes are becoming less frequent in recent years. Indeed, the number reported annually has grown steadily; since 1951 the increase has been phenomenal.[10] However, as Harris [13] points out, much of the increase probably results from

[10] From a previous high of 300 tornadoes in 1951, the annual total shot up to 870 in 1955, according to Weather Bureau [31] figures.

more complete reports. Since 1951 utilization by the Weather Bureau of data obtained from private press-clipping services has definitely done much to appreciate the annual total. In any event, the question, if any, seems to be whether there are more, not fewer, tornadoes.

There is also doubt that tornadoes struck consistently in less densely populated areas during the second 19 years. Indeed, the general increase of population in the country suggests the opposite possibility. If individual death strikes causing 25 or more fatalities in urban areas are considered, there is remarkably little difference either in number of cases or number of deaths between the first and second 19 years (table 15). Though 2 fewer communities were struck by devastating tornadoes in the second 19 years, the number of persons killed was even greater than in the first 19 years.

Whether or not tornadoes were generally less violent in the second 19 years than in the first cannot be determined conclusively on the basis of any available evidence. Yet there certainly is no obvious reason to suspect any significant decrease in their intensity. There likewise seems to be no reason to believe that the numerous fortuitous circumstances which may affect the number of deaths were, on the whole, likely to be either decidedly more or less favorable in the first 19 years than in the second. Moreover, with such a large number of cases covering so many years and such diverse conditions, it seems not unreasonable to expect that chance variations might, at least approximately, have compensated for each other in both halves of the 38-year period.

Though it is obviously impossible to prove it, the decline in number of deaths seems most likely to have resulted from improved storm warnings and better use of these warnings by the public. This factor can operate through (a) better tornado forecasting, (b) better detection and tracking of tornadoes already in progress, (c) more adequate dissemination of such information among people in the affected areas, (d) more effective use of warnings by a better-informed public.

Though specific tornado forecasts for limited areas are generally credited, since their inception in 1952, with reducing somewhat the potential number of deaths, and though better detection and tracking of tornadoes in progress, especially by use of radar, is beginning to be available in some areas, these most promising developments are obviously too recent to have affected substantially the number of deaths during the period under investigation. However, to the limited extent the more specific forecasts may have been effective, it is clear that they operated at the close of the second 19 years.

TABLE 15.—*Tornado-death strikes causing 25 or more fatalities in urban areas, 1916–53*

Years	Number of large towns or cities struck*	Number of deaths
1916–34	18	1,197
1935–53	16	1,267

*Towns and cities with population of 2,500 or greater.

Somewhat more significant because of their longer standing, are the volunteer tornado-warning networks established during World War II to provide at least a few minutes' warning for vital military and manufacturing establishments in the tornado belt. Flora [9] observes that these proved so effective that after the war they were increased in number. Though these rudimentary warning systems can scarcely be considered a satisfactory solution to the problem of protecting the public at large, there are several documented cases where they functioned with great effectiveness. It is clear that to whatever limited extent these networks were effective, they tended to reduce tornado deaths in the second, not the first, 19 years.

Means for adequate dissemination of warnings and for education of the public go hand in hand. Thus better education of the public, not merely in a formal sense but also through the tremendous broadening of knowledge and experience of the average citizen as a result of modern developments in communications and transportation, has enabled people to utilize in an increasingly effective manner whatever severe storm indications may have been available, whether warnings issued by the Weather Bureau or signs based on local observations. This greatly increased comprehension has characterized successive periods within the years studied, but the rate of increase has certainly been most marked during the last 20 or 25 years, since the widespread use of radio, the auto, and mass education media like motion pictures and, more recently, television. At the same time the tremendous increase in telephone subscribers and in use of the telephone, radio, and television have greatly augmented means for disseminating warnings of tornado-breeding weather situations or of tornadoes already in progress. In all these respects, too, the benefits to be derived in reducing tornado casualties have been either more decidedly or exclusively identified with the second 19 years.

HOURLY DISTRIBUTION OF TORNADO DEATHS

Tornado deaths occur at all hours of the day or night, but their hourly distribution is quite uneven. For the years 1916 through 1953, a large majority took place in afternoon and early evening (table 16). Thus the 8 hourly intervals, beginning at 1331 LST and ending at 2130 LST include nearly three-fourths of all deaths tabulated; the remaining 16 hours account for but slightly more than one-quarter of the total. Incidentally, every one of the 8 leading hours accounted for more than 4.17 percent, the mean hourly proportion of all deaths tabulated, and every 1 of the other 16 hours accounted for less than this mean proportion (fig. 2).

Within the 8 leading hours, 3 consecutive ones in the afternoon had an outstandingly large proportion of deaths, namely, those beginning at 1431, 1531, and 1631 LST, in order of decreasing magnitude. It is apparent from the chronological arrangement of hourly variations that there was a rather abrupt onset of tornado-death activity in early afternoon, culminating rather quickly in a maximum during the second of the 8 leading hours. The subsequent decline was much slower and it was punctuated at the end of the 8-hour interval, between 2031 and 2130, by a substantial secondary maximum.

Following this secondary maximum, there was a sharp drop in number of deaths during the first of the remaining 16 hourly intervals. Thereafter the decline was general, but slow, reaching a minimum value between 0531 and 0630 LST. Following the minimum, the hourly death total increased slowly at first, with one notable irregularity, and then more rapidly as early afternoon approached.

The reason for the primary maximum between 1431 and 1530 LST, as well as for the preponderance of deaths in it and the succeeding hourly intervals is obvious. In general, this hourly regime of deaths results from a marked increase in tornadic activity as a result of the trigger action of thermal convection during the warmest hours of the day.

There is another circumstance, not primarily meteorological, which should tend to reduce the

TABLE 16.—*Tornado deaths, by groups or hours, 1916–53**

Hours (LST)	Number of deaths	Percent of all deaths tabulated
1331–2130	5,874	73.6
2131–1330	2,114	26.4
All hours	7,988	100.0

*This analysis of hourly distribution is based on a total of 7,988 fatalities, consisting of those among the 8,742 deaths for which time of the tornado strike could either be established from reliable reports or estimated with reasonable certainty within 1 hour of the probable time of occurrence. Each tornado death is assigned to the hour at which the tornado struck whether the death was immediate or occurred at some later time.

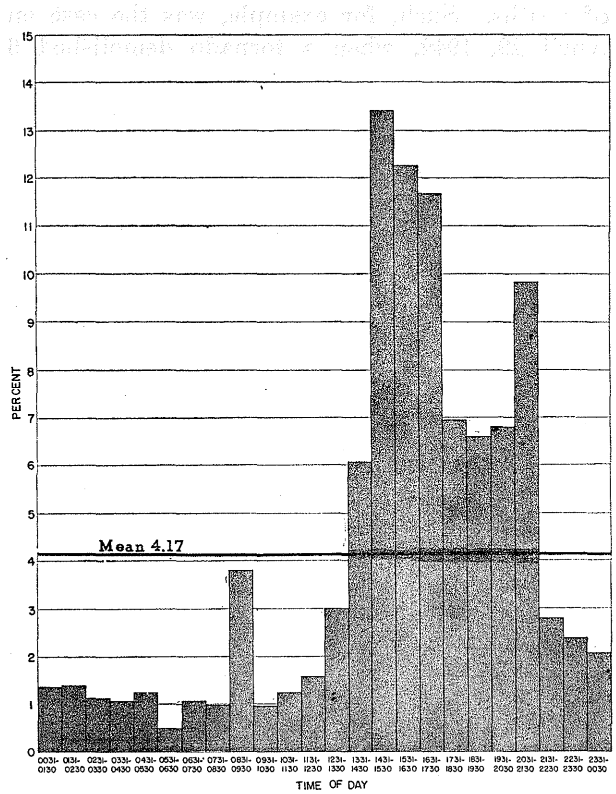

FIGURE 2.—Hour of tornado deaths, expressed as a percent of all tornado deaths capable of being timed within one hour of their occurrence. Data for years 1916–1953.

incidence of deaths subsequent to such a sharp onset of tornadic activity. As individual storms are born and observed, and as their apparent course of movement becomes established, those which are destined to be long-lived and unusually violent should claim an ever-decreasing proportion of potential casualties as communities in their projected paths become alerted. However, some of the all but incredible records of storms that have struck important population centers without warning, after having traveled toward them steadily for hours, lend a considerable measure of doubt concerning the success with which this inherent advantage has been exploited prior to the quite recent past.

The secondary maximum from 2031 to 2130 LST undoubtedly results from the tendency of fatalities to increase somewhat during evening hours, when darkness obscures approaching funnels, and when increasing numbers of people are grouped together in homes, and some are already asleep. This opinion is based on numerous instances in which accounts of casualties reveal the significance of these circumstances in augmenting the number of deaths. Such, for example, was the case on April 29, 1942, when a tornado demolished 6 houses and killed 15 persons in the shallow valley of Sappa Creek, east of Oberlin, Kans., at about 2230 LST. According to the *Topeka Daily Capital* [28], all victims were in their nightclothes, indicating that they had already retired. These deaths were confined to 4 families, 2 of which were wiped out. Even when most people are not in bed asleep, deaths may be increased by darkness. Thus, in discussing the early evening storm that struck in Jay and Adams Counties, Ind., on March 28, 1920, Holcomb [18] states flatly that loss of life was increased because, in the gathering darkness, few realized that a tornado was approaching.

The small proportion of deaths in each of the remaining 16 hourly intervals results most importantly from fewer tornadoes because of greater stability in the lower atmosphere during these hours. The wide departure from regularity exhibited by the bar for the hourly interval from 0831–0930 LST (fig. 2) is largely, but not entirely, explained by one exceptional disaster during hours when tornado deaths are generally few. The deaths at Gainesville, Ga., shortly after 0830 LST on April 6, 1936, comprise 203 of 303 deaths represented in that hourly interval.

CHAPTER II

AREAL DISTRIBUTION OF TORNADO DEATHS

Since paths of tornadoes are generally rather short and narrow, it is to be expected that the effects of any given storm are usually felt only over a very limited area. Even for a considerable period of years, tornadoes sweep over but a small fraction of the area of any one State, including those in regions most frequented by such storms.[1]

Localized as these tornado tracks are, the areal distribution of tornado deaths is even more restricted. Not only do a mere fraction of all tornadoes cause fatalities, but it is customarily only here and there along their paths that death-dealing tornadoes kill people. At least between 1916 and 1953 there were several States within whose borders tornado fatalities were not reported.[2] Moreover, every State, including those in the major tornado-death region, has a number of counties without reported deaths in the same period. Unquestionably, too, there are extensive areas in this country where no one has ever been killed by a tornado.

AREAS HAVING FEW TORNADO DEATHS

The most distinctive broad-scale feature of tornado-death distribution in the United States is the fact that deaths are almost entirely confined to that part of the country lying east of the Rocky Mountains (chart 16). Of the 8,742 deaths represented on this map, only 6 took place in the Western Highland.[3] Moreover, none of the six occurred in any State bordering the Pacific Ocean.[4]

The virtual absence of tornado deaths west of the Great Plains is primarily a result of meteorological factors and settlement patterns. That the wide areas with few or no people between the Great Plains and Pacific Coast valleys contribute not only to the fewness of deaths but also to the small number of tornadoes reported cannot be questioned. It is extremely doubtful however, that population distribution is the more important factor. In the Western Highland there are several areas, such as the Columbia Plateau of Washington, the Snake River Valley, and the piedmont at the western base of the Wasatch Mountains which have more and larger clusters of population than those of the northern Great Plains. Yet not 1 death was reported from the areas just mentioned between 1916 and 1953, and only 5 deaths were reported during these years in the whole northern part of the Western Highland (chart 16).

Even more striking is the absence of any reported tornado deaths from the entire area west of the crest of the Sierra Nevada and Cascades. In these Pacific Coast Valleys—the Puget-Willa-

[1] Day [5] divided the United States into equal areas of 10,000 square miles each and, using data for the years 1916 through 1928, computed the frequency with which tornadoes were observed in any part of each square. Values obtained ranged from zero to between two and three, the latter in northeastern Kansas and nearby parts of Nebraska, and in central Arkansas and most of Iowa.

[2] Eleven States, Washington, Oregon, California, Nevada, Utah, and Arizona in the West, and Delaware, Connecticut, Rhode Island, Vermont, and Maine in the Northeast reported no tornado deaths between 1916 and 1953. Maine, however, reported one fatality in 1954.

[3] The six: two in Idaho; three in Montana, and one in New Mexico.

[4] There are, however, records of one, and possibly two, death strikes by tornadoes in Pacific Coast States. Henry [16] lists a tornado, that occurred at Long Creek, Grant County, Oreg., on June 3, 1894, and killed "several" persons. It is to be noted, incidentally, that Long Creek is east of the Cascades, not on the Pacific slope. More recently, on April 8, 1926, one of a series of hundreds of whirlwinds triggered off by an oil tank-farm fire, killed two persons near San Luis Obispo, Calif. Hissong [17] refers to these disturbances as "whirls" and "tornadoes." Yet, whether by design or by chance, in writing of the one that caused the two fatalities he never specifically calls it a tornado. In one instance, however, he refers to it as a funnel, and he remarks concerning the orientation of debris about the destroyed place as indicative of counterclockwise rotation. Accompanying the article are five photographs showing funnel clouds, but data relating to them suggest that they were all taken after the fatalities occurred and, hence, do not constitute a record of the death-dealing whirlwind. Whatever the reason, neither any of these whirlwinds nor the two deaths caused by one of them is included in the Weather Bureau log of tornadoes for 1926. Therefore these two deaths have not been included in the 8,742 fatalities used in this study.

mette, the Central Valley and coastal valleys of California, and in the Los Angeles basin—are population centers the equal to those east of the Rockies, yet not one tornado death was officially recorded in these moderately to densely settled regions over a period of 38 years. The factor more important than population distribution is lack of frequent or violent tornadoes.

East of the Cascades, in the northern part of the intermontane region, neither frequent nor particularly devastating tornadoes occur. In the southern part of the intermontane region tornadoes are few, and in spite of some clustering of people around oases, but one death was reported from this large area between 1916–53. It is interesting to note that Arizona, Nevada, and Utah reported no deaths at all during the 38 years covered by this investigation.

Not so striking as the virtual absence of tornado deaths in the Far West is lack of fatalities in areas adjacent to the Canadian border, in the Great Lakes region and the northern parts of States farther east (chart 16).[5]

Chief reasons for the general absence of deaths along this section of the Canadian border are the decrease in population compared with areas farther south, and a waning in the frequency and intensity of tornadoes. The latter factor appears to be the more important of the two, however, since there are some parts of this area within which population is large enough and dense enough so that some deaths could be expected if tornadoes were frequent or severe. Though tornadoes are not unknown in this northern border area, they are few in number, have paths of no great length or width, and are apparently weakly developed. Not one of two dozen or more tornadoes reported from representative parts of the area between 1916 and 1950 caused any deaths, and only one has since.

DELIMITATION OF TORNADO-DEATH REGIONS

South of the border area just discussed, and east of the western margin of the Great Plains, tornado deaths are widespread. A glance at the dot map (chart 16) reveals, however, that the distribution of deaths is quite uneven. In order to organize these widespread but areally contrasted death clusters into groups whose characteristics possess some measure of homogeneity, this part of the country has been divided into a number of tornado-death regions.

In determining regional boundaries it is assumed that two characteristics of tornado-death occurrence merit special emphasis, namely, the number of deaths and the manner of their distribution. The number and localized concentration of deaths are shown in detail on the dot map (chart 16). The map of death areas summarizes contrasts in the areal continuity of death distribution (chart 17).[6] In fixing the detailed configuration of parts of some boundaries, however, some consideration is given to distribution of counties experiencing repeated death strikes as well as to seasonal contrasts in the regime of tornado deaths and tornado-death days. Where data are virtually lacking, most notably in eastern Kentucky, West Virginia, and much of western Virginia, the precise position of boundaries is frankly speculative, and rests primarily on a subjective estimate of tornado-death potentialities in the area concerned.

Preparatory to delimitation of the tornado-death regions, the map of death areas was superimposed on the dot map (chart 16), and a sheet of tracing paper was placed over both on a light table. First, heavy dotted lines were drawn so as to generalize the utmost extent of territory from which tornado deaths were reported. Then, within that part of the country which experienced death-dealing tornadoes, boundaries were drawn so as to include within one and the same region contiguous areas having similar attributes with respect to number, concentration, and continuity in distribution of tornado fatalities. The resulting pattern (superimposed on chart 17) shows the affected part of the United States divided into four large tornado-death regions.

[5] It may be interesting to note that according to the Weather Bureau [30] one person was reported to have been killed by a small tornado north of Caribou, in Aroostook County, Maine, on August 11, 1954.

[6] To construct this map a piece of tracing paper was placed over the dot map on a light table. Lines were then drawn so as to enclose those portions of counties in which tornado deaths occurred, and, conversely, so as to exclude all counties or parts thereof from which no fatalities were reported. However, death groups within the same or contiguous counties were connected by attenuated links.

