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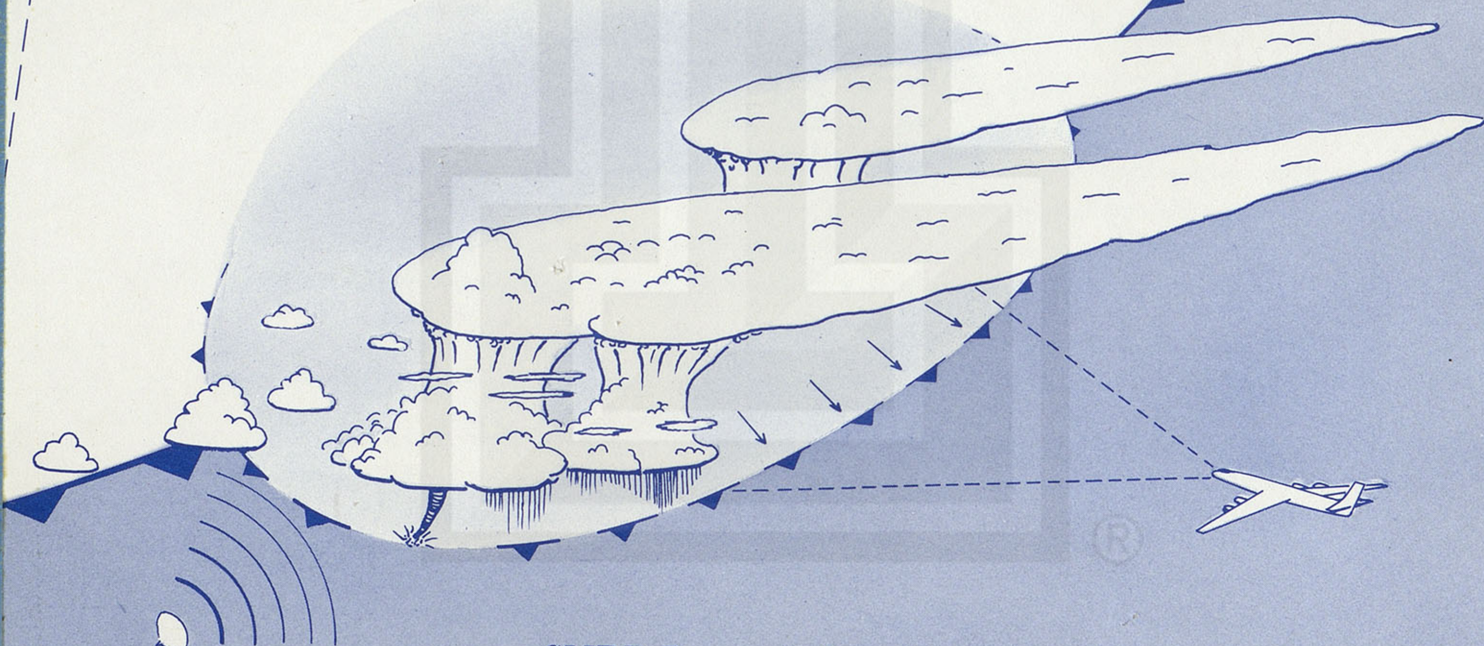
SATELLITE & MESOMETEOROLOGY RESEARCH PROJECT

Department of the Geophysical Sciences
The University of Chicago

CHARACTERIZATION OF 1965 TORNADOES BY THEIR AREA AND INTENSITY

by

Jaime J. Tecson



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February 1972

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ABSTRACT

The proposed characterization of tornadoes simultaneously by two parameters, namely, individual damage area and intensity of damaging winds, was applied on tornadoes reported in the NOAA publication - STORM DATA - for the year 1965.

Analyses on the annual and diurnal variation of tornado occurrences as individually characterized and considered as two major classes, as well as distribution by state and by regions were presented. An attempt was made to gain some insight on possible behavior of the large-area tornadoes and the strong-intensity ones.

1. INTRODUCTION

One of the disadvantages of investigating or learning to know more of most physical phenomena that occur in the atmosphere such as hurricanes, tornadoes, and related tornadic storms, to name a few, is that because of their immense size they cannot yet be ideally duplicated in laboratories under controlled conditions. One approach, therefore, is a closer observation and a more thorough documentation of the behavior and occurrence of these storms as they actually occur.

Indeed this method of investigation, on the one hand, is easily one of the simplest and one of the most straightforward means of evaluating the storm's characteristics. On the other hand, there are inherent factors and limitations to be aware of, such as the scarcity of the data available, the representativeness of such data,

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the limited interpretations of the results and probable or possible misinterpretation of the data used.

Documentation of occurrences of tornadic storms is presently compiled by the National Weather Service of NOAA in the monthly publication entitled STORM DATA and in some other publications. These storms are classified as tornadoes, funnel clouds or funnels aloft, and waterspouts. This classification, by far, clearly and best defines the different types of severe storm phenomena.

If instead of classifying a tornado, for example, in its general name as just a tornado, per se, it is felt that perhaps a sub-classification could be established for tornadoes so that they could be distinguished from one another; this to be accomplished by specifying one or more of its "characteristic" properties. Such further breakdown in classification might indeed provide a better insight to gaining additional knowledge in learning more of the behavior of tornadoes.

Fujita (1970a) in studying historical data on tornadoes has suggested that they can be parameterized in a number of ways; that is, on their length and width of paths, maximum wind speeds, times of occurrences, locations, casualties and property damages. Subsequently, Fujita (1971) proposed a scheme for "characterizing" tornadoes and hurricanes by area and intensity. Looking back at earlier periods, it is interesting to note that Seelye (1945) had made a classification of tornadoes in New Zealand using an arbitrary scale in units which is a measure of the intensity of the tornado depending on the type and extent of structures damaged.

The aim of this paper, considering that the source data is only for one year and also that this is an initial attempt to classify tornadoes into two parameters (according to damage area and wind intensity) through the exhaustive use of STORM DATA reports, is largely to observe how this type of reclassified data would behave in the hope that additional and more meaningful climatic or non-meteorological characteristics of tornadoes could be derived. It is not intended to draw any firm conclusions from these results yet but rather to find out some new pattern or behavior. Of course, with more years of data thus processed, stable characteristics would eventually show up.

All data were processed from cards through the IBM System/360 Model 65 computer facility of the University of Chicago.

2. CLASSIFICATION SCHEME

In the proposed classification of tornadoes, two parameters are used as criteria to "characterize" them following Fujita (1971). One is the "Individual Tornado Area, a" defined as

$$a = \ell \times \bar{w}$$

where ℓ is the length of the tornado and $\bar{w}$ is the mean width. The other is tornado intensity or the Fujita (F)-scale of damaging winds estimated from structural and/or tree damage, characteristic ground marks, damage descriptions, etc. caused by the tornado. It must be realized that the method of determining damage lengths and widths may vary subjectively; likewise, the proposed scale for damaging winds is an educated guess or best estimate of the speed ranges of the maximum wind that may have affected an area. In order to take into account the human factor that could introduce variations in classifying the phenomena according to this scheme and with the aim of limiting occurrences of such errors consistent with producing meaningful results, it should be noted that the scales for damage area were designed to permit an assessment with "one order of magnitude" accuracy while that for intensity allow an error estimate of at least 30 mph wind speed.

3. SOURCE AND TREATMENT OF DATA

Data utilized for this report were obtained from the monthly STORM DATA publication of the National Weather Service for the year 1965. The descriptive account for each phenomena was carefully evaluated in relation to the damage data. Where multiple storms occur in a day, a best estimate was made for a breakdown into individual storms. Only data on tornadoes, funnel clouds and waterspouts reported in the continental United States were used. Incidentally, Alaska had no tornadic storms reported.

Realizing the difficulties in collecting these data, especially in reporting the simultaneous occurrences of funnel clouds and waterspouts, it became necessary to assign numerical values to the adjective listings used in STORM DATA as follows: few or plural form of storms - 2, several - 3, scattered - 4, many - 5, large number - 8 and numerous - 10. A modification to STORM DATA was introduced. Data on the Palm Sunday Tornado occurrences were re-evaluated in the cases where a survey was made by T. Fujita. One restraint was also imposed to minimize the possibility of inflationary effects and bias that could result in family outbreaks of weak-intensity and small-area tornadoes. The restraint defines that if 2 or more tornadoes classified as F0 or TR or DM tornadoes (explained elsewhere) occur within 1 hour or less than 10 miles of each other, then they are considered only as one occurrence or one count.

This report presents some statistics mainly on time and space distribution of tornado occurrences in the continental United States in 1965, classified simultaneously according to two parameters of damage area and damaging wind, as well as funnel clouds and waterspouts.

4. DISCUSSION AND RESULTS

During the year 1965 there was a total of 1720 tornadic storm occurrences based on the classification scheme and criteria established for data evaluation described earlier. Of these, 893 or 52% were tornadoes, 752 or 44% were funnel clouds and 75 or 4% were waterspouts. Waterspouts appeared to be most observed over the Florida coast. Alaska had no tornadic storms reported. Hawaii had one tornado, 2 funnel clouds and 4 waterspouts; however these were not included in this report.

a. Annual and Diurnal Distributions

Fig. 1a shows the annual distribution of tornadoes and funnel clouds. The peak occurrence was in May with an abrupt start in April. Fig. 1b is the monthly breakdown of the occurrences of tornadoes, funnel clouds and waterspouts. Tornado occurrences doubled in May as compared to the adjoining months. 83% occurred during the spring and summer with 60% accounting for the former. Funnel clouds appeared to reach maximum occurrence in May and June, the peak lagged tornadoes by a month. Waterspouts, on the other hand, were observed to peak much later in August. The diurnal distribution of tornadoes and funnel clouds as shown in Fig. 2a indicated the maximum occurrence between 1600 H and 2000 H Local Standard Time, gradually tapering off evenly earlier and later in the day. The local times as reported indicate the time of the beginning of the occurrence. Note that the time base begins at 0600 H. This is considered by Fujita (1971) as the start of a "Tornado Day". It is encouraging to note that 88% of the tornadoes that were reported had the specific time of observation included. Of the tornado occurrences alone, as seen in Fig. 2b, about three-fourths

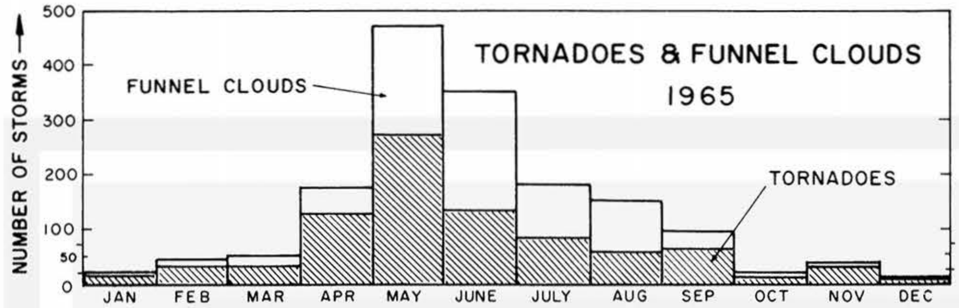

Fig. 1a. Annual distribution of tornadoes and funnel clouds for 1965.