REGION I

Tornado-Death Characteristics of Region I

Compared with all others, Region I is characterized in superlatives. In every tornado-death attribute selected, Region I outranks each of the other three, usually by a very wide margin.

Region I has the most deaths, 6,563 (table 17). These deaths constitute slightly more than three-fourths of the national total, in an area covering less than one-fifth of continental United States and supporting less than one-fifth of the country's inhabitants. Moreover, the fact that it outranks each of the other regions in number of tornado fatalities cannot be ascribed primarily to differences in area or population. Region I has nearly 12 deaths per 1,000 square miles, more than 3 times the comparable figure for the next ranking region; its 23 deaths per 100,000 inhabitants is over 5 times greater (table 18).

Continuity in pattern of death distribution in Region I is likewise unmatched elsewhere in the country (chart 17). The compact heart of the region is completely enclosed by a cordon of counties, each of which reported one or more deaths. Within the area thus enclosed, a majority of counties, but by no means all, reported some tornado fatalities. Even within the transitional eastern and western sections of Region I, tornado deaths are about as continuous and the pattern of death areas about as dense as they are in any area of comparable size outside the region.

In number of tornado-death days, that is, days on which one or more tornado fatalities were reported within its boundaries, Region I, with 406, is also outstanding (table 19). This notable frequency of death days is likewise reflected in the high proportion, nearly half, of its death-reporting counties which recorded fatalities on two or more days (table 20). Even more conspicuous is the position of Region I in higher death-day categories; of 54 counties in the United States which experienced 4 or more death days, all but 3 are situated in Region I. This heavy concentration of multiple-death-day counties in Region I is strikingly depicted on the county map (chart 18), which shows the geographical distribution of all counties reporting tornado fatalities on two or more days.

Region I also stands first in number of fatalities per tornado-death day, 16 persons (table 19). Even more commanding, however, is the margin

Table 17.—*Tornado deaths (1916–53), area and population (1950), by regions*

Region	Deaths		Area	Population
	Number	Percent of United States total	Percent of United States total	Percent of United States total
I	6,563	75.1	18.4	18.7
II	1,702	19.5	15.6	26.6
III	352	4.0	9.6	32.2
IV	125	1.4	19.2	3.2
Other United States	0	.0	37.2	19.3
Total	8,742	100.0	100.0	100.0

Table 18.—*Tornado deaths (1916–53), per unit area and population (1950)*

Region	Area (thousand square miles)	Deaths per thousand square miles	Population (hundred thousand)	Deaths per hundred thousand
I	554.3	11.8	281.9	23.2
II	470.2	3.6	400.8	4.2
III	291.3	1.2	487.4	.7
IV	577.6	.2	47.7	2.6
Other U. S.	1,129.0	.0	289.2	.0

Table 19.—*Tornado-death days, average number of deaths per death day and largest total on any day, by regions, 1916–53*

Region	Number of tornado-death days	Average number of deaths per tornado-death day	Highest death total any calendar day
I	406	16.2	788
II	190	9.0	150
III	86	4.1	90
IV	48	2.6	17

Table 20.—*Counties having 2 or more, 3 or more, 4 or more, and 5 or more tornado-death days, by regions, 1916–53*

Region	2 or more		3 or more		4 or more		5 or more	
	No.	Percent of regional total	No.	Percent of regional total	No.	Percent of regional total	No.	Percent of regional total
I	247	47.3	125	23.9	51	9.8	19	3.6
II	68	22.6	13	4.3	2	.7	1	.3
III	16	18.8	2	2.4	1	1.2	1	1.2
IV	3	5.5	0	0	0	0	0	0

TABLE 21.—*Tornado deaths in March and April, Regions I and II, 1916–53*

Region	Deaths on all days		Deaths on days with 25 or more deaths	
	Number	Percent of regional total	Number	Percent of March-April total
I	4,117	62.7	3,312	80.4
II	385	22.6	206	53.5

by which Region I leads all others in maximum number of deaths reported on any calendar day. On March 18, 1925, within Region I, tornadoes killed or fatally injured the staggering total of 788 persons (table 19).

Widespread tornado deaths are most peculiarly identified with areas in Region I in March and April (charts 4 and 5). Indeed, more than three-fifths of all tornado deaths in this region occurred in March and April, and days with 25 or more fatalities accounted for slightly over four-fifths of the 2-month regional total (table 21).

Region I is subjected to violent tornadoes with a frequency exceeding that of any other part of the country, but this important factor alone could not guarantee a single fatality. To have tornado deaths there must be people. With a population exceeding 28 million (table 18), Region I has plenty of inhabitants to serve as potential tornado victims. Moreover, though much of the region is still dominantly rural, in many sections the clustering of people in places such as small hamlets, around industrial plants, and in workers' quarters on large landholdings has contributed to some remarkably high spot death totals outside urban communities.

In addition to the foregoing basic factors, there are several others that tend to augment the number of tornado deaths in Region I. Among them is the prevalence of lightly constructed houses, sometimes insecurely anchored to foundations and often without basements that could provide adequate storm refuge. The proportion of this type of housing, typical also of other parts of the warmer South, is certainly higher than in the North where a colder climate demands more substantial dwellings.

The hazard during violent storms in Region I has been further increased by the crowding of some of the underprivileged into mere shanties. In storm reports, repeated comments have been made concerning the disproportionately large number of such unfortunate people who have been killed in 1 or 2 houses, in workers' quarters on plantations, or in congested residential sections of towns and cities. In more than one report it is noted that up to 10 or 15 deaths have resulted when just a couple of buildings were demolished by a small tornado. To say that there has been marked improvement in the quality of housing in recent years does not obviate the fact that such conditions were more widespread during much of the period under investigation. Moreover, the relative isolation of the underprivileged, a factor that must have been of much greater importance in former years when contacts were fewer, education meager, and communications and transportation more limited, has contributed to tornado casualties by putting these people at a disadvantage in diagnosing and getting reports on impending danger.

PATTERN OF DEATHS IN REGION I

Within Region I the pattern of deaths is characterized by the presence of many large spot totals, each represented by a good-sized circle, between which there is a fairly dense scattering of deaths, individually and in small clusters. As befits the definition of a tornado-death region, this arrangement of fatalities is typical of most areas within this part of the country.

The Largest Groups of Deaths.—Even the larger, more conspicuous death clusters owe their size and prominence primarily to the effects of single notable storms. Of 17 localized areas in Region I that accumulated 50 or more tornado deaths between 1916 and 1953, the large size of only one, the group at Heber Springs, Ark., depends on increments from as many as 2 days (table 22). In 11 of the 17 cases, all deaths resulted from just 1 exceptionally deadly tornado strike; in 5 of the remaining 6, more than four-fifths of the deaths occurred under similar circumstances.

Most large death groups mark the place where a mighty vortex passed across a village, town, or city. In Region I, all 5 death clusters numbering more than 100 victims were situated in urban areas, as were 4 of those totaling between 50 and 99 (table 22). Of the remaining 8, only 1 took place in what might be called strictly rural territory; the other 7 were in small towns and villages of less than 2,500 inhabitants.

The Murphysboro Tornado.—Some of the larger

TABLE 22.—*Localized death groups in Region I consisting of 50 or more persons, 1916–53*

Place	Number of deaths represented by circle	Date(s) of major death strike(s)	Number of deaths, major death strike	Population*
Murphysboro, Ill. area	240	Mar. 18, 1925	240	8,182
Tupelo, Miss. area	223	Apr. 5, 1936	216	8,212
Gainesville, Ga. area	205	Apr. 6, 1936	203	10,243
West Frankfort, Ill	127	Mar. 18, 1925	127	14,683
Waco, Tex	114	May 11, 1953	114	84,706
Woodward, Okla	95	Apr. 9, 1947	95	5,915
Poplar Bluff, Mo., area	92	May 9, 1927	86	7,551
DeSoto (town and township), Ill	76	Mar. 18, 1925	76	{673 1,454
Rocksprings, Tex	72	Apr. 12, 1927	72	998
Antlers, Okla	69	Apr. 12, 1945	69	2,506
Peggs, Okla	60	May 2, 1920	60	157
Judsonia-Bald Knob area, Ark	59	Mar. 21, 1952	49	{1,122 2,022
Warren, Ark	55	Jan. 3, 1949	55	2,615
Chilton County, Ala	53	Mar. 21, 1932	51	Rural
Griffin, Ind	52	Mar. 18, 1925	52	208
Higgins, Tex	51	Apr. 9, 1947	51	675
Heber Springs, Ark	50	{Nov. 25, 1926 June 5, 1916	22} 20}	1,401

*Population of chief village, town, or city struck, at census nearest day of highest death total.

death clusters are constituent parts of a whole string of deaths which mark the path of an historic storm. Most conspicuous among them is the row of dots and circles across southeastern Missouri, southern Illinois, and southwestern Indiana delineating the path of the storm of March 18, 1925 (charts 16 and 4). The 737 lives claimed by this huge vortex constitute more than 8 percent of all tornado deaths in the entire country between 1916 and 1953. Included in this astounding total were 234 deaths in the city of Murphysboro, Ill., the largest spot death total in the 38-year period, 127 in West Frankfort, Ill., and 76 in DeSoto town and township, Illinois.[7]

Henry [15] points out that the tremendous destruction caused by this storm derived in part from the exceptionally large area it swept in view of its width (from ¼ to 1 mile), and its length (over 200 miles). Granting that this was a vortex of record-breaking proportions, number and distribution of people were the most important factors determining the number and arrangement of fatalities. Thus in the first three Illinois counties, in which the storm passed over several towns and villages, fatalities numbered 565 over a distance of approximately 48 miles. Conversely, in the last two Illinois counties, in which the storm passed through open countryside, only 66 deaths were reported in a distance of about 44 miles. Moreover, had this storm followed a course across Illinois but a few miles farther south, the number of deaths would probably have numbered in the tens rather than the hundreds. Indeed, in Missouri where its path, though somewhat narrower, passed through rural territory, fatalities totaled just 13 over a distance of approximately 85 miles.

This storm also illustrates, even if in a negative way, the importance of receiving some warning of the approaching danger, and the need for some safe shelter. In the paper previously referred to, Henry added that the general absence of storm cellars and of houses with basements in this area left few satisfactory refuges. Moreover, he continues, in western Illinois, where casualties were heaviest, few people reported having seen a funnel cloud; when they went into their homes for shelter, many believed that only a severe thunderstorm was approaching.

The Tupelo and Gainesville Tornadoes.—The other two localized death totals exceeding 200 persons are situated in the Southeastern States, and recall the tornado disasters of early April 1936. The larger of the two consists of 223 fatalities in Lee and Itawamba Counties, Miss. (charts 16 and 5). Of these, 216 were killed in Tupelo on April 5, 1936 by a tornado that cut a swath averaging 400 yards in width from southwest to northeast across residential areas of this small city. It is significant to note that this vortex struck at about 2100 LST on a Sunday, when darkness obscured the approaching storm, and many families were probably gathered together in their homes.

A little less than 12 hours later, on the morning of April 6, two funnels, whose paths joined temporarily, swept a 4-block-wide path of destruction across business and residential sections of Gainesville, Ga. The resulting 203 deaths comprise all but two of those represented by the large circle in northern Georgia (charts 16 and 5).

These two extraordinary death strikes, born of the same atmospheric disturbance and closely related in time, were responsible for one of the most concentrated doses of death ever meted out by tornadoes. In just over 20 hours, between 1400 LST on April 5 and approximately 1000 LST on April 6, 1936, these and other tornadoes claimed the appalling total of 452 lives, chiefly in Mississippi, Georgia, Alabama, and Tennessee. Though split between two calendar days, this is the second-highest 24-hour tornado-death total for the period covered by this investigation. It is interesting to note that the four largest death clusters, which in-

[7] For all years of record, the Murphysboro total was exceeded just once, by the 306 deaths at St. Louis on May 27, 1896.

clude all those comprising more than 200 fatalities, occurred in connection with this and the March 18, 1925, series of tornadoes. Conversely, it is to this grim harvest of deaths by large and violent vortices in urban areas that these two record-breaking tornadic episodes owe their noteworthy rank.

The Waco Disaster.—In contrast to the four biggest death groups, all of which occurred in large towns or in small cities having less than 15,000 inhabitants, the disaster in the city of Waco, Tex., on May 11, 1953, accounted for the fifth-largest group of fatalities in Region I (table 22, charts 16 and 6).[8] Brooks [2] remarks that the tornado responsible for this catastrophe was the first to strike the downtown section of a large city during business hours. The 114 fatalities which resulted from this unhappy coincidence are anything but reassuring to those who must live and work in the many rapidly growing urban centers of our Southern States.

It is only a matter of chance that any of the four largest spot death totals did not happen in a big city rather than in one of the smaller urban settlements. That tornado casualties in the latter areas can equal or exceed those in the former is understandable, however, in view of limitations placed on the area subject to tornadic winds by the relatively small diameter of even the larger vortices. It is evident therefore that any good-sized town presents a target of sufficient dimensions to enable a tornado of notable size and development to amass a death toll ranking among the largest.

Large Death Groups in Small Towns.—Smaller towns and villages, on the other hand, do not present comparable death possibilities, even when almost completely demolished. There is, for example, the case of Rocksprings, Tex., seat of Edwards County, a small town with a population of about 1,000. On April 12, 1927 a tornado, which passed directly overhead, virtually wiped out the settlement and left but 12 standing buildings, of which 6 were badly damaged. Jarboe [20] remarks that no town was ever more nearly destroyed by a tornado, an observation that seems credible in view of the extreme violence of the storm and the fact that the width of its destructive path across the 1-square-mile townsite varied between 7/8 and 1 1/8 miles. The resulting death toll, one of the largest for any town under 2,500 population between 1916 and 1953, was 72 persons (charts 16 and 5).

Among still smaller communities, the disaster at Peggs, Okla. on May 2, 1920 may well serve as an example of the most inexorably deadly tornado strike ever recorded in this country. In a town occupied by less than 200 persons, fatalities ultimately reached a total of 60 (charts 16 and 6). Reihle [24] notes that few except those who sought the protection of storm cellars escaped injury. Ironically the only undamaged structure left in town is said to have been a frame building used as a jail. The malicious caprice of this violent storm is further illustrated by its brief but devastating contact with the ground. The vortex hopped a range of hills to the west of town before descending into the valley, where it carved a mile-wide path of utter desolation just 3 miles long, and then lifted without leaving further traces.

This same calamity also illustrates the distressing delay in aid that has sometimes followed such complete destruction in an isolated community, especially a generation ago. Reihle relates that during the evening of that day many people west of Peggs watched the tremendous cumulus cloud with which the tornado was subsequently known to have been associated, and had observed the bright rays of the setting sun on its top as well as the intermittent glow of lightning from within. Yet it was 6 hours before news of the disaster reached the nearest town from which calls for aid could be dispatched.

Though death possibilities are more limited in villages such as these, it is clear nevertheless that a square hit by an unusually well-developed vortex can result in fairly high casualties even in small communities.

Large Death Groups in Rural Areas.—The 53 deaths in Chilton County, Ala., constitute the only instance among the 17 largest death clusters in Region I where fatalities did not occur chiefly or exclusively in a village or larger node of settlement (table 22). Fifty-one of these fatalities occurred on March 21, 1932, in rural areas northwest of Clanton. On this memorable March afternoon and evening, a series of at least 10 tornadoes scourged widespread areas in central and northeastern Alabama, leaving in their wake a total of 268 dead and dying victims in 13 counties (charts 16 and 4). This series of storms is remarkable

[8] The 115 fatalities at Flint, Mich., in Region II, constitute the fifth-largest localized group of deaths in the country, as well as the largest total in a big city between 1916 and 1953.

because of the large number of deaths amassed in rural areas. Not more than a few tens of the victims lost their lives in good-sized towns; well over half of the death total took place in farming districts.

Individual Deaths and Smaller Groups.—Though the very large death clusters to which reference has been made constitute prominent features of tornado-death distribution as portrayed on the maps, individual deaths together with those in medium-sized and smaller clusters comprise a majority of all fatalities in Region I. Such deaths represent either the work of small tornadoes, or instances where well-developed vortices passed through farming country, or failed to cut squarely across a compact settlement. It is these much more numerous but less spectacular death strikes, spread over many different days and affecting many different districts which serve to fill out the pattern of deaths in Region I and impart to that pattern its notably continuous distribution of deaths.

Atypical Areas in Region I.—Though the pattern of deaths within Region I possesses a considerable measure of uniformity, there are some systematic departures from the prevailing mode of distribution. Most striking is the absence of deaths in southern West Virginia, and in many parts of eastern Kentucky and Tennessee (chart 16). Though people are few in some localities within these areas, which lie in the Appalachian Plateau, the overall density of population is actually greater here than in many other parts of Region I where tornado deaths are far more numerous (chart 19). On the other hand, there is a very close correlation in these areas between lack of deaths and lack of reported tornadoes (charts 16 and 20). Though there is little doubt that the seemingly complete absence of tornadoes over such wide areas is but a reflection of incomplete reports from these remote and uncommunicative districts, it is probable that the number of all tornadoes is far less, and it is certain that the incidence of exceptionally destructive ones is much lower than in the heart of the tornado country farther south and west.