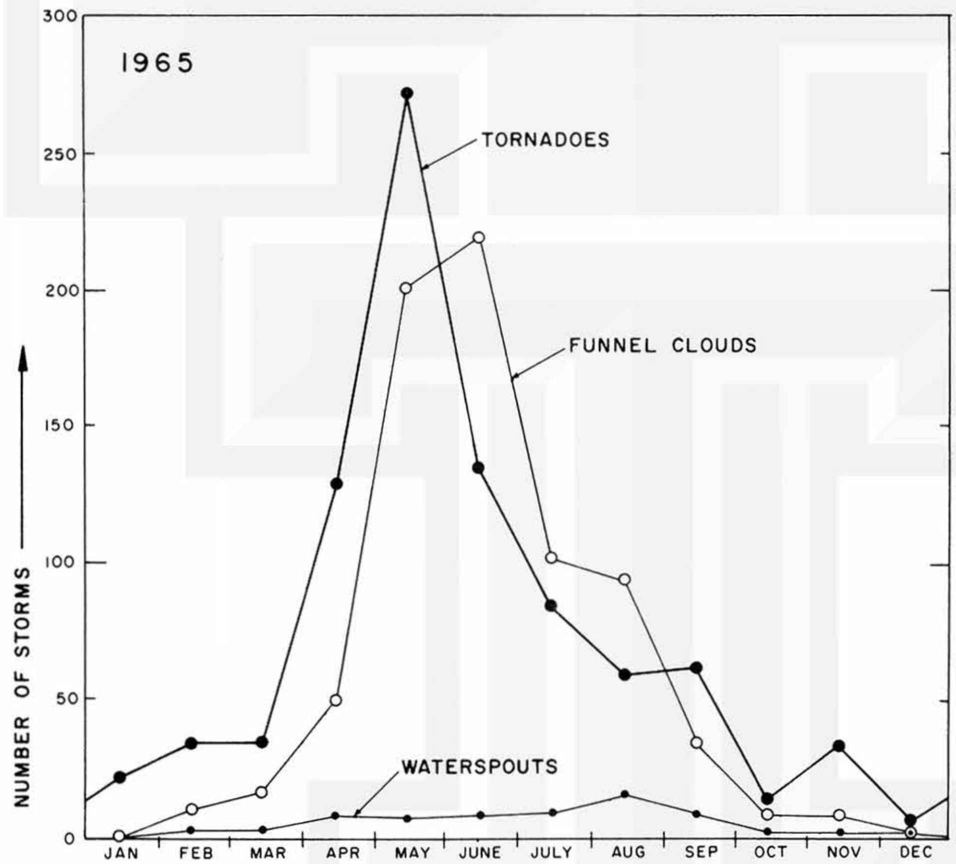

Fig. 1b. Annual distribution of tornadoes, funnel clouds and waterspouts for 1965.

or 71% were reported between 1400-2200 H. Before noon time, there were more funnel clouds reported than tornadoes but which became the reverse after then. As for waterspouts, there appeared to be a decrease in occurrences between 1400 H and 1600 H, in spite of the fact that visual observing should be at its best.

Table I reproduces the scales for the characterization of tornadoes simultaneously by two parameters, namely, individual tornado damage area as proposed and revised by Fujita (1971) and intensity of the damaging wind (Fujita 1970b, 1971). These were the criteria used in this report.

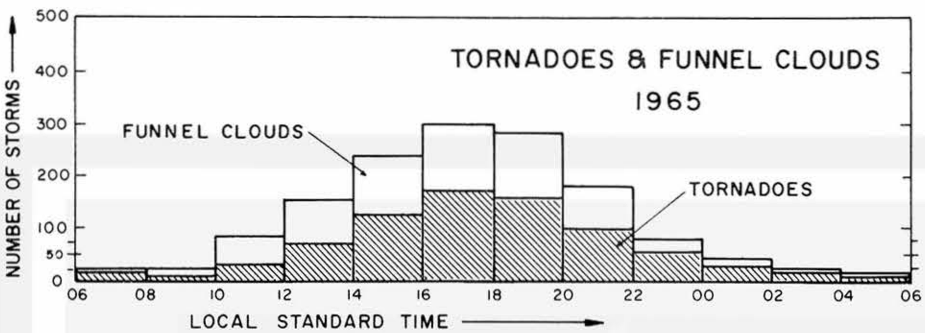

Fig. 2a. Diurnal distribution of tornadoes and funnel clouds for 1965.

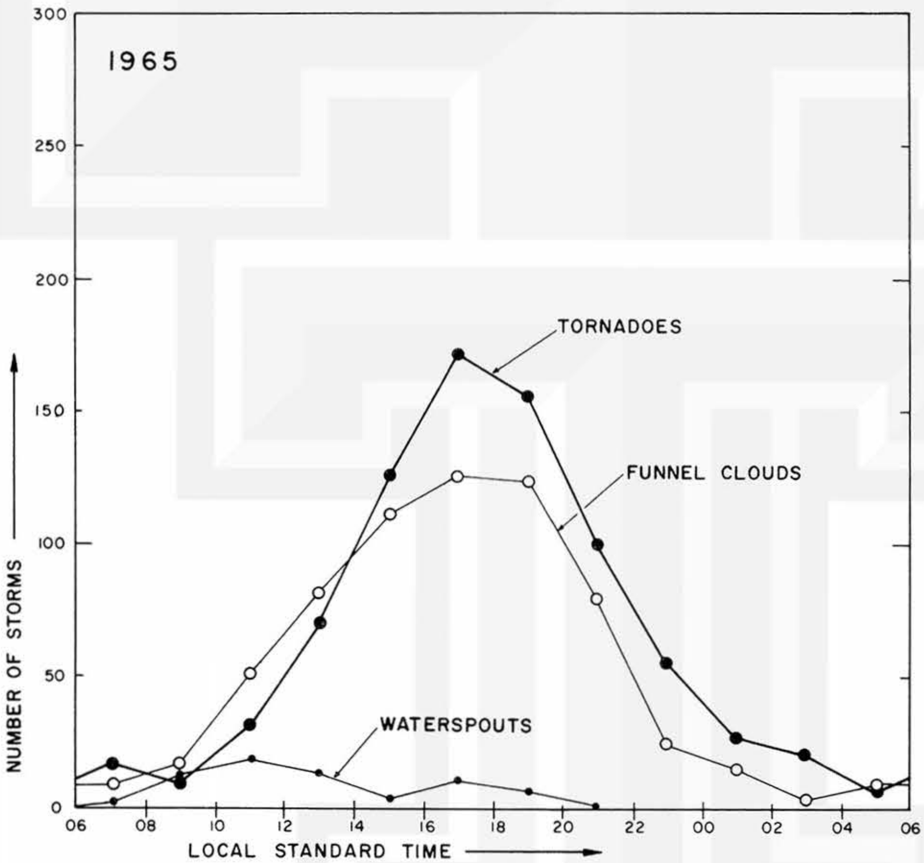

Fig. 2b. Diurnal distribution of tornadoes, funnel clouds and waterspouts for 1965.

Table I. Characterization of Tornadoes by their Area and Intensity

TORNADO DAMAGE AREA (a=Damage Area in Sq. Mi.)			TORNADO INTENSITY (I = Estd. Max Wind in MPH)		
TR	Trace Tornado	(a < 0.001)	F0	Gale Tornado	(40 < I ≤ 72)
DM	Decimicro Tornado	(0.001 ≤ a < 0.01)	F1	Weak Tornado	(72 < I ≤ 112)
MI	Micro Tornado	(0.01 ≤ a < 0.1)	F2	Strong Tornado	(112 < I ≤ 157)
ME	Meso Tornado	(0.1 ≤ a < 1.0)	F3	Severe Tornado	(157 < I ≤ 206)
MA	Macro Tornado	(1.0 ≤ a < 10.0)	F4	Devastating Tornado	(206 < I ≤ 260)
GI	Giant Tornado	(10.0 ≤ a < 100.0)	F5	Incredible Tornado	(260 < I ≤ 318)
DG	Decagiant Tornado	(100.0 ≤ a)	F6-F12	Inconceivable Tornado	(318 < I ≤ 818)

For estimating tornado intensity, the Fujita or F-scale of damaging wind is sub-divided into 7 categories ranging from F 0 through F 6 - F 12. The F-scale wind speed is defined to be the "fastest 1/4 mile wind" that could damage structures and is designed to connect smoothly the Beaufort Force wind at one end of the scale and the speed of sound in the atmosphere at the other end of the scale. In order to better appreciate this scale, damage specifications in plain-language form are included to associate characteristic ground damage patterns or characteristics with each category. These damage specifications, which were based mostly on engineering estimates of wind speeds causing such damage, were obtained from a large number of aerial and ground photographs of tornado damage.