This waning tornado activity is probably the joint result of topography and increasing distance from the center of the chief tornado belt. The probable significance of topography is suggested by the manner in which the belt of substantial tornado-death activity is projected far out across the Atlantic slope, around the southern end of the Blue Ridge (chart 16).

Despite the apparent influence of topography on tornado activity in the Appalachian Plateau section of Region I, it is significant to notice that neither altitude nor topographic barriers seem to preclude the occurrence, at least occasionally, of extremely violent tornadoes. Within Region I, the series of vicious storms that claimed a total of 29 lives in northeastern Tennessee on March 14, 1933, bears witness to this fact. This situation is even more emphatically demonstrated by the historic series of storms that killed 150 persons on June 23, 1944, a little farther north, in the Region II section of the Appalachian Plateau. Indeed, it is primarily because of its apparent notable, if infrequently realized, tornado-death potential that this doubtful area is included with Region I.

The other obvious large-scale departure from the pattern of death distribution generally prevalent in Region I is in central and southern Texas. The marked decline in density of deaths in this area (chart 16) is matched by a similar decline in density of population (chart 19) and in number of tornadoes reported (chart 20). Undoubtedly the chief factor in this instance is declining population. It is to be doubted that there is anywhere near a commensurate decrease in the frequency or severity of tornadoes. In any event, the obvious relationship between areal distribution of reported tornadoes and of population, especially around Austin and Abilene, seems to corroborate the assumption that previous reports from less densely settled areas are probably not representative.

In spite of a decline in density of deaths, these parts of Texas have many more tornado fatalities and an obviously higher death potential than peripheral areas farther south and west. In these and most other respects this transitional area resembles more closely adjacent parts of Region I and, hence, is included with them.

Tornado-Death Characteristics of Region II

Though Region II includes many Midwestern areas closely identified with tornadoes, and though it ranks second in every chosen category of statistics, the general level of tornado-death activity therein is far below that of Region I.

The 1702 tornado fatalities reported from Region II (table 17) comprise scarcely more than one-quarter the total for Region I, in spite of the fact that Region II has an area but slightly smaller and a population substantially larger than those of the former region (table 18). Then, too, the number of tornado-death days for Region II is less than half the comparable figure for Region I, and the average number of fatalities per death day, 9, is only a little more than half as many (table 19). The absolute daily death maximum in Region II, 150 persons on June 23, 1944, marks an even wider departure from the comparable total of 788 deaths reported in Region I on that fateful March day nearly 20 years earlier.

The marked disparity between Regions I and II in number and geographical distribution of multiple-death-day counties has already been noted (chart 18). In fact, fewer than one-quarter of all death-reporting counties in Region II experienced two or more death days, and a negligible fraction of 1 percent had four or more (table 20).

Region II also lacks the conspicuous continuity in distribution of death areas characteristic of Region I (chart 17). Whereas death areas predominate in the heart of the latter region, in Region II the arrangement of death areas is chiefly elongate or isolated, and most are embedded in large expanses of no-death territory.

It is not until May and June that tornado deaths become widespread in this part of the country (charts 6 and 7). Indeed, deaths in these 2 months constitute nearly three-fifths of the annual total in Region II (table 23), a very nearly complete reversal of the comparable figures in Region I (table 21). Thus the peak of the tornado-death activity in Region II occurs later in the season.

Most important cause for the sharp drop noted in tornado-death activity in Region II, compared with Region I, is the lesser frequency of extremely violent tornadoes, especially those occurring in groups or families. But there are other factors. Thus in the Midwest the prevailing pattern of rural settlement is dispersed, with each farmhouse set apart from those nearby. Moreover, the generally well-informed, weather-wise farmers possess a considerable awareness of local signs that presage the possibility of tornadoes. In the western part of Region II in particular, storm cellars are common, and they are used with great effectiveness during periods of threatening weather. Under such conditions, and with fewer exceptionally violent tornadoes, the size of casualty lists resulting from death strikes in farming areas is much smaller than in Region I.

In the central and eastern part of Region II, on the other hand, the high degree of urbanization tends to counteract somewhat the advantages deriving from the generally dispersed character of rural settlement. Here, if it were not for a marked decrease in tornado activity, much more numerous deaths in urban areas would raise substantially the level of tornado-death activity in the region as a whole.

Pattern of Deaths in Region II

In Region II the pattern of deaths consists of a fairly uniform scattering of deaths, individually and in small clusters, punctuated in just a few places by a large localized group. In contrast to Region I, very large clusters are far less numerous, and in no sense do they constitute the backbone of death distribution. Compared with Region I, there is also a remarkable decline in the density of deaths, partly because of the small size of most scattered death groups, and partly because of the relatively large areas of few or no deaths that separate the individual units.

Table 23.—*Tornado deaths in May and June, Regions I and II, 1916–53*

Region	Deaths on all days		Deaths on days with 25 or more deaths	
	No.	Percent of regional total	No.	Percent of May-June total
I	1,446	22.0	1,095	75.8
II	991	58.3	661	66.7

Large Groups of Deaths.—In Region II there are but 6 localized groups of deaths consisting of 50 or more persons, and only 2 others having from 25 to 49 (table 24). Each of these 8 large clusters owes its size to the deadly effect of just 1 vortex. Moreover, without exception the place struck was some city, town, or village. The three biggest occurred in urban areas of large or medium size. Only one, the smallest, was in a town of less than 2,500 inhabitants. In contrast to Region I, the largest localized group of deaths in strictly rural areas within Region II was the 15 perons killed near Oberlin, Kans.

In view of the exclusive association in Region II of very large death groups with tornado strikes in urban areas, it is interesting to note that 5 of the 6 accounting for more than 50 fatalities occurred along or east of the Mississippi River, where the higher proportion of urban inhabitants results in larger and more vulnerable targets than exist farther west. Included in these 5 are the 4 largest, all of which had 75 or more fatalities. In contrast to Region I, at least for the 38-year period covered by the investigation, no tornado strike in a small village resulted in a death total of notable size. In fact, except for Tyler, Minn., no community of less than 2,500 inhabitants in Region II suffered more than 19 tornado fatalities.

The Flint Disaster.—In spite of the large death toll (115) at Flint, Mich., on June 8, 1953, the tornado responsible for this disaster completely missed the heart of the city. All deaths in that vicinity took place along an 8-mile, east-west path through residential areas in the city's northern suburbs. The vortex was large and well developed; where it struck the northern outskirts of Flint its path of destruction is said to have been one-half mile wide. According to the report of an aerial survey made by personnel of the Detroit office of the Weather Bureau [29], this storm displayed a remarkable persistence in following east-west sections of highways, a peculiarity that greatly increased the number of casualties and the damage to property.

The St. Louis Tornado of 1927.—Though the September 29, 1927, tornado in St. Louis, Mo., passed northwest of the business district, its path lay well within the city limits, and crossed closely built-up and densely settled areas. That casualties were not even higher than the 72 reported fatalities can be attributed, perhaps, to its rather

TABLE 24.—*Localized death groups in Region II consisting of 25 or more persons, 1916–53*

Place	Number of deaths represented by circle	Date of major death strike	Number of deaths, major death strike	Population*
Flint, Mich	115	June 8, 1953	115	163, 143
St. Louis, Mo., area	80	Sept. 29, 1927	72	821, 960
Lorain, Ohio, area	78	June 28, 1924	73	37, 295
Shinnston, W. Va., area	75	June 23, 1944	72	2, 817
Fergus Falls, Minn	59	June 22, 1919	59	7, 581
Mattoon, Ill	54	May 26, 1917	54	13, 552
Charleston, Ill	38	May 26, 1917	38	6, 615
Tyler, Minn	36	Aug. 21, 1918	36	858

*Population of community hit, at census on date nearest to the death strike.

discontinuous path, and to the fact that the storm caused general destruction over only a 2½-mile portion of its path. In making the obvious comparison between this vortex and the great St. Louis tornado of May 27, 1896., Hayes [14] offers the considered opinion that the more recent one was probably not as violent.

The Mattoon Tornado.—Though death totals in the two small cities, Mattoon and Charleston, Ill., struck by this tornado, are not among the largest in Region II, they are of special interest because of the noteworthy characteristics of the storm. The tornado in question was first observed in western Illinois, close to the Mississippi River, at about noon on May 26, 1917. During the next 7 hours and 20 minutes it traveled nearly 300 miles to southeastern Indiana, the longest tornado path ever recorded. This vortex was most destructive in the 10 miles between Mattoon, where 54 persons were killed, and Charleston, where 38 more lost their lives. In Mattoon most of the damage took place in a section of the city occupied by small cottages of working people; in Charleston there was extensive destruction in both residential and business districts. This well-developed storm caused but 11 additional deaths elsewhere along its path, which passed chiefly through rural areas.

The Hennipin County, Minn. Tornadoes.—One more feature of death distribution in Region II seems to merit comment. Though few counties in this part of the country reported deaths on more than two days, Hennipin County, Minn. recorded the remarkable total of five death days between 1916 and 1953 (chart 18). The most obvious explanation for this unusual situation seems to be the coincidence of a very large population center and an area of considerable tornado activity in summer months. In several instances light to moderate casualties have resulted from passage of tornadoes across densely settled districts. The fact that southern Minnesota is subject to notable tornado-death activity in summer is also suggested by the fact that both Fergus Falls and Tyler, the only places west of the Mississippi River having 25 or more tornado deaths during the period covered by this study, are both situated in this general area.

TORNADO DEATHS IN PERIPHERAL AREAS

Tornado deaths in peripheral areas were generally few and scattered. Together, Region III, which borders the heart of the tornado-death country on the east and south, and Region IV, which adjoins it on the west, accounted for scarcely more than 5 percent of all tornado fatalities between 1916 and 1953. Of the two, Region III, with 4 percent of the 38-year national total, ranked higher in number of persons killed.

Region III

With 352 tornado fatalities, Region III displays a sharp drop in number of deaths compared with Regions I and II (table 17). In most other categories of tornado-death statistics too, Region III as a whole is far outranked by either Region I or II (tables 18, 19, and 20). However, within Region III, which extends through nearly 20° of latitude and embraces areas having marked differences in population, there are some noteworthy contrasts in tornado-death characteristics.

The Northeast.—In the Northeast, from Pennsylvania and New Jersey northward, deaths were generally few and extremely scattered. The one notable exception was Worcester County, Mass., where one remarkable tornado claimed a total of 90 lives on June 9, 1953 (charts 16 and 7). Seventy-eight of these fatalities occurred over a distance of about 8 miles in densely settled sections of Holden, Worcester, and Shrewsbury. The grim irony of the unhappy coincidence which caused the path of this formidable vortex to cross a succession of towns and cities is emphasized by the relative obscurity of a contemporaneous tornado which cut a 29-mile swath several miles south and east of the Worcester storm (see [23]). According to the Weather Bureau [32], this second storm was well-developed and potentially devastating, but property damage was light and fatalities lacking because its path lay mostly over wooded territory.

Most important reason for the generally low level of tornado-death activity in the Northeast is infrequency of violent tornadoes. On the other hand, the large population and high degree of urbanization enhance considerably such limited tornado-death possibilities as exist in this part of the country.

The Southeast.—Between Maryland and the southern end of the Florida peninsula, though number of people and density of population show a substantial drop in comparison with the Northeast section of Region III, the level of tornado-death activity does not. In the Southeast tornado deaths were not only more numerous, but their distribution was more continuous, and individual death units generally included more fatalities than in the Northeast (chart 16). Moreover, the tornado-death picture was not so completely dominated by the work of one unprecedented storm.

However, within the Southeast there were two rather large areas where deaths were either few or absent. No tornado deaths were reported in the more mountainous sections of Region III, between Maryland and North Carolina (chart 16), whether the consequence of a virtual lack of tornadoes (chart 20) because of high altitude and rough topography, or just a fortunate failure of occasional vortices to strike with sufficient force in populated areas. On the other hand, in the Florida peninsula tornado deaths were sparse, but not absent. In the latter area there seems to be no dearth of tornadoes, but such storms reported from Florida have short, narrow paths, and cause little damage and few, if any, casualties.

The markedly high level of tornado-death activity in other sections of Region III, between Virginia and Georgia, may result from their position in the lee of the highest portion of the Appalachian Highland. Fawbush, Miller, and Starrett [7] find indications of a small regional maximum of tornado frequency about 100 miles east of the mean Appalachian ridge. It is also possible that this part of Region III, lying as it does to the leeward

TABLE 25.—*Months having greatest concentration of tornado deaths, Gulf Coast section of Region III, 1916–53*

Months	Tornado deaths	
	Number	Percent of regional total
Nov.-Apr.	74	92.5
All other	6	7.5
Total	80	100.0

of Region I, shares in a very limited degree the high level of tornado-death activity of that part of the country. In any event, 19 of 50 fatalities reported from North Carolina between 1916 and 1953 occurred on two days marked by higher casualty lists in nearby areas within Region I.[9]

The Gulf Coast.—Along the Gulf Coast, from the Florida Panhandle westward, the density and distribution of tornado deaths is not unlike that on the Piedmont and Atlantic Coastal Plain of Virginia and North Carolina (chart 16). However, along the Gulf Coast, the density of tornado tracks is even greater than in the latter area (chart 20), and the number of counties reporting deaths on two or more days exceeds the combined total in all other parts of Region III (chart 18).

The fairly high level of tornado-death activity suggested by these comparisons with other sections of Region III results primarily from the deadly work of frequent tornadoes, many of which are quite severe but none of which causes damage over a very wide or very long path. As might be expected from its southerly location, death-dealing tornadoes in this area are concentrated in winter (table 25), a fact that may contribute to the moderate intensity of these storms. That such vortices cause no more fatalities is to be attributed not only to the limited area they customarily sweep, but also to the generally low density of rural population in this part of Region III.

The pattern of tornado deaths along the Gulf Coast, like the population, is scattered (chart 16). Most conspicuous, perhaps, in comparison with either nearby parts of Region I or other sections of Region III, is the complete absence of any localized group of deaths as large as 10. In view of the fact that the Gulf Coast has many urban centers, including several large cities, it would not be surprising to find that long-range tornado-death potentialities in this section of Region III embrace a 1-day maximum considerably higher than the record of 7 persons between 1916 and 1953.

[9] The 13 deaths in Greensboro and vicinity and one near Mebane on the evening of April 2, 1936, followed a 24-hour death toll of 31 persons in Region I sections of Alabama and Georgia. Four deaths in Chatham County and 1 in Martin County took place on Apr. 30, 1924, a day when 106 persons lost their lives in parts of South Carolina, Alabama, and Georgia lying within Region I.

REGION IV

The keynote in Region IV is few and scattered deaths in an area having considerable tornadic activity but low population density. For the entire 38 years, tornado fatalities total a mere 125 (table 17). Moreover, areas in which these deaths occurred are more isolated and more widely scattered than those in any of the other three tornado-death regions (chart 17). The 48 tornado-death days, though small in an absolute sense, are fairly numerous in view of the size of the death total. The wide distribution of deaths among death days is also reflected in the size of the absolute daily maximum, just 17 fatalities (table 19). There is also but slight tendency for tornadoes to strike repeatedly in one area; of 55 counties over which the 125 deaths were scattered, only 3 reported deaths on more than 1 day, and none on more than 2 (table 20).

Most important among reasons responsible for this very low level of tornado-death activity in Region IV are small population and wide dispersal of settlement. Indeed, when the small population is taken into consideration, tornado deaths in Region IV amount to between two and three persons per 100,000 inhabitants, well over half the comparable figure for Region II and nearly four times that for Region III (table 18). Though the frequency and intensity of vortices in Region IV are apparently sufficient to support a substantially higher level of tornado-death activity but for the notably sparse population, it is doubtful that the destructive capability of tornadoes in this part of the country is, in general, equal to that in Region I. Indeed, many funnels reported from these western plains are small and evanescent, and some never even reach the ground. These characteristics typical of tornadoes in Region IV doubtlessly help to reduce the number of deaths below what might otherwise be expected in view of the probable frequency of their occurrence.

Among other factors which contribute, at least in a minor way, to the low level of tornado-death activity in Region IV are the conspicuous development of funnels and the generally level topography. Henry [16] has observed that funnels seem generally to be more clear-cut and well defined in the Plains States than they are along the Gulf and Atlantic slopes. Beebe [1] comments that many photographs of tornadoes are of those associated with a type of airmass especially common over western and northern Plains States in summer and with which excellent visibility is customarily associated. The generally level topography and unobstructed outlook over wide areas in Region IV permit such prominent funnels to be seen and followed for miles over the prairie. As a consequence, the approach of a tornado is frequently more easily apprehended in these lands than in the East, and people are more likely to seek safe shelter or avoid the path.

The pattern of deaths within Region IV is quite simple. Largest spot total is the 10 persons killed in one house a few miles northeast of Thurman, in Washington County, Colo. This death group, though larger than any other, is typical of the tendency of deaths to be scattered individually or clustered together in one spot. Usually each of these units represents the place where the path of some well-developed vortex passed across a town, a school, or a farm. Moreover, in but few instances is there any connection in time or in space between adjacent units. In all these respects the pattern of deaths reflects the work of occasional well-developed tornadoes in a region whose population is small and widely dispersed.

CHAPTER III

CONCLUSIONS

Two factors are inseparable for the occurrence of tornado deaths. They are, obviously, tornadoes and people. In the United States, which has both a high incidence of tornadoes and many people, from a few tens to several hundreds of persons lose their lives each year as a result of these devastating windstorms. However, because of variations in the distribution of population as well as in the seasonal and areal distribution of tornadoes, there are marked contrasts from one part of the country to another in the number and seasonal regime of tornado deaths.

Since tornadoes have now been reported from all States, there is no part of the country that can be said to enjoy complete immunity from the possibility of tornado deaths. There are, however, quite extensive regions where the hazard to life from this source is so slight as to be practically nil. Foremost among them is the Pacific Slope, west of the Cascade-Sierra Nevada divide. Only slightly greater risk exists elsewhere in the Western Highland, and in the eastern United States in the vicinity of the Canadian boundary, east of western Minnesota.

It is within the remainder of the United States that tornadoes constitute a significant peril to life. In each of the four tornado-death regions there is what might be called a basic tornado-death hazard, which depends chiefly on the frequency and severity of tornadoes, and the number and distribution of people. Granted this basic hazard, it is possible to reduce it by any of several means. On an individual basis, people will always attempt to get out of the path of a vortex or reach safe shelter once they have become aware of the impending danger. In recent years, Weather Bureau tornado alerts, covering quite limited areas, represent a most significant break-through, which can be exploited on an organized and effective basis to protect whole communities. Far beyond the foreseeable future, there is the as yet doubtful prospect of weather control. All these and other factors may in the future alter substantially the degree of risk in any region. It should be understood, however, that as long as people and tornadoes occupy the same space they constitute a predisposing cause of tornado deaths that must be evaluated and overcome. And overcoming this susceptibility to casualties will always be realized at a cost, in money, in foresight and painstaking planning by disaster agencies, and in intelligent cooperation by the public. It is appropriate, therefore, to examine regional contrasts in this basic death hazard as indicated, at least to a first approximation, by experience over the period from 1916 through 1953, and to relate the varying degree of risk to certain obvious preventive measures.

The greatest basic tornado-death potential exists in south-central United States, within that part of the country identified as Region I. This region suffers the highest incidence of devastating vortices, and, probably, the most violent ones as well. Lacking effective tornado-death control, all parts of the region face the grim possibility of tens or hundreds of tornado casualties. In urban centers the death possibilities are extremely high, with maximum probable totals numbering in the hundreds. Moreover, the rapidly increasing urbanization in this part of the country constitutes a further incentive to expand the positive death-reduction measures already initiated. Though the maximum expectable toll in small villages is substantially less, perhaps 50 to 75 persons, such communities are liable to almost complete destruction. This latter prospect coupled with the general absence of tornado-proof buildings complicates death-evasion plans in small population centers. However, in Region I, every community, large or small, should undertake positive disaster-control measures. Even strictly rural areas, if moderately densely populated, may experience widespread fatalities. In the latter areas perhaps the best solution is the construction of sufficiently numerous storm cellars, and schooling of the inhabitants in their effective use.

Though the basic tornado-death danger in that portion of the North Central States lying within

Region II is substantially lower, the possibility of sudden death from these violent storms is still a threat with which to reckon. In this part of the country only cities and large towns seem to present targets of sufficient size to be in danger of large-scale disaster. However, in small villages deaths may occasionally number as many as a few tens. It is apparent, then that the potential risk is sufficiently great in all these population centers to justify the expense and effort needed to organize for an effective reduction of tornado casualties. In the open countryside, tornadoes may claim from one to ten or more lives on individual farmsteads at intervals along their paths. Fortunately in these areas storm cellars are already used effectively. Chiefly what is needed is an increase in the number and distribution of these refuges, especially in eastern North Central States, and an imaginative use of steadily improving tornado alerts.

In Regions III and IV, where the basic death hazard is far below that in the other two regions, the need for elaborate plans to reduce the number of deaths is open to some question. In the Northeast, infrequent well-developed vortices striking in large towns or cities constitute the only important danger to life from tornadoes. In view of the high degree of urbanization, positive preventive measures are probably worth the price. The same, however, cannot be said for rural areas in this part of Region III.

The tornado-death risk appears to be very small in most of peninsular Florida, too. However, in view of necessary hurricane precautions in this area, it might be improvident to neglect to dovetail some measure of tornado protection into local disaster control, at least in urban areas.

In other parts of the Southeast lying within Region III, as well as the Gulf Coast section of the same region, the tornado-death hazard is relatively higher, though still small in an absolute sense. In these areas the danger in urban centers is certainly great enough to demand precautions to reduce tornado casualties, even if no danger were to exist from hurricanes.

In the Great Plains, tornado-death potentialities are also small, but in this instance the limited danger depends very significantly on low density of population. This latter fact constitutes a clear warning to growing cities, which are most numerous in the Southern Plains, not to depend too heavily on past immunity for protection. Though the death hazard is rather small in rural areas, the unequalled ease with which funnels can be observed throughout the Plains encourages a continually expanding and more effective use of local signs in conjunction with whatever official tornado alerts may be possible in this sparsely inhabited, windward section of the chief tornado belt.

From season to season there are considerable fluctuations in the mean basic hazard in any given region. Thus in winter the possibility of tornado deaths is so slight as to be negligible anywhere in northern United States. In the North Central States tornado disasters occur rarely as early as March; in the Northeast there is little possibility through May. By October the danger throughout the North has again dropped to a very low level. Even the chief centers of tornado-death activity in the South have a seasonal respite from the specter of sudden death. By June the death possibilities are small in Southeastern States, and much reduced in the Southwest. From July to late September, the risk is very small anywhere in the South.

It is a well-known fact that people in many communities or localized areas, even within the chief tornado belt, have considered the immediate vicinity in which they reside to be immune from tornadic destruction. In some instances this belief seems to have evolved primarily as a result of prolonged freedom from tornado disaster. In other instances the opinion seems more firmly based on some tangible consideration, such as the existence of a topographic barrier to the windward, or location on the shore of a large lake. The record is replete, however, with cases of tornado strikes, some of them disastrous, in places whose site was hopefully supposed to be tornado-proof. At least until a great deal more is known about the mechanism that gives rise to tornadoes, and the complex factors that control their trajectories as well as their decline, it is unwise to depend for protection on such baseless assumptions.

On the contrary, far into the foreseeable future the only justifiable precaution against tornado deaths in those parts of the country where a significant basic risk exists is the planned use of Weather Bureau alerts and any local signs of an approaching vortex. In this connection it is significant to note that the capabilities of meteorologists do not in the foreseeable future embrace the control of tornadogenesis, or of the trajectories or life cycle of tornadoes already in progress. For the time being at least, the saving of lives depends strictly on control of the position and movements of people. However, with enthusiastic public support, and with the technical knowledge now becoming available, prospects for cutting the expectable annual tornado death toll in this country appear to be brightening rapidly.

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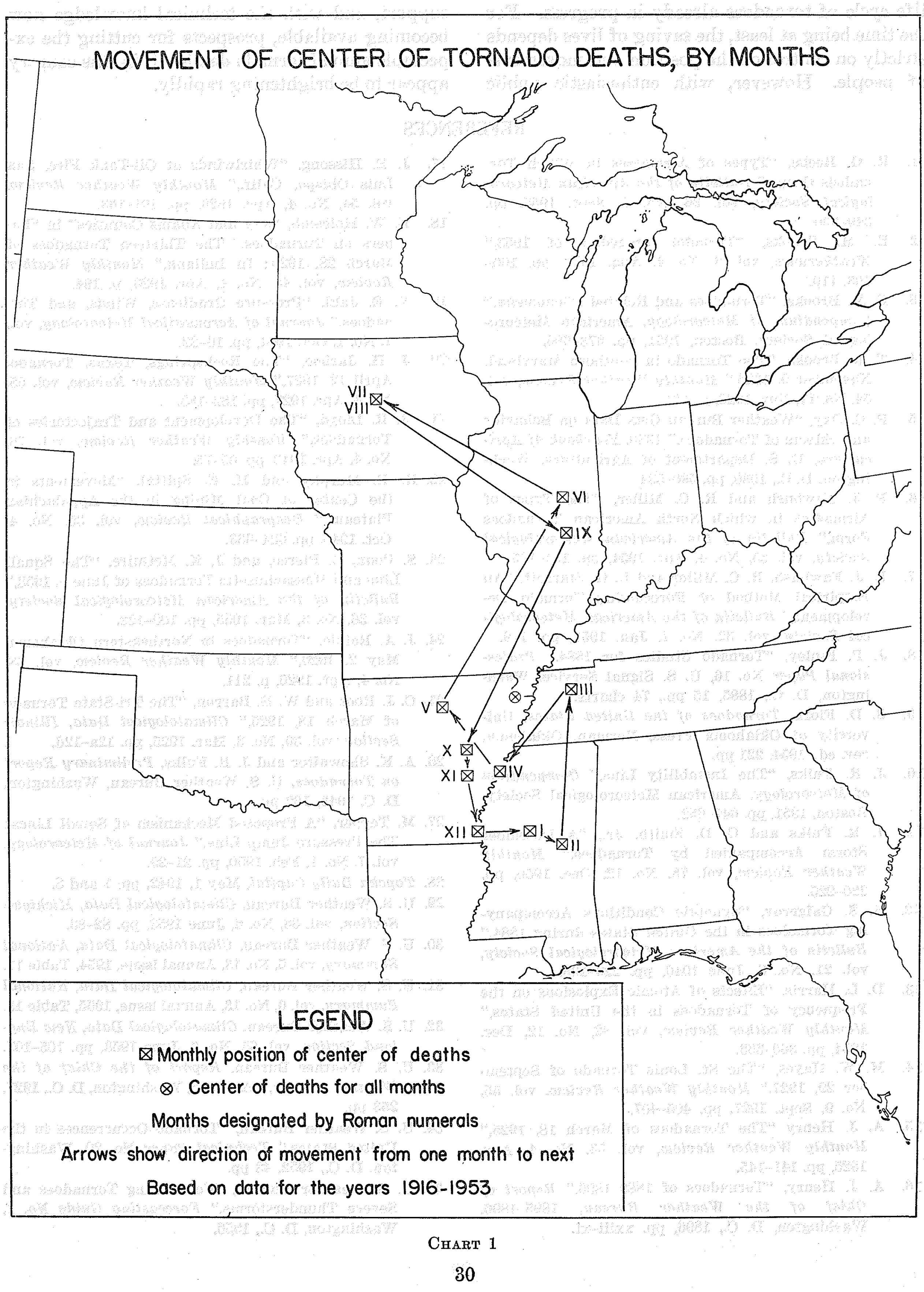
MOVEMENT OF CENTER OF TORNADO DEATHS, BY MONTHS
VII
VIII
VI
IX
V
III
X
XI
IV
XII
I
II
LEGEND
Monthly position of center of deaths
Center of deaths for all months
Months designated by Roman numerals
Arrows show direction of movement from one month to next
Based on data for the years 1916-1953

CHART 1

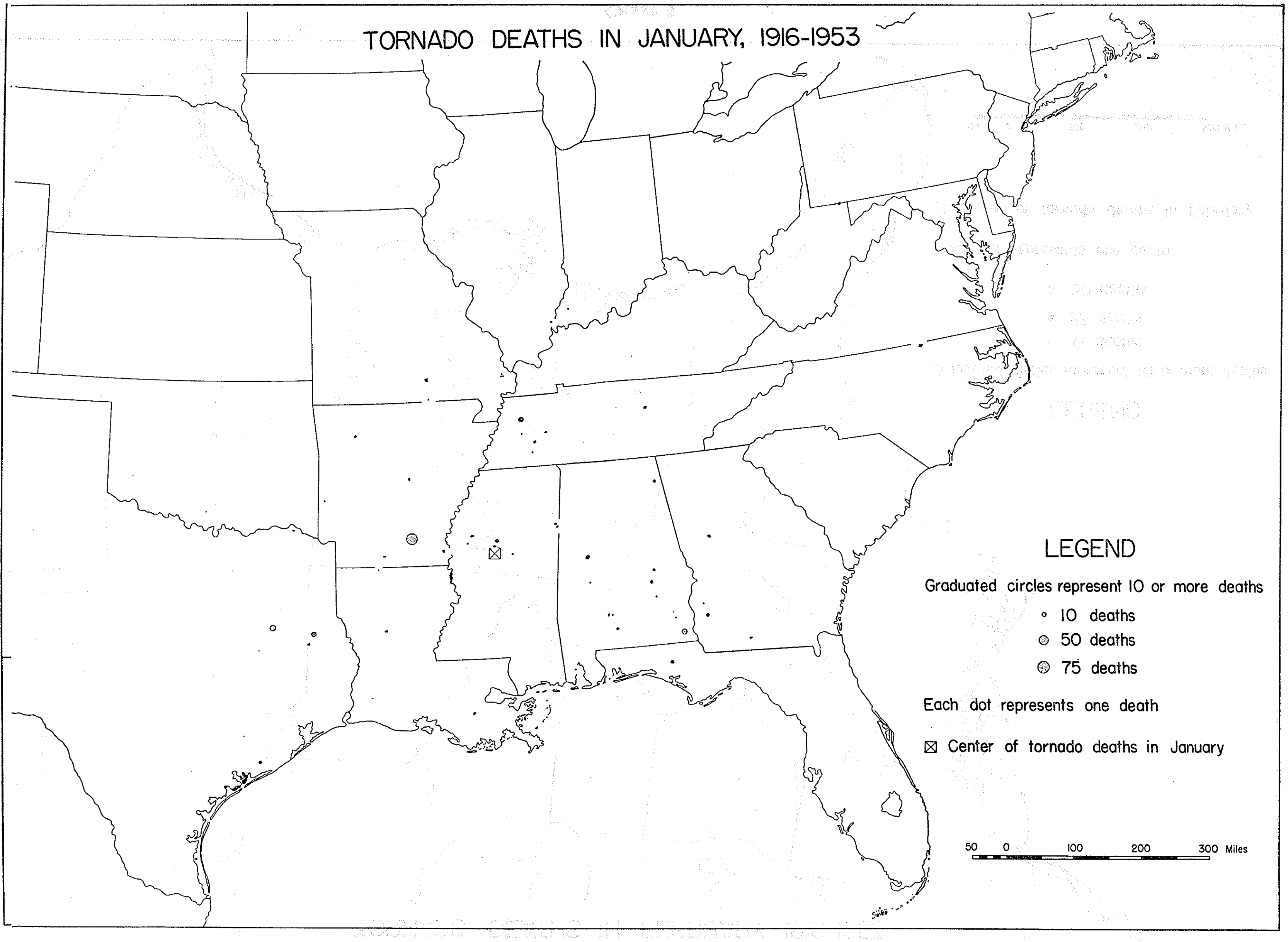
TORNADO DEATHS IN JANUARY, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
50 deaths
75 deaths
Each dot represents one death
Center of tornado deaths in January
50 0 100 200 300 Miles