In Fig. 3a is represented the percentage distribution of tornado occurrences according to individual damage area. About three-fourths (or 74%) of the outbreaks

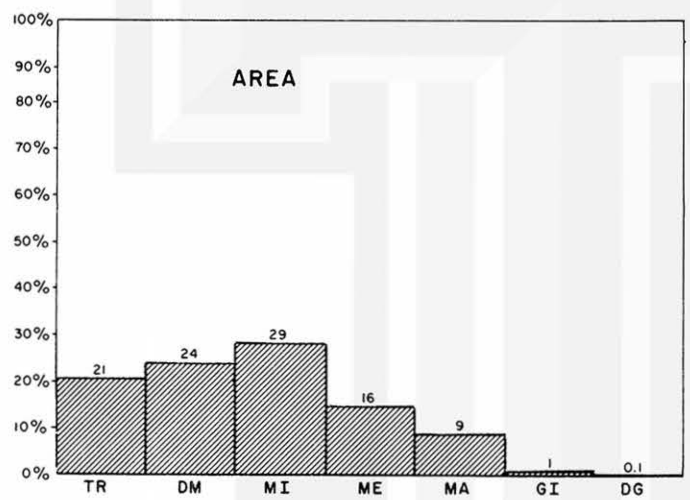

Fig. 3a. Percentage distribution of 893 tornado occurrences for 1965 according to individual damage area.

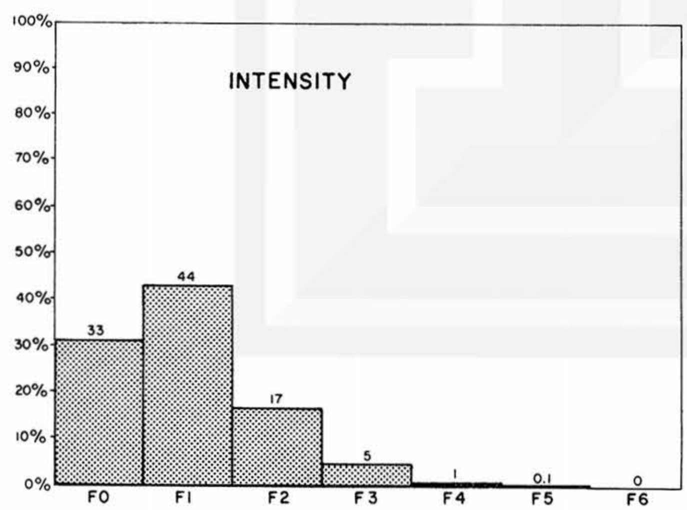

Fig. 3b. Percentage distribution of the above according to intensity of damaging winds.

had less than .1 square mile of damage reported. The most frequent occurrence was of the Micro Tornado type. The percentage distribution according to the intensity of damaging wind in Fig. 3b indicated that a little more than three-fourths (77%) of the reported occurrences had estimated maximum winds of less than 113 mph. Fig. 3, therefore, suggested that a large number of reported tornadoes for 1965 were of the weak-intensity and small-area types.

The annual distribution of tornado occurrences in 1965, simultaneously classified into 2 parameters, is depicted in Fig. 4. The number in each block is the total