CHART 2

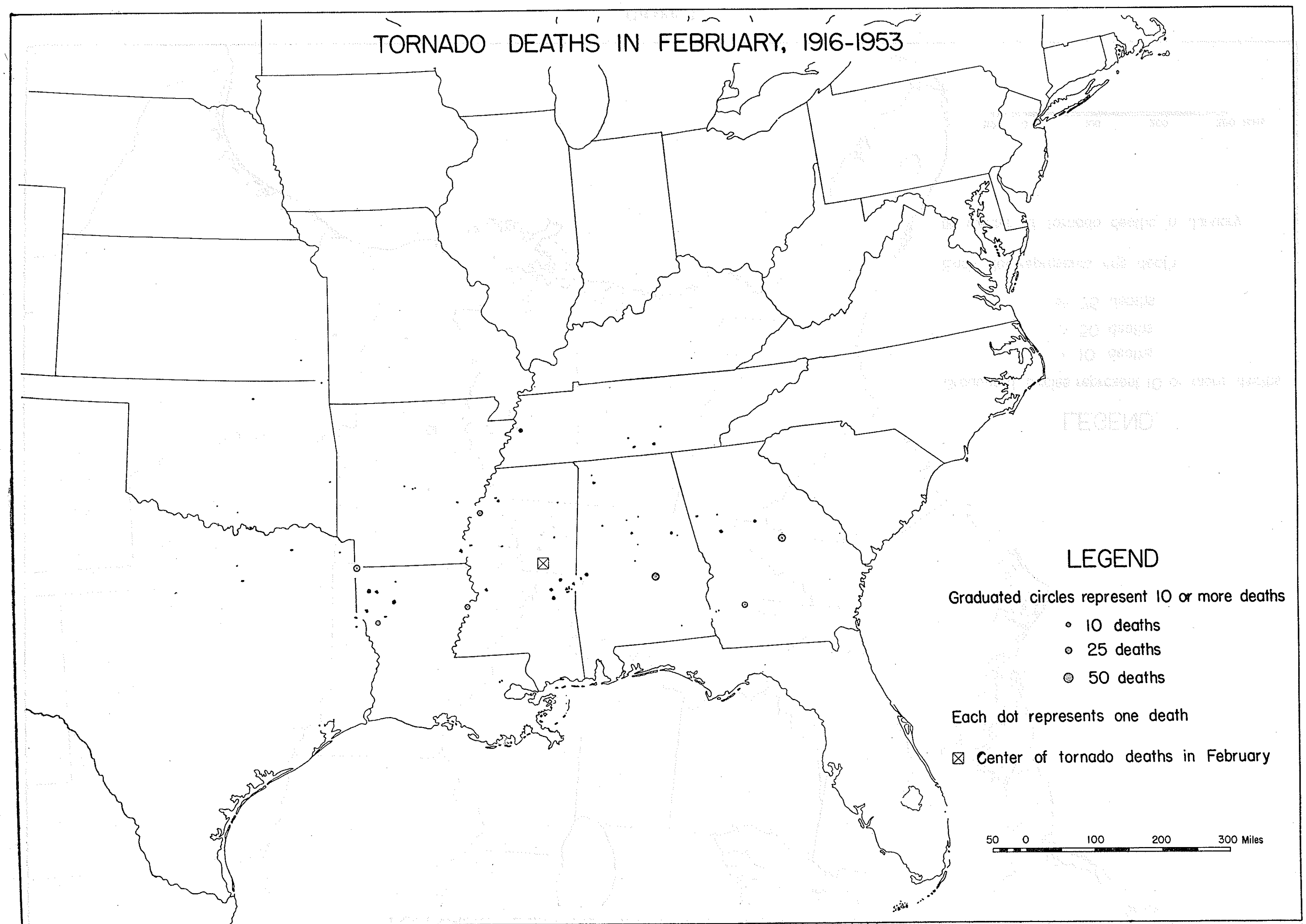
TORNADO DEATHS IN FEBRUARY, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
Each dot represents one death
Center of tornado deaths in February
50 0 100 200 300 Miles

CHART 3

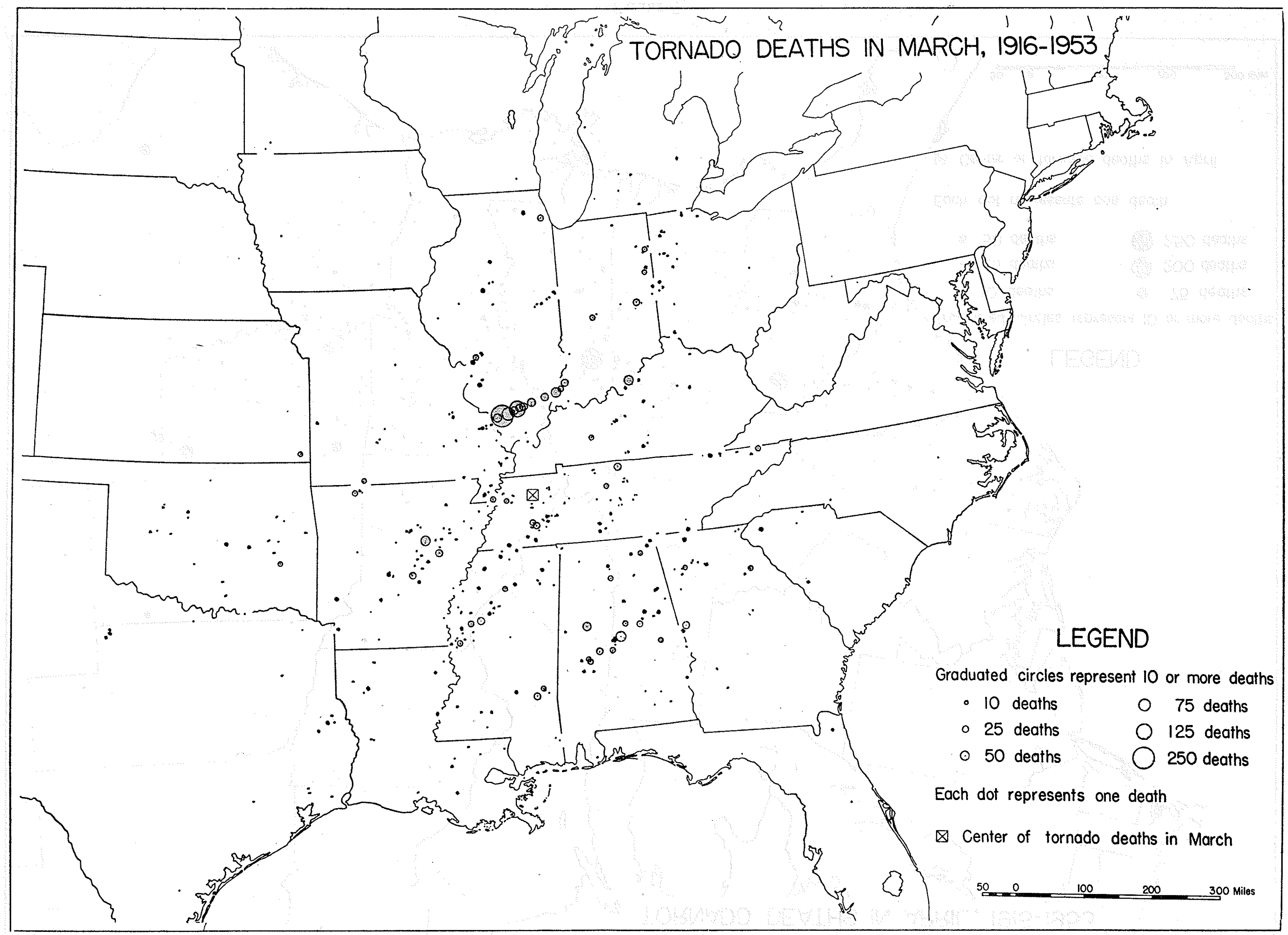
TORNADO DEATHS IN MARCH, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
75 deaths
125 deaths
250 deaths
Each dot represents one death
Center of tornado deaths in March
50 0 100 200 300 Miles

CHART 4

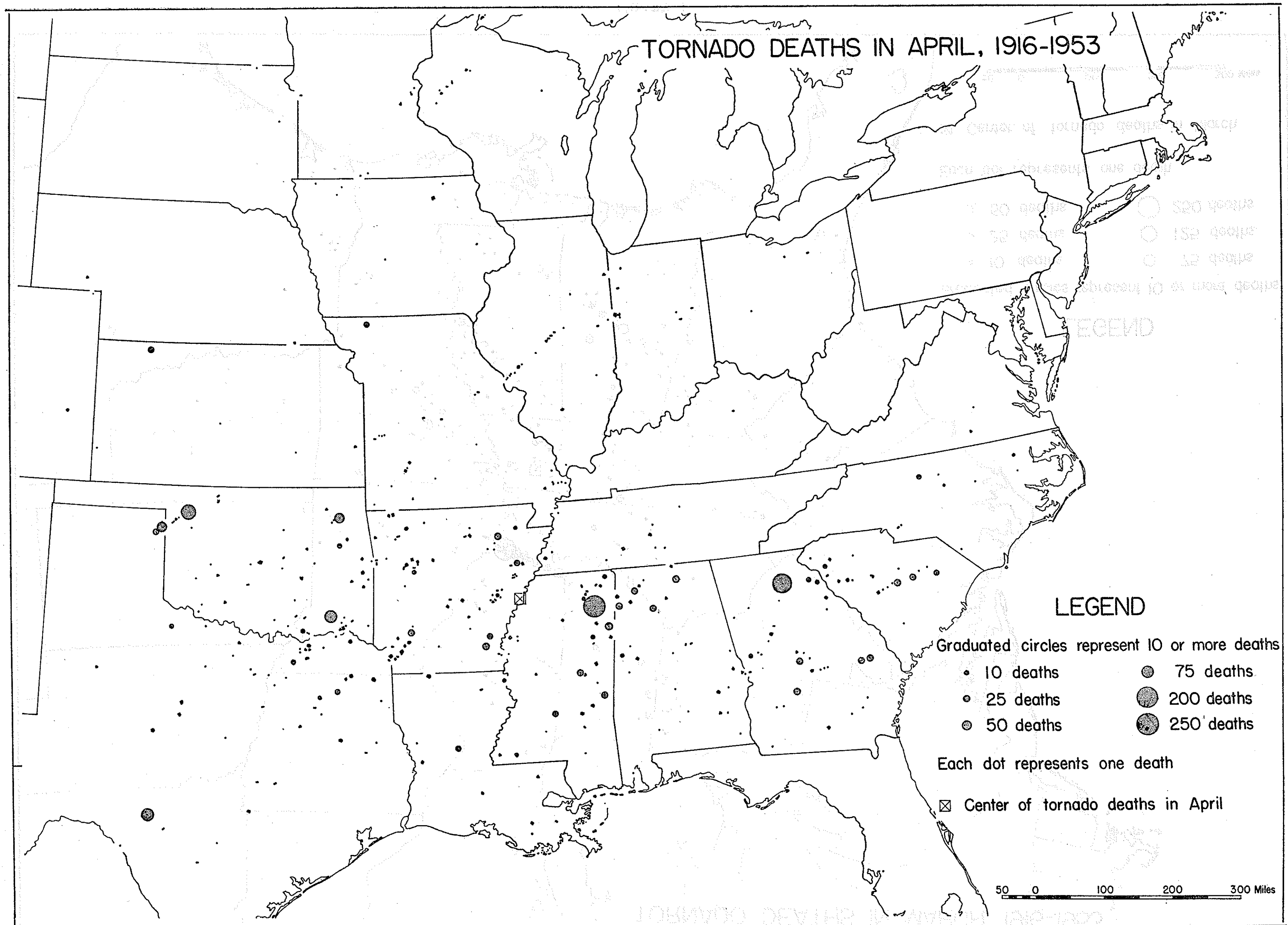
TORNADO DEATHS IN APRIL, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
75 deaths
200 deaths
250 deaths
Each dot represents one death
Center of tornado deaths in April
50
0
100
200
300 Miles

CHART 5

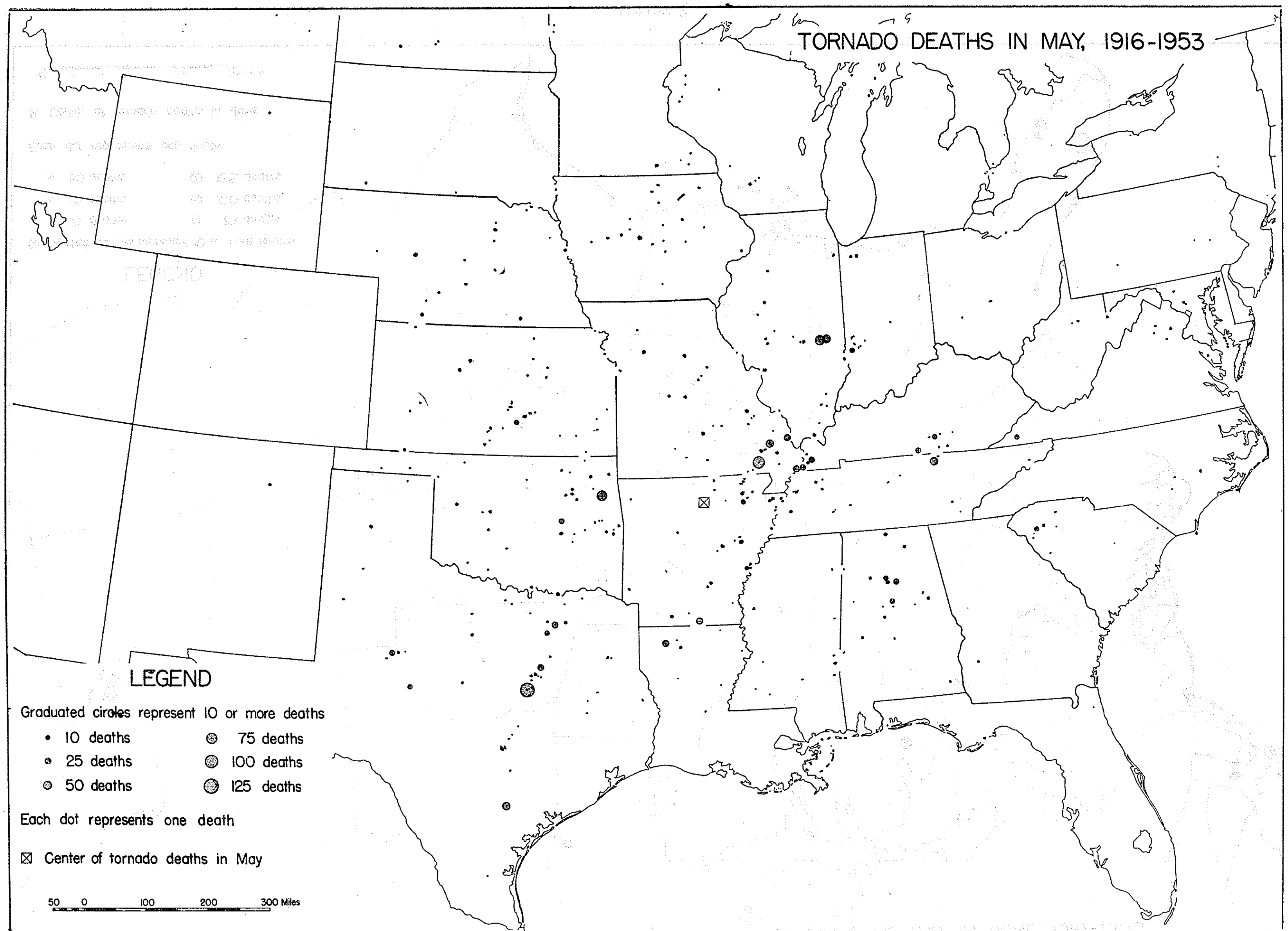
TORNADO DEATHS IN MAY, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
75 deaths
100 deaths
125 deaths
Each dot represents one death
Center of tornado deaths in May
50 0 100 200 300 Miles

CHART 6

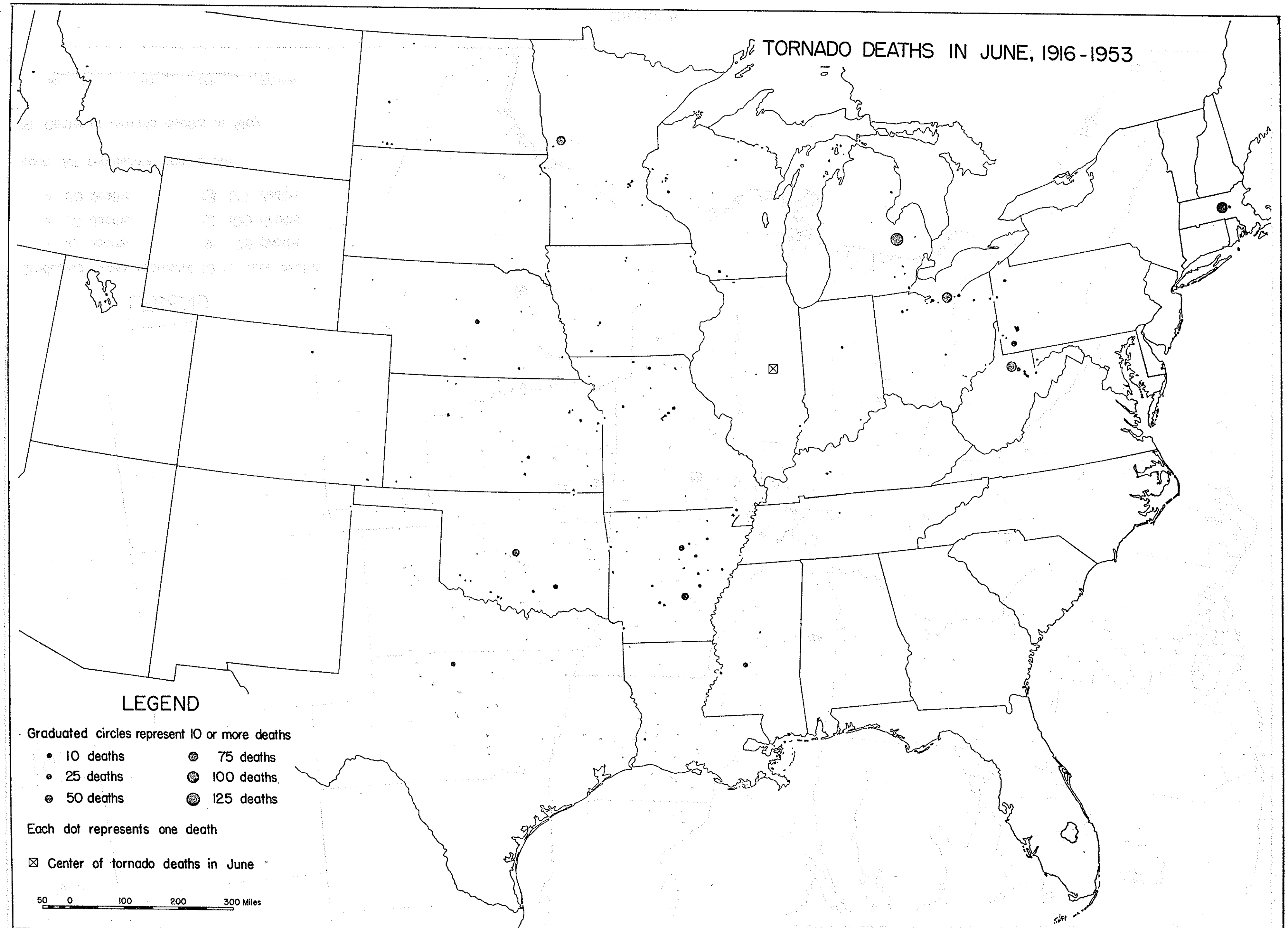
TORNADO DEATHS IN JUNE, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
75 deaths
100 deaths
125 deaths
Each dot represents one death
Center of tornado deaths in June
50
0
100
200
300 Miles