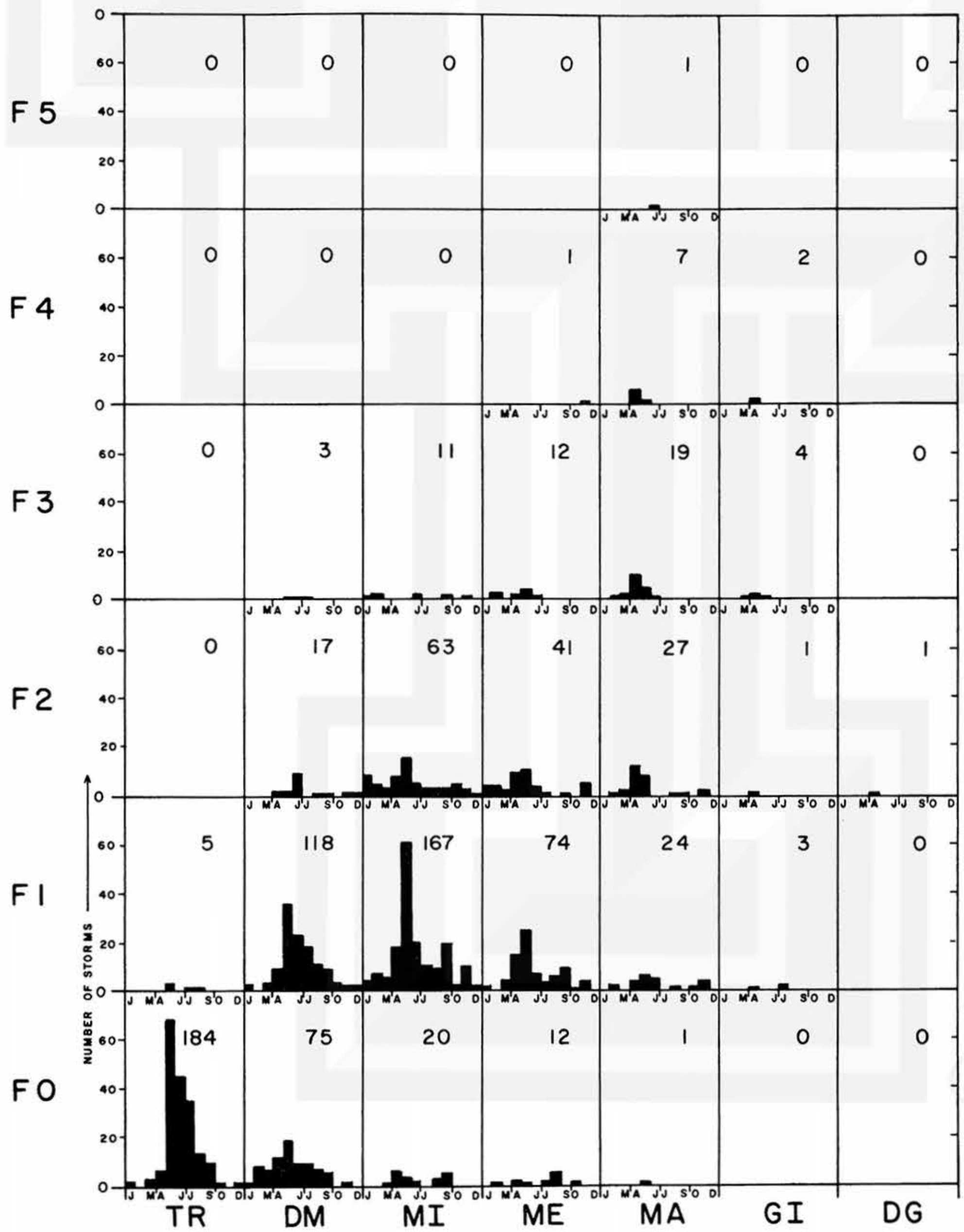

Fig. 4. Annual distribution of tornado occurrences according to both damage area and intensity of damaging winds. (Numbers in each block indicate total occurrences.)

occurrence for each two-way classified type. The month of May seemed favored for the outbreak of the weak-intensity and small-area types like F0 and TR, F1 and DM, and F1 and MI tornadoes, with April most likely for the larger-area and more-intense ones (Palm Sunday tornadoes).

On the other hand, Fig. 5 illustrates the diurnal distribution of tornado incidence where specified times of beginning of occurrences were reported. For the weak-inten-

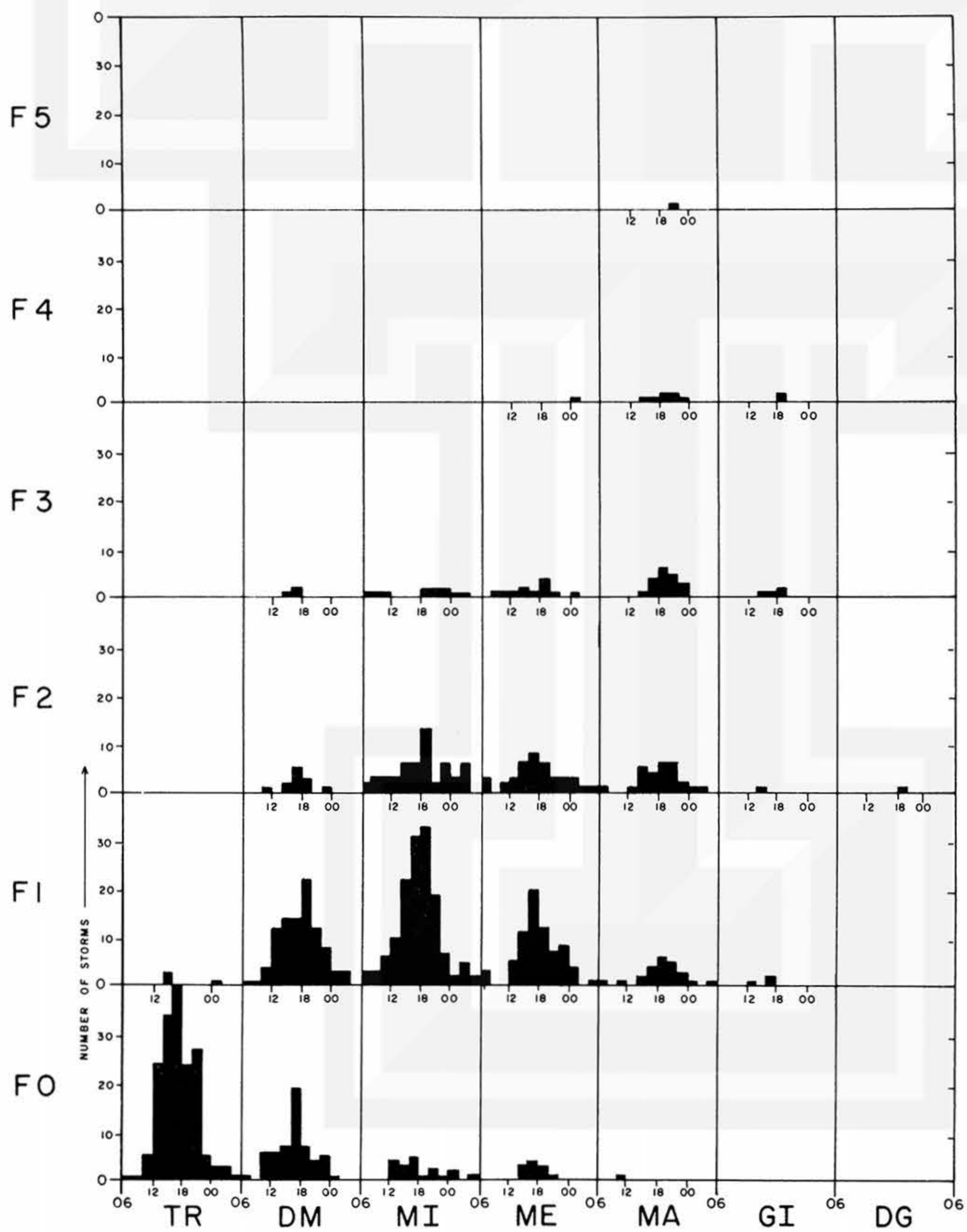

Fig. 5. Diurnal distribution of tornado occurrences according to both damage area and intensity of damaging winds.

sity and small-area tornadoes the peak periods of occurrences appeared to be about 1800 H or earlier while the strong-intensity and large-area ones started later than 1800 H. When Fig. 3b is analyzed for its annual distribution pattern, it is shown in Fig. 6a. Likewise, Fig. 6b is the annual distribution of Fig. 3a. For tornadic storms

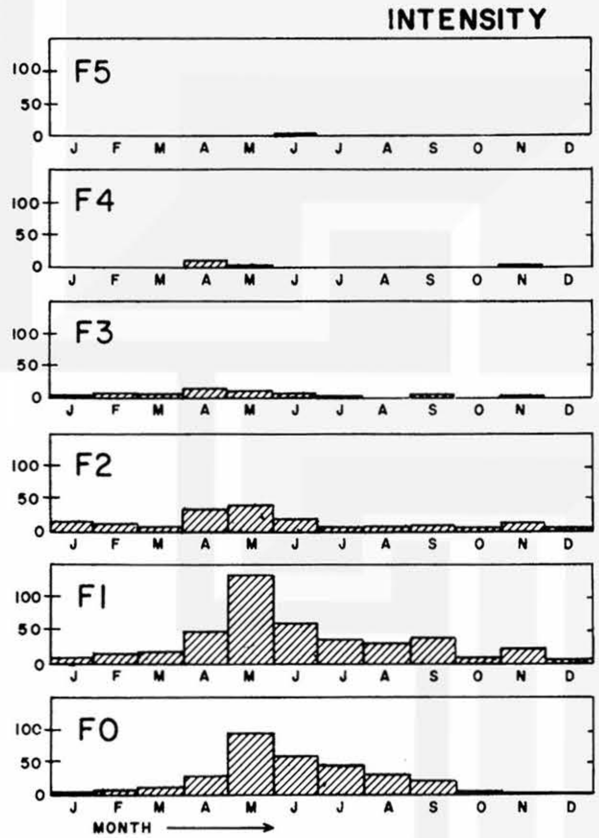

Fig. 6a. Annual distribution of tornadoes according to intensity of damaging winds.