CHART 7

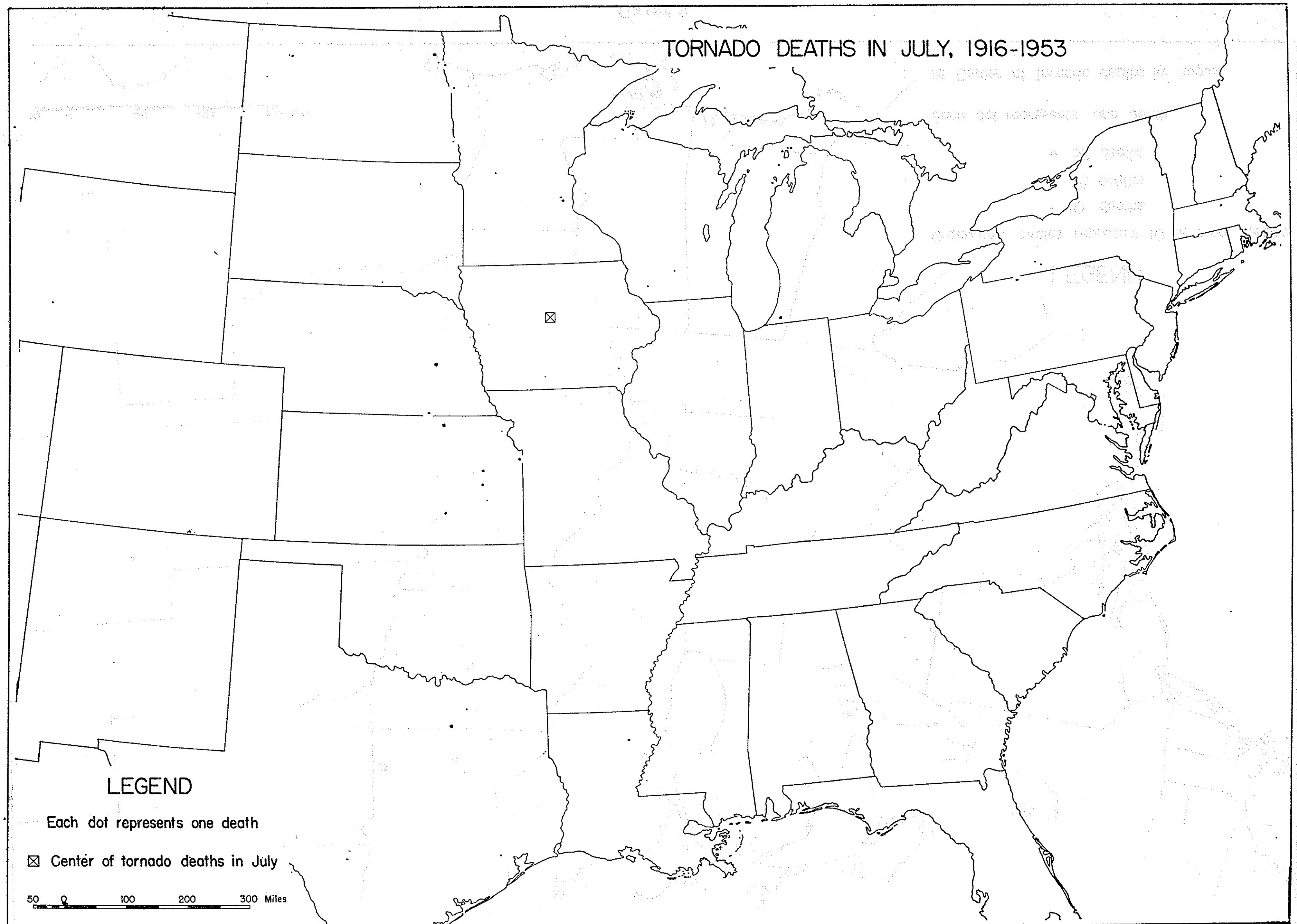
TORNADO DEATHS IN JULY, 1916-1953
LEGEND
Each dot represents one death
⊠ Center of tornado deaths in July
50 0 100 200 300 Miles

CHART 8

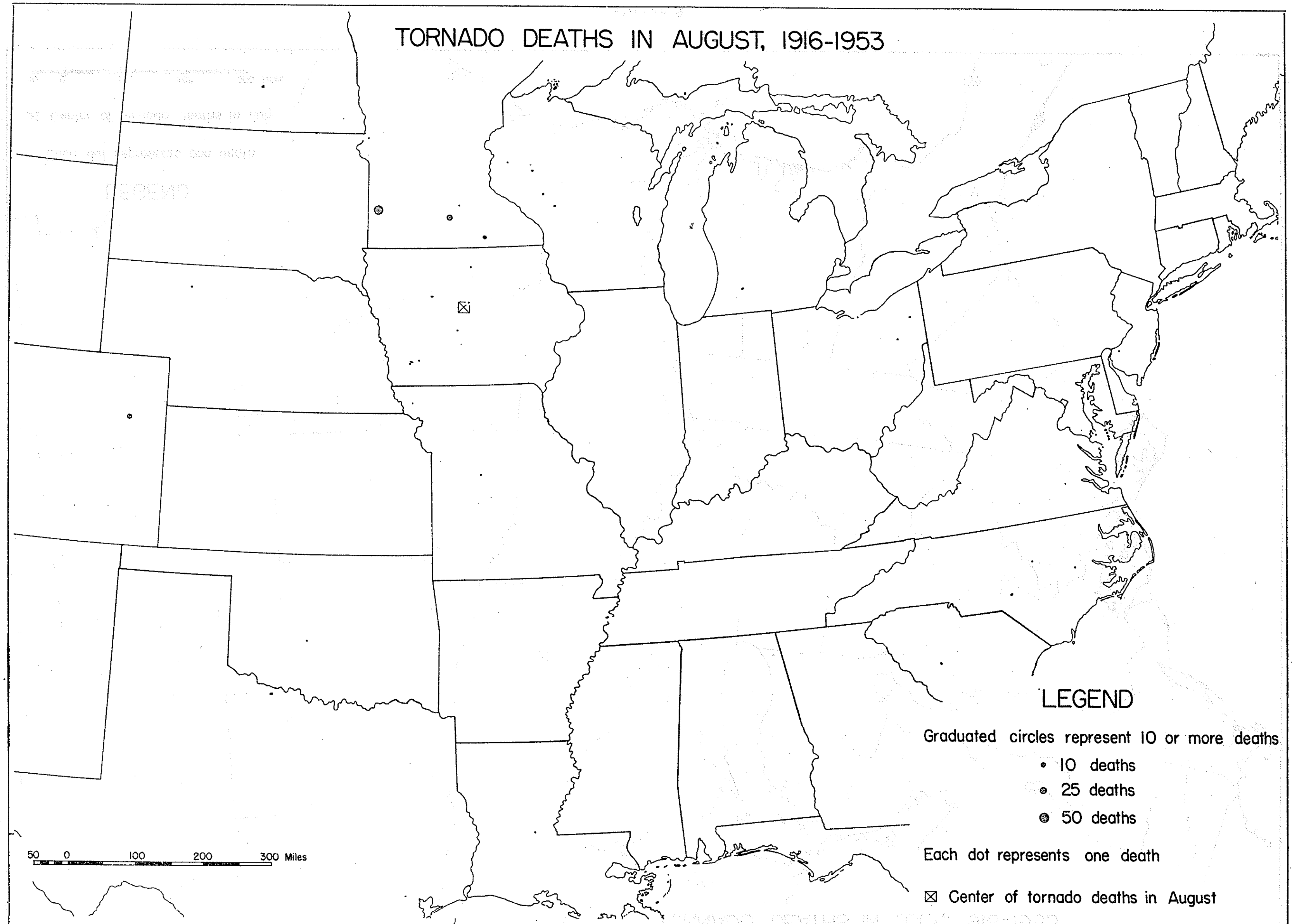
TORNADO DEATHS IN AUGUST, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
Each dot represents one death
Center of tornado deaths in August
50 0 100 200 300 Miles

CHART 9

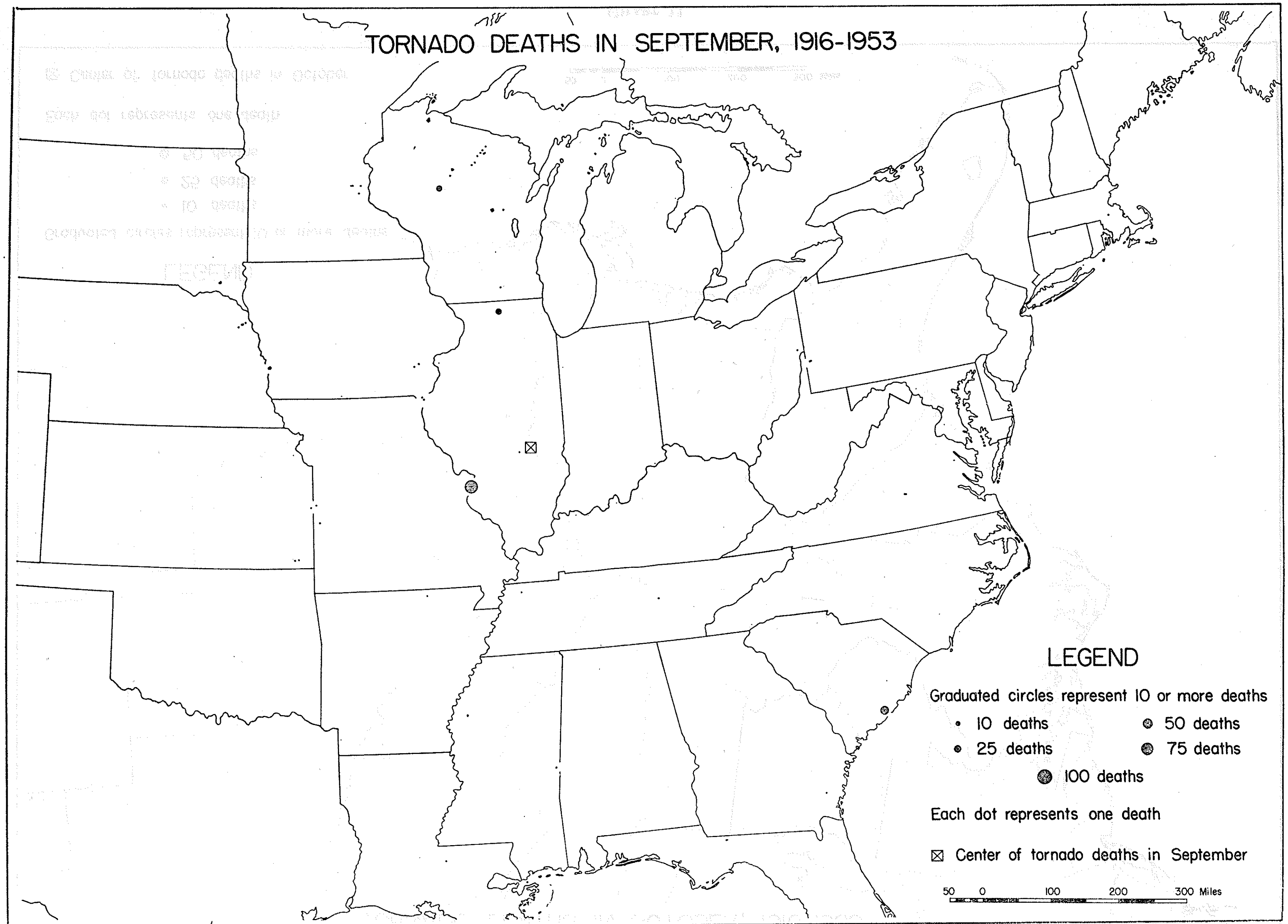
TORNADO DEATHS IN SEPTEMBER, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
50 deaths
25 deaths
75 deaths
100 deaths
Each dot represents one death
Center of tornado deaths in September
50 0 100 200 300 Miles

CHART 10

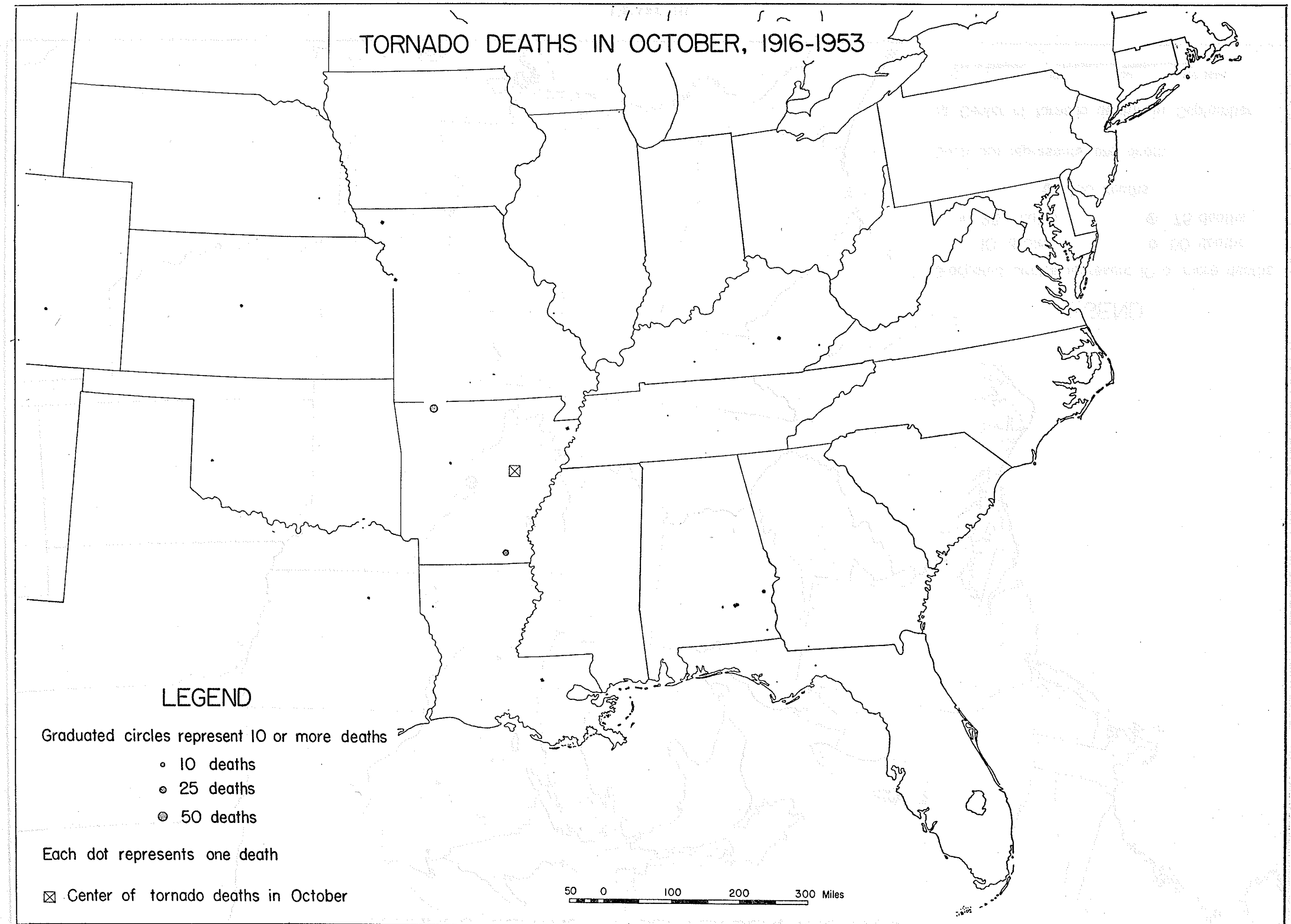
TORNADO DEATHS IN OCTOBER, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
Each dot represents one death
Center of tornado deaths in October
50 0 100 200 300 Miles

CHART 11

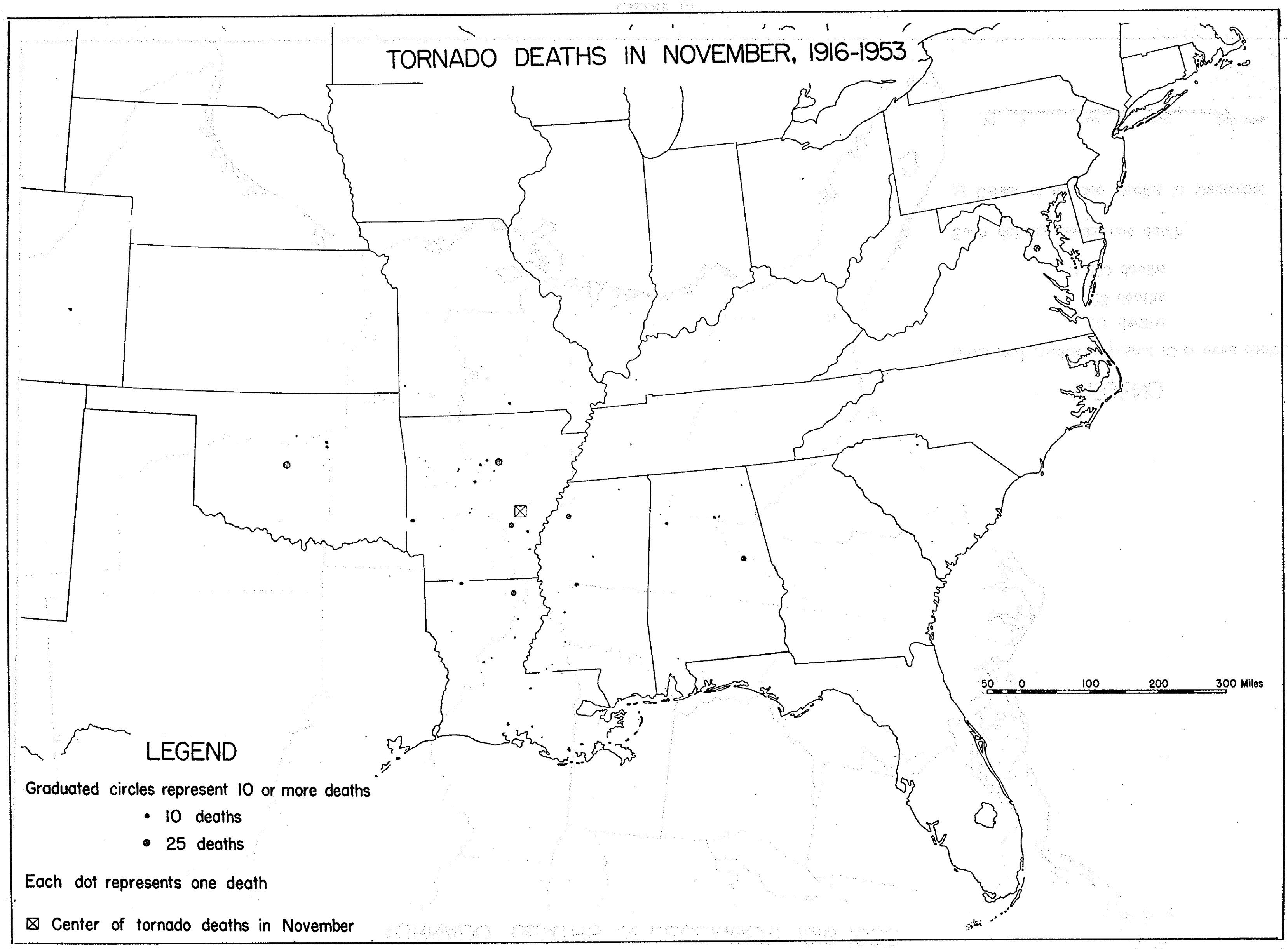
TORNADO DEATHS IN NOVEMBER, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
Each dot represents one death
Center of tornado deaths in November
50 0 100 200 300 Miles

CHART 12

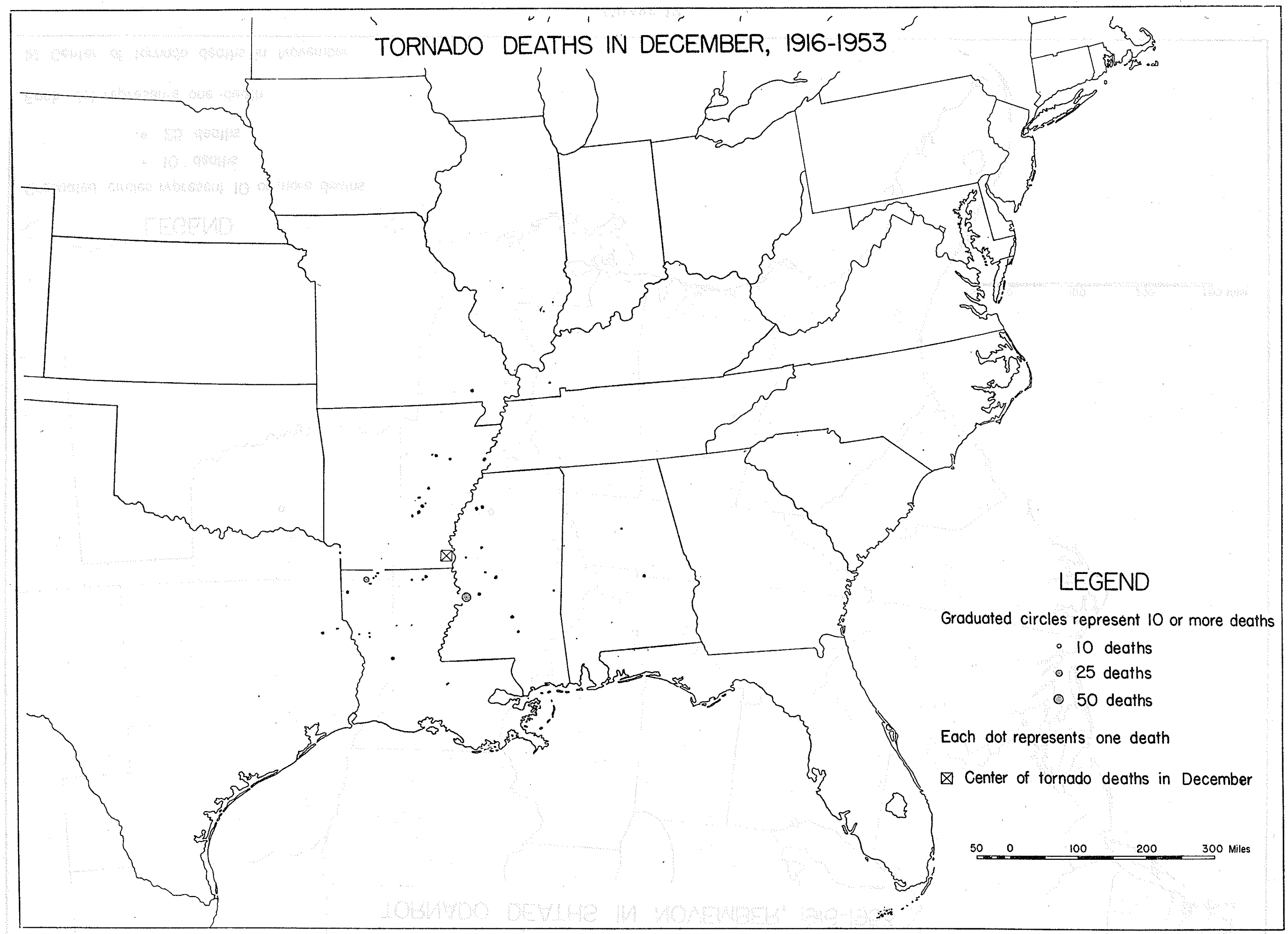
TORNADO DEATHS IN DECEMBER, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
Each dot represents one death
Center of tornado deaths in December
50
0
100
200
300 Miles

CHART 13

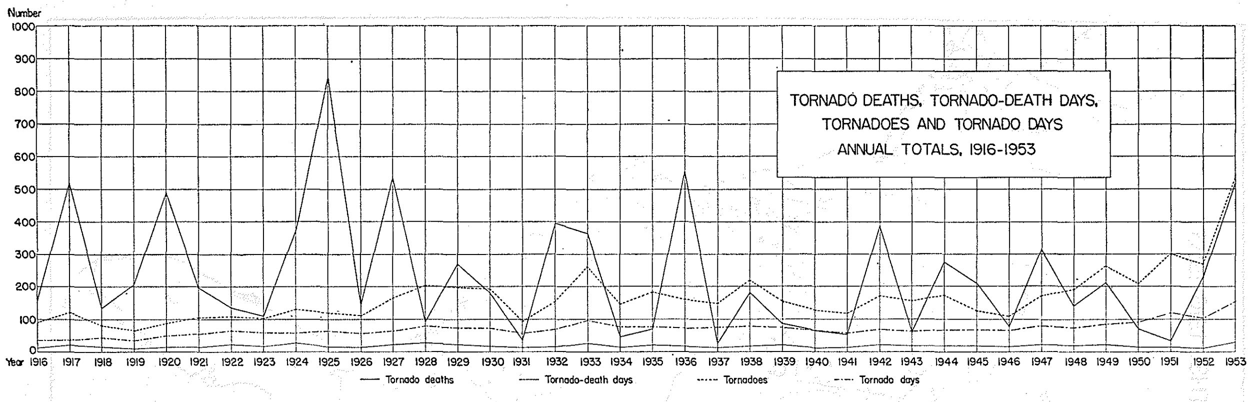

CHART 14

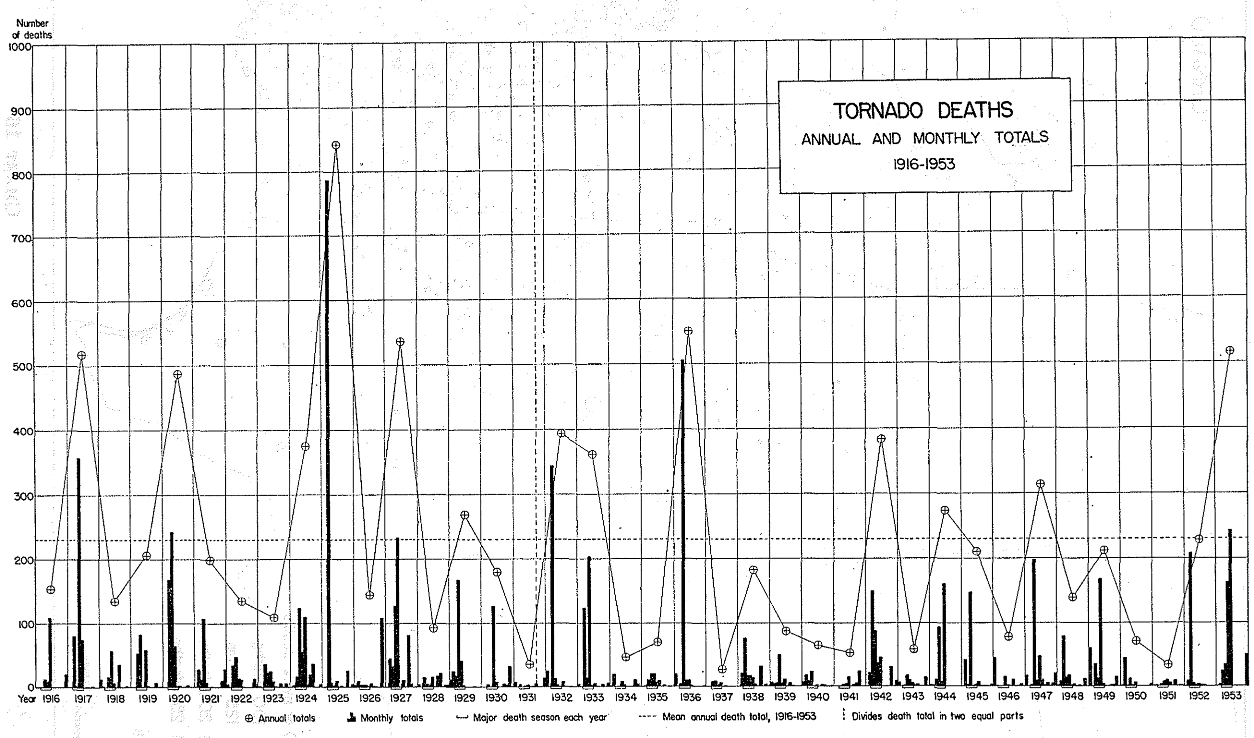

CHART 15

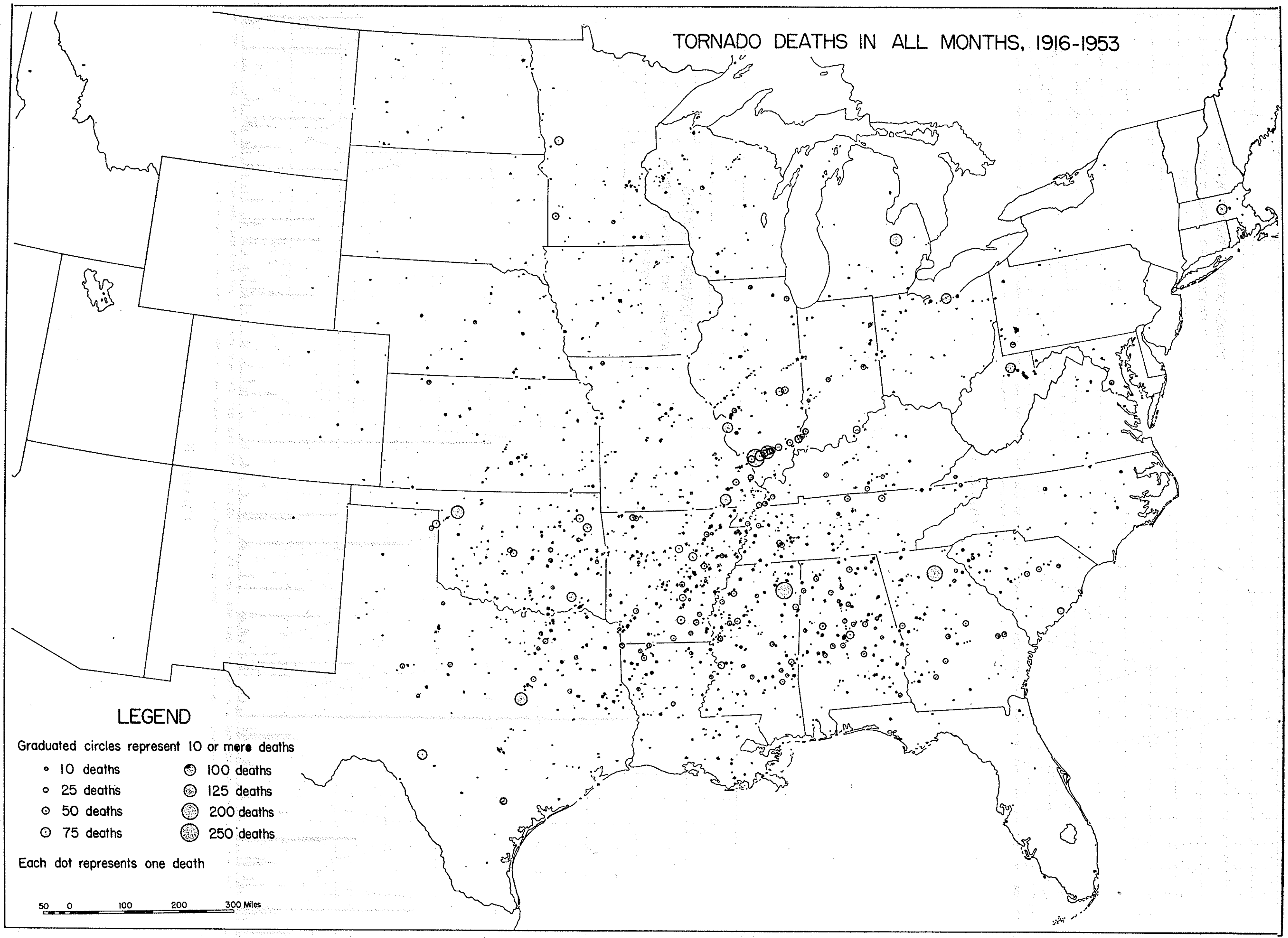
TORNADO DEATHS IN ALL MONTHS, 1916-1953
LEGEND
Graduated circles represent 10 or more deaths
10 deaths
25 deaths
50 deaths
75 deaths
100 deaths
125 deaths
200 deaths
250 deaths
Each dot represents one death
50 0 100 200 300 Miles