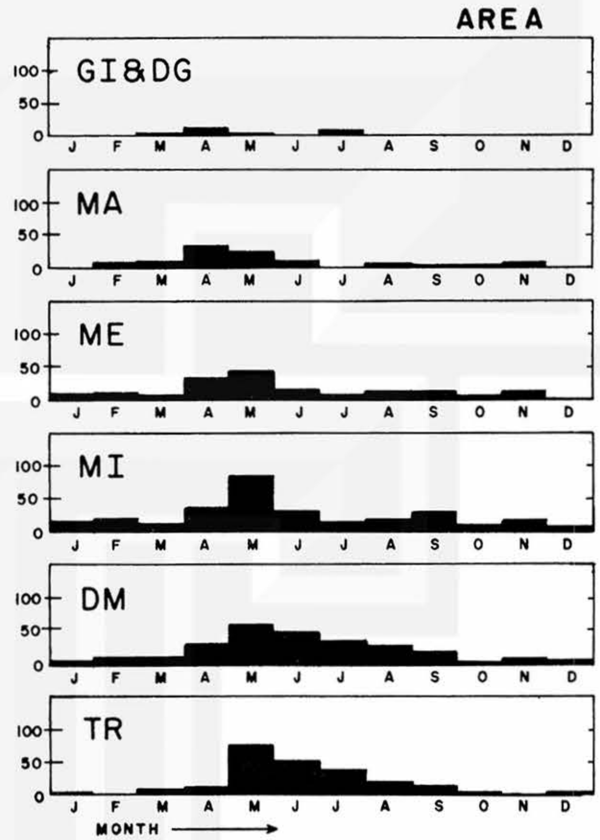

Fig. 6b. Annual distribution of tornadoes according to individual damage area.

of damage area less than 1 square mile, the peak frequency was in May while April had more incidence of tornadoes with damage areas of 1 square mile or greater. Fig. 6a indicates that F 2 and less-intense tornadoes were prevalent in May and F 3 and F 4 storms occurred a month earlier. Fig. 7a shows the distribution in time of the different tornadoes categorized according to intensity of damaging wind. By examining this figure it appeared that the stronger-intensity tornadoes tended to develop later in the day. It showed that whereas F 0 storms peaked between 1600 and 1800 H, tornadoes of the F 1, F 2, F 3 and F 4 classes were observed to be maximum between 1800 H and 2000 H while F 5 tornadoes developed between 2000 H and 2200 H. Figure 7b, on the other hand, shows the diurnal distribution of the different tornadoes classified according to damage area. No generalization of interest may be made here except that peak occurrences were observed between 1600 H and 2000 H.

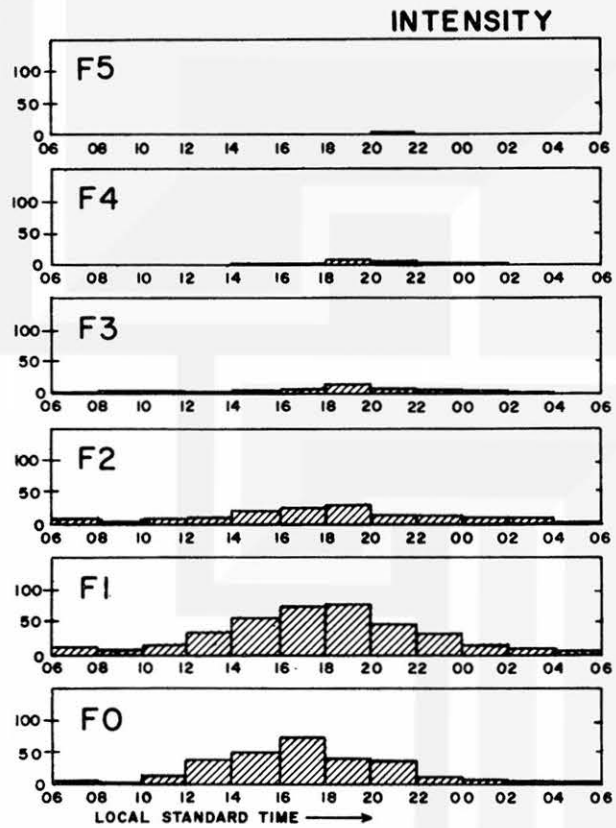

Fig. 7a. Diurnal distribution of tornadoes according to intensity of damaging winds.

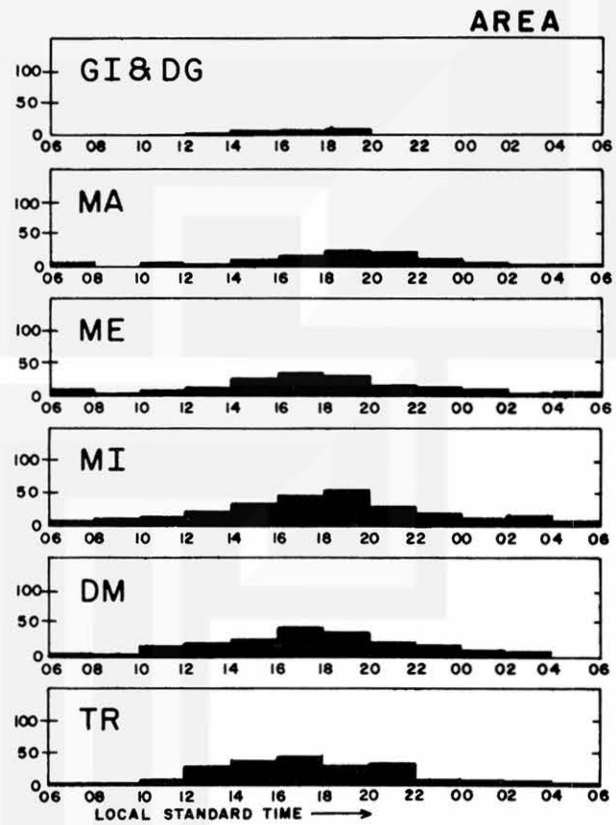

Fig. 7b. Diurnal distribution of tornadoes according to individual damage area.

b. Geographical Distribution

The ensuing figures depict the geographical distribution of tornado occurrences in 1965 by state and by region, annually and diurnally.