CHART 16

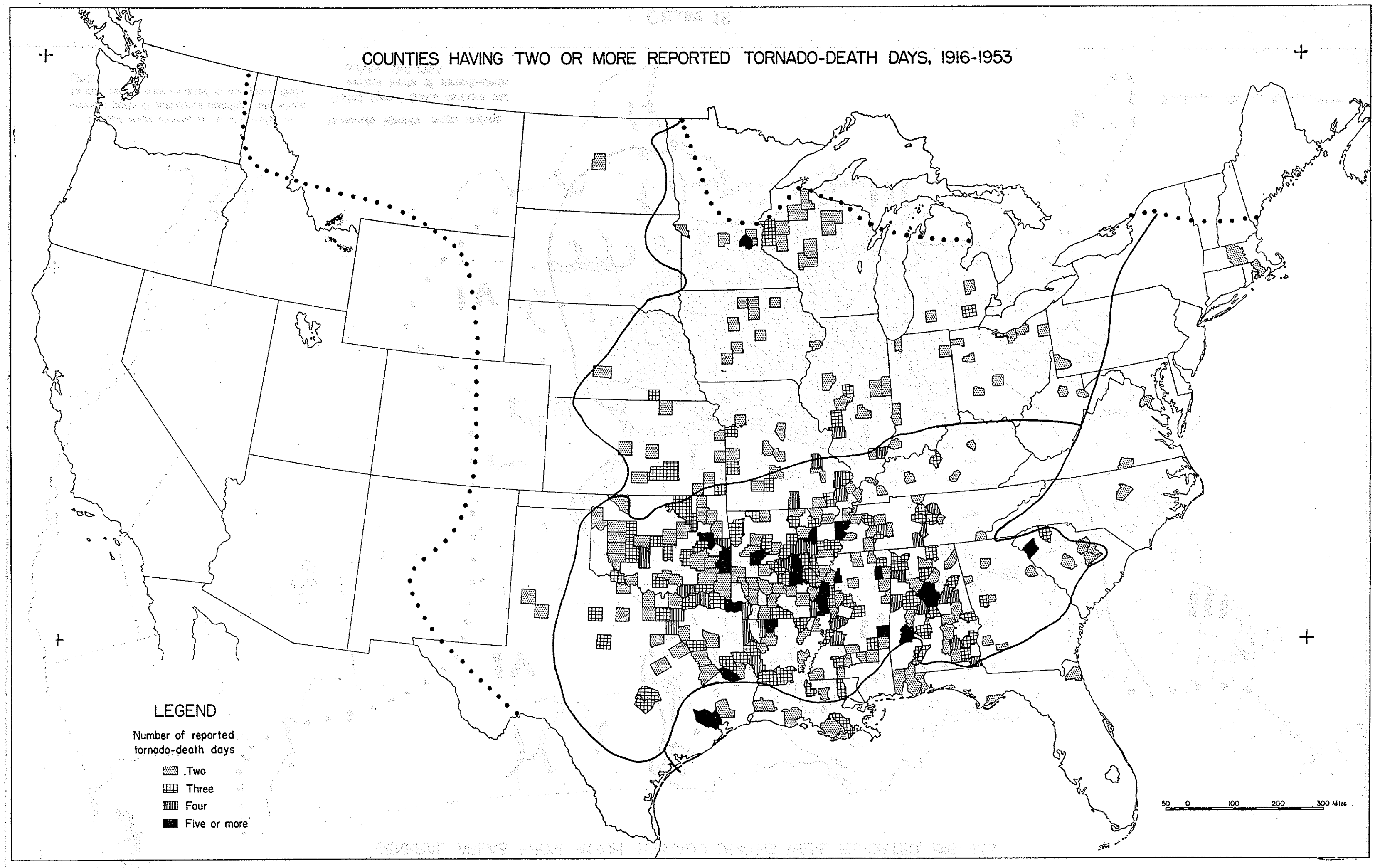
COUNTIES HAVING TWO OR MORE REPORTED TORNADO-DEATH DAYS, 1916-1953
LEGEND
Number of reported tornado-death days
Two
Three
Four
Five or more
50 0 100 200 300 Miles

CHART 17

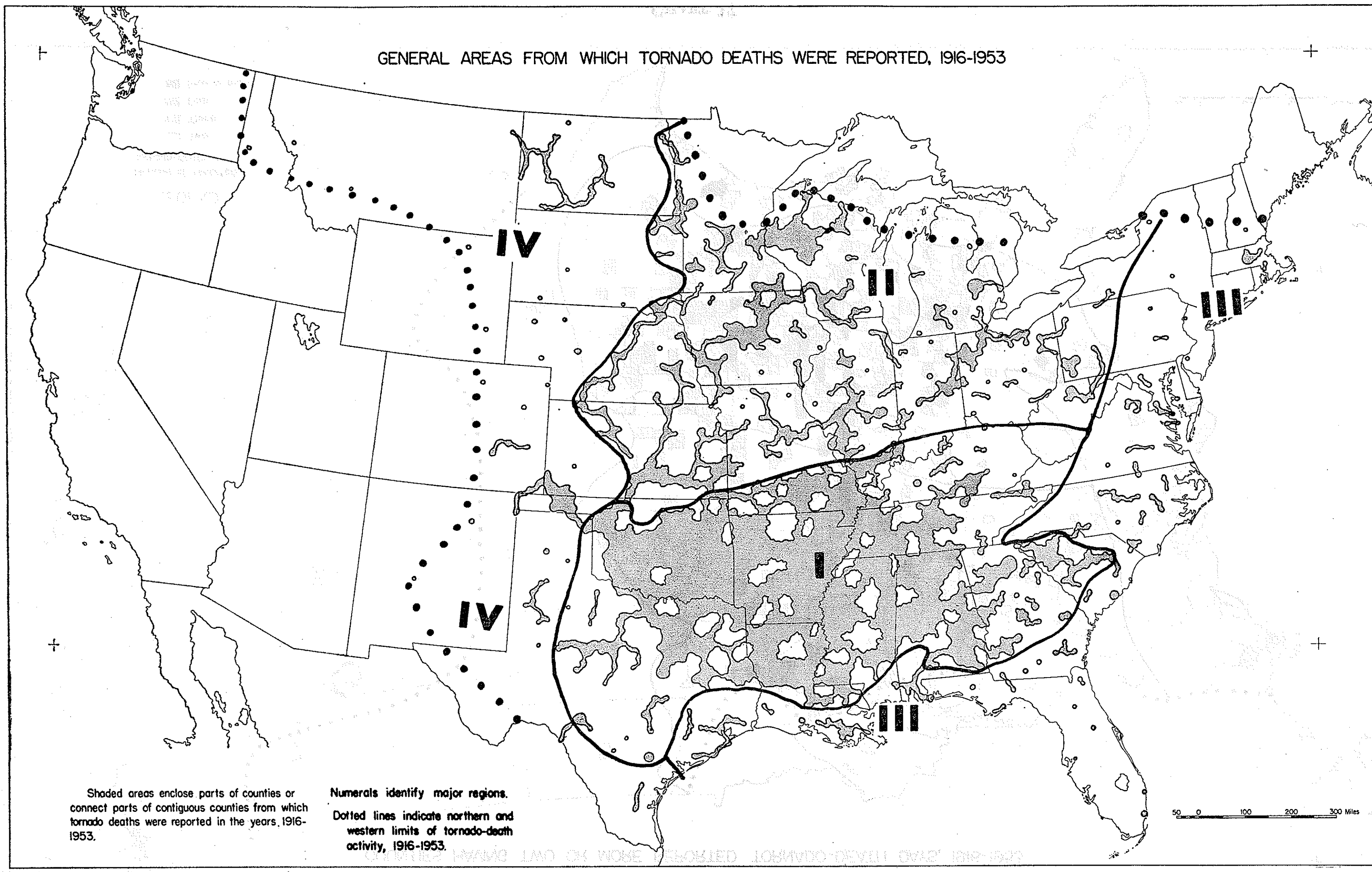
GENERAL AREAS FROM WHICH TORNADO DEATHS WERE REPORTED, 1916-1953
IV
II
III
I
IV
III
Shaded areas enclose parts of counties or connect parts of contiguous counties from which tornado deaths were reported in the years 1916-1953.
Numerals identify major regions.
Dotted lines indicate northern and western limits of tornado-death activity, 1916-1953.
50 0 100 200 300 Miles

CHART 18

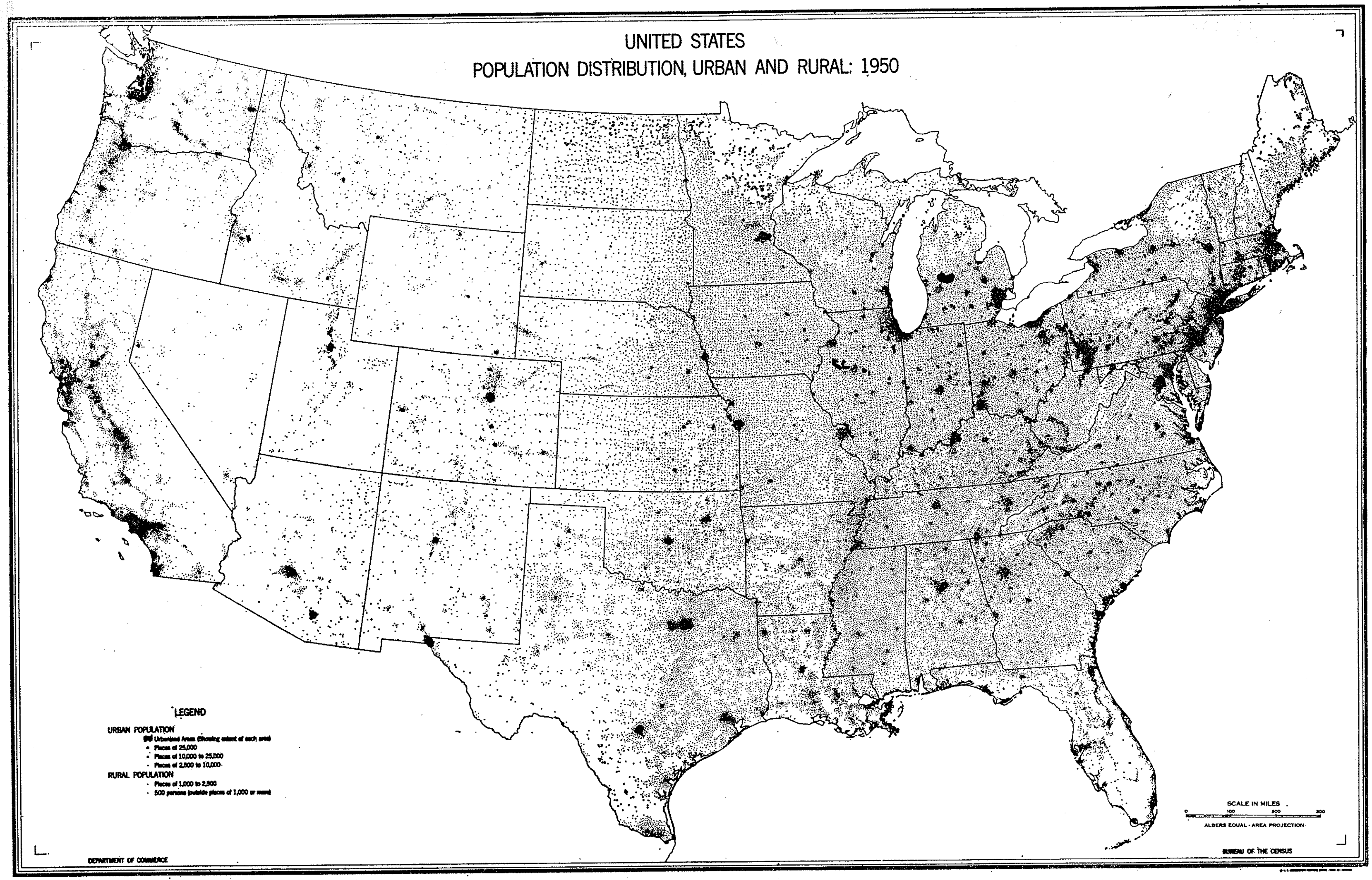
UNITED STATES
POPULATION DISTRIBUTION, URBAN AND RURAL: 1950
LEGEND
URBAN POPULATION
Places of 25,000
Places of 10,000 to 25,000
Places of 2,500 to 10,000
RURAL POPULATION
Places of 1,000 to 2,500
500 persons (outside places of 1,000 or more)
DEPARTMENT OF COMMERCE
SCALE IN MILES
0
100
200
300
ALBERS EQUAL - AREA PROJECTION
BUREAU OF THE CENSUS

CHART 19

U. S. GOVERNMENT PRINTING OFFICE: 1957

Tracks of All Tornadoes, 1916-50

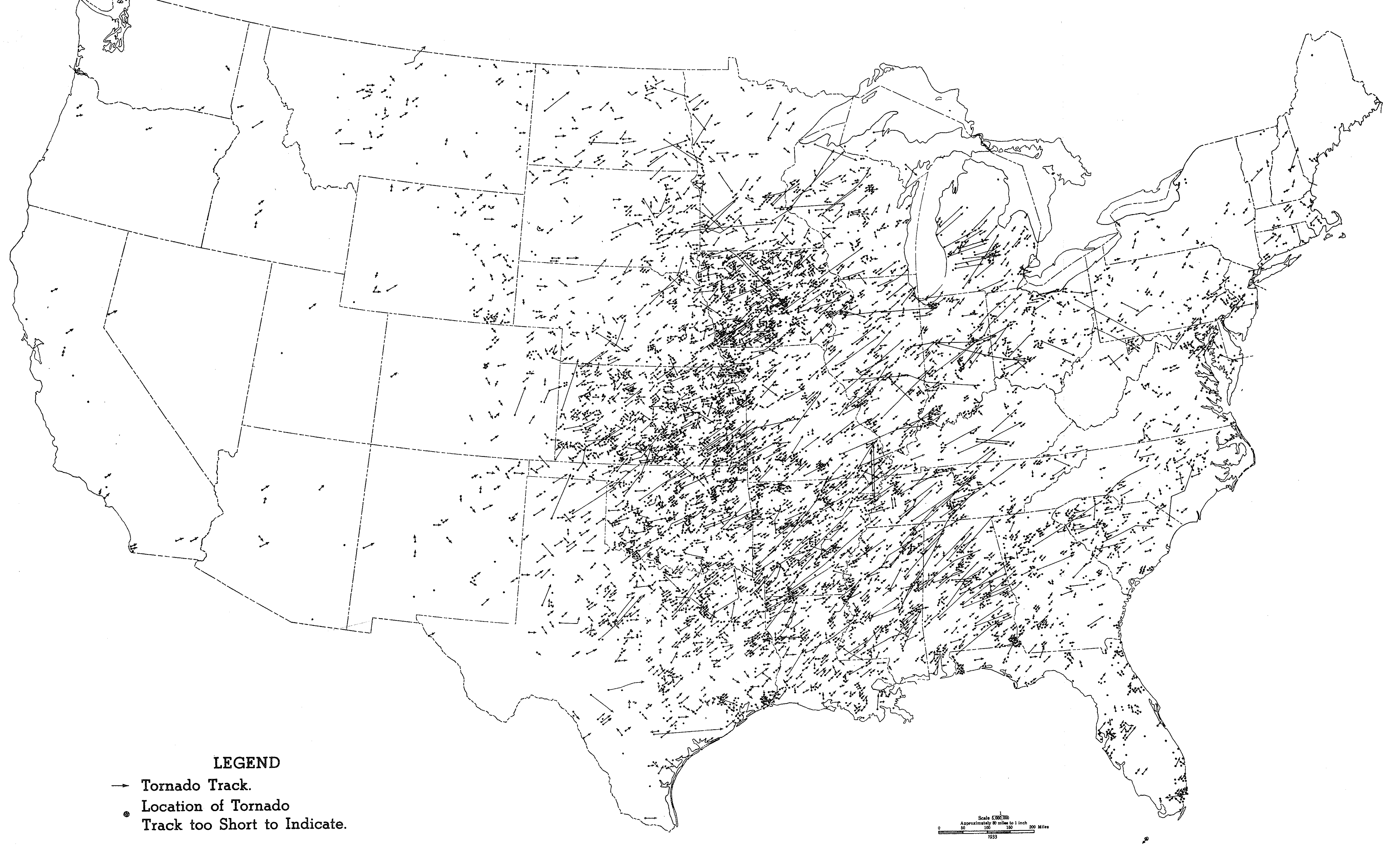

Chart 20

420320 O - 57 (Face blank p. 48)