Wilson and Morgan, Jr. (1971) in an investigation of long track tornadoes and their significance have concluded that long tornadoes (track lengths of more than 100 miles) "are more lethal and damaging (deaths per mile or per hour) than shorter ones". It may be safely implied that they could correspond to the large-area tornadoes classified in this paper. Similarly, it may be reasonably stated that there could be a positive correlation between casualties and damage to property and strong-intensity tornado occurrences. Since economic losses and casualties play an important role in any society it may perhaps be of particular interest to again look into the large-area and strong-intensity tornadoes as a class.

The geographical distribution of the percentage occurrences of tornadoes with individual damage areas 0.1 square mile or greater is shown in Fig. 8. Only states

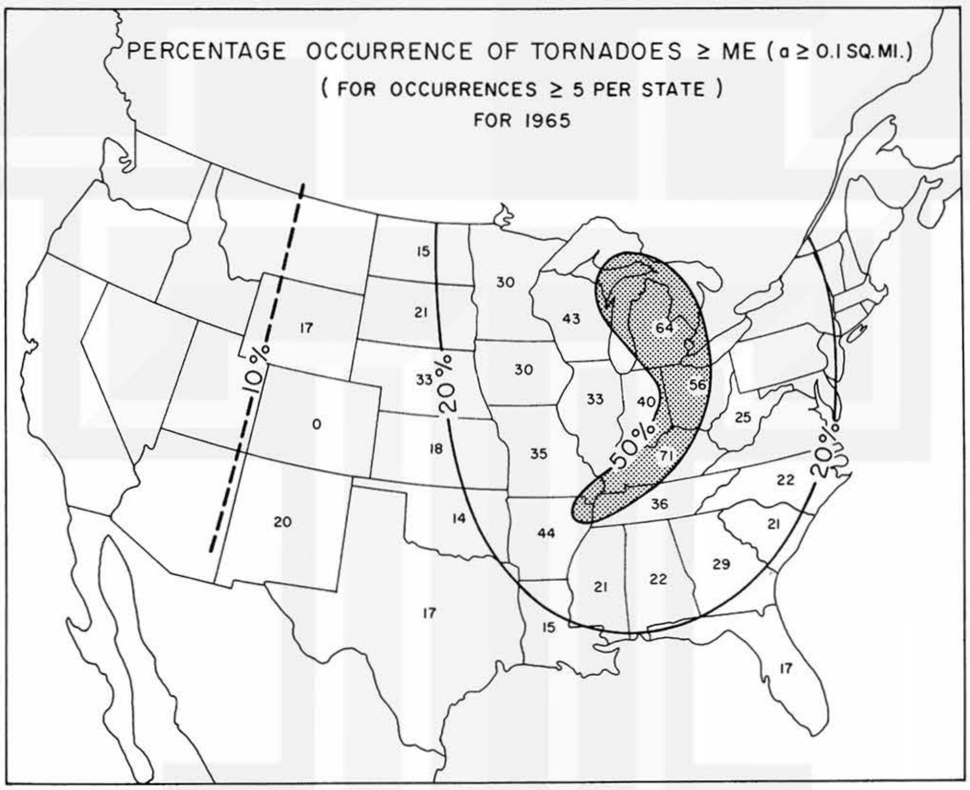

Fig. 8. Percentage occurrences of tornadoes with individual damage areas of .1 square mile or greater (Meso Tornadoes and larger tornadoes) for states with at least 5 occurrences in 1965.

which reported 5 or more occurrences in the year were considered, with percentage values indicated at its geographical center. Areas with 50% or more occurrences appeared to be in the vicinity of the Great Lakes and southwest through Kentucky and Arkansas. Following the same procedure, Fig. 9 presents the percentage occurrence of tornadoes with damaging winds of the F 2 range and greater. The extent of the 50% value is much longer than area-wise, extending down to Louisiana and Mississippi. The general configuration appears the same for both cases suggesting that the large-area tornadoes are also mostly the strong-intensity ones affecting the same area. The absence of values in the western United States is conspicuous in both figures.

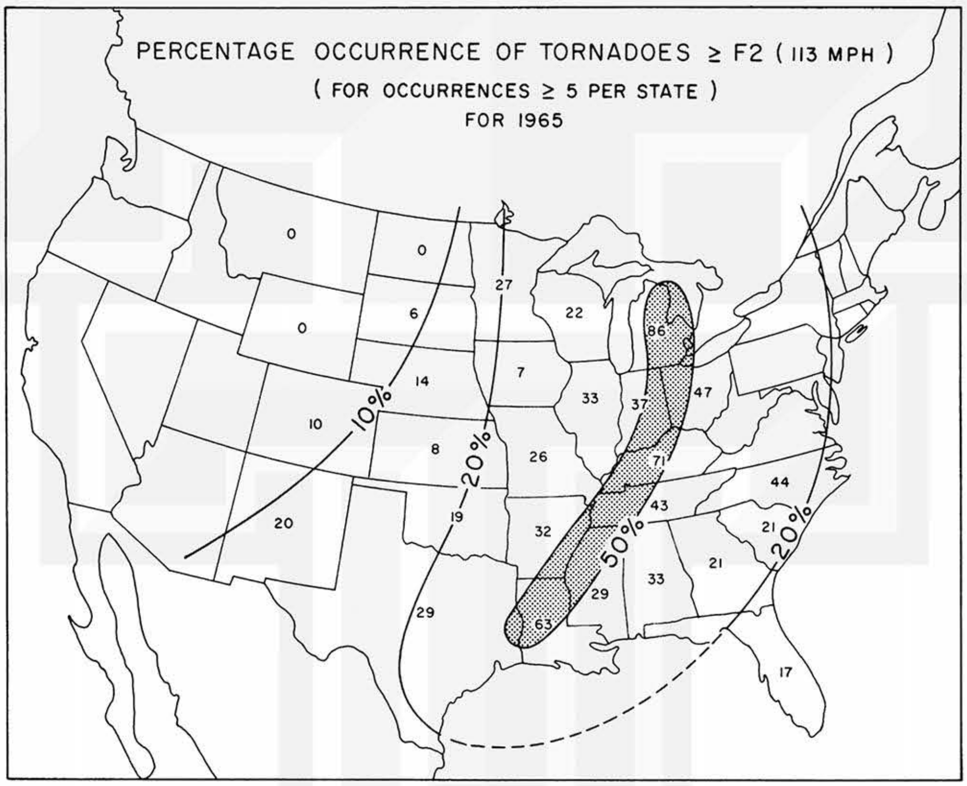

Fig. 9. Percentage occurrence of tornadoes with intensity of damaging winds greater than 112 mph (F 2 and more-intense tornadoes) for states with at least 5 occurrences in 1965.

Various groupings of states in connection with tornado statistics had previously been used (Wolford, 1952; Lee, 1958). Table II lists the grouping of the United States into six areas, arbitrarily chosen according to geographical location, used in this report. There are six regions defined thus.

Table II. Regional Division of the Continental United States (except Alaska).

NORTHWEST (3 States)	MIDWEST (12 States)	EAST (15 States)
Idaho	Arkansas	Connecticut
Oregon	Illinois	Delaware
Washington	Indiana	Maine
	Iowa	Maryland
WEST (6 States)	Kansas	Massachusetts
Arizona	Kentucky	New Hampshire
California	Michigan	New Jersey
Colorado	Missouri	New York
Nevada	Ohio	North Carolina
New Mexico	Oklahoma	Pennsylvania
Utah	Tennessee	Rhode Island
	Texas	South Carolina
NORTH (7 States)		Vermont
Minnesota	SOUTH (5 States)	Virginia
Montana	Alabama	West Virginia
Nebraska	Florida	
North Dakota	Georgia	
South Dakota	Louisiana	
Wisconsin	Mississippi	
Wyoming		

The annual variation of tornado occurrences according to area in the six regions is shown in Fig. 10a, while that according to intensity is depicted in Fig. 10b. Considering both figures, it is rather interesting to note that the peak occurrences varied considerably, with February and July in the South, May in the North and Midwest, June in the West and August in the East areas. Fig. 10a shows that the Giant Tornadoes were spawned in the North and Midwest regions. The Northwest experienced the fewest outbreaks. Intensity-wise, the strongest tornadoes appeared in the Midwest in April, June and November while the North experienced it in May as is seen in Fig. 10b. No outbreaks of this type occurred in other regions.

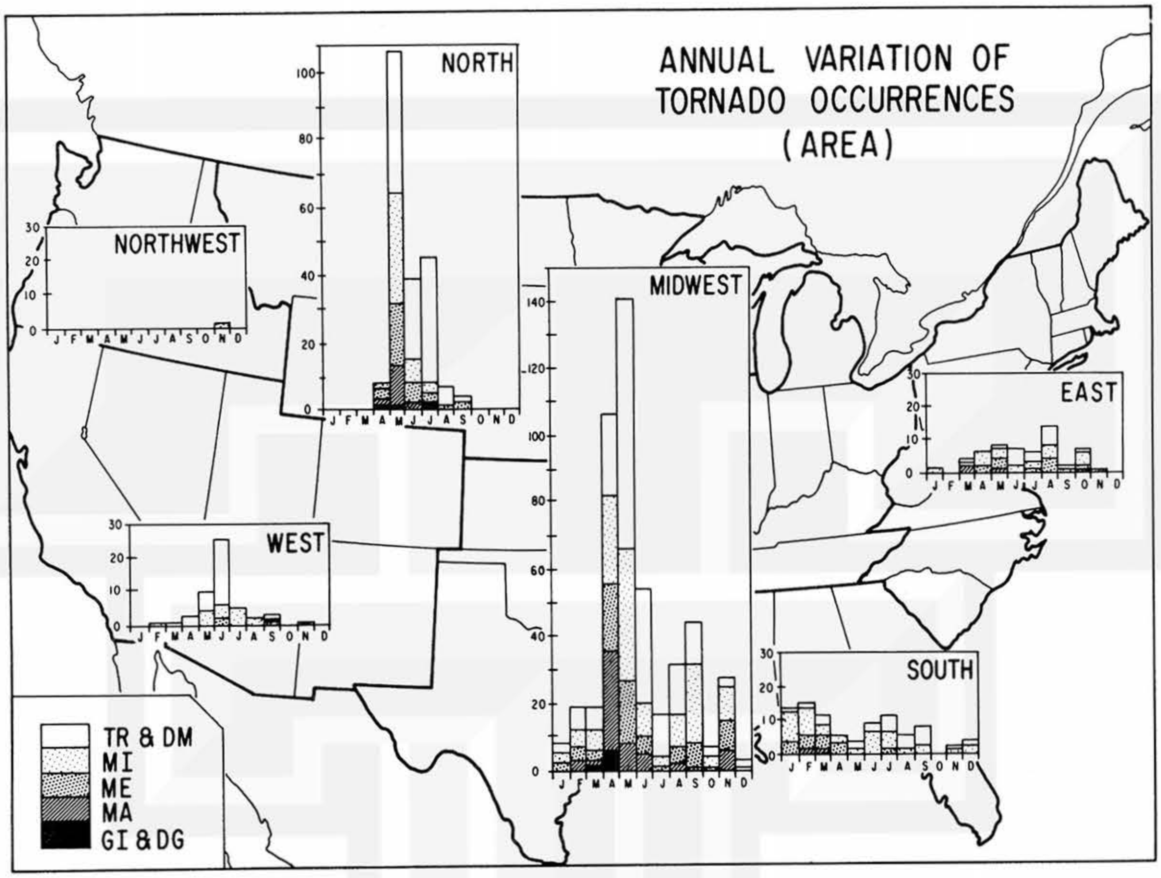

Fig. 10a. Annual variation of tornado occurrences by geographical region according to individual damage area.

The diurnal variation of tornado occurrences according to damage area is presented in Fig. 11a, while Fig. 11b shows the distribution according to intensity. For both figures, peak occurrences were observed between 1200 H and 1400 H in the West, between 1600 H and 1800 H in the North, East and South while between 1800 H and 2000 H in the Midwest. The frequency pattern for the North and the Midwest was quite similar except for the peak lag in the latter. The pattern for the South appeared flat. The Midwest area appeared to experience tornadoes anytime throughout the day while the others did not. It indicated that the North had more large-area tornadoes

(Meso Tornadoes or greater) than it had strong-intensity ones (F 2 tornadoes or greater). The intensity distribution for the F 4 and F 5 tornadoes in the Midwest covered a wide period from 1400 H to 0200 H of the following day, while the area distribution of the GI and DE types were scattered and exhibited less wider time range.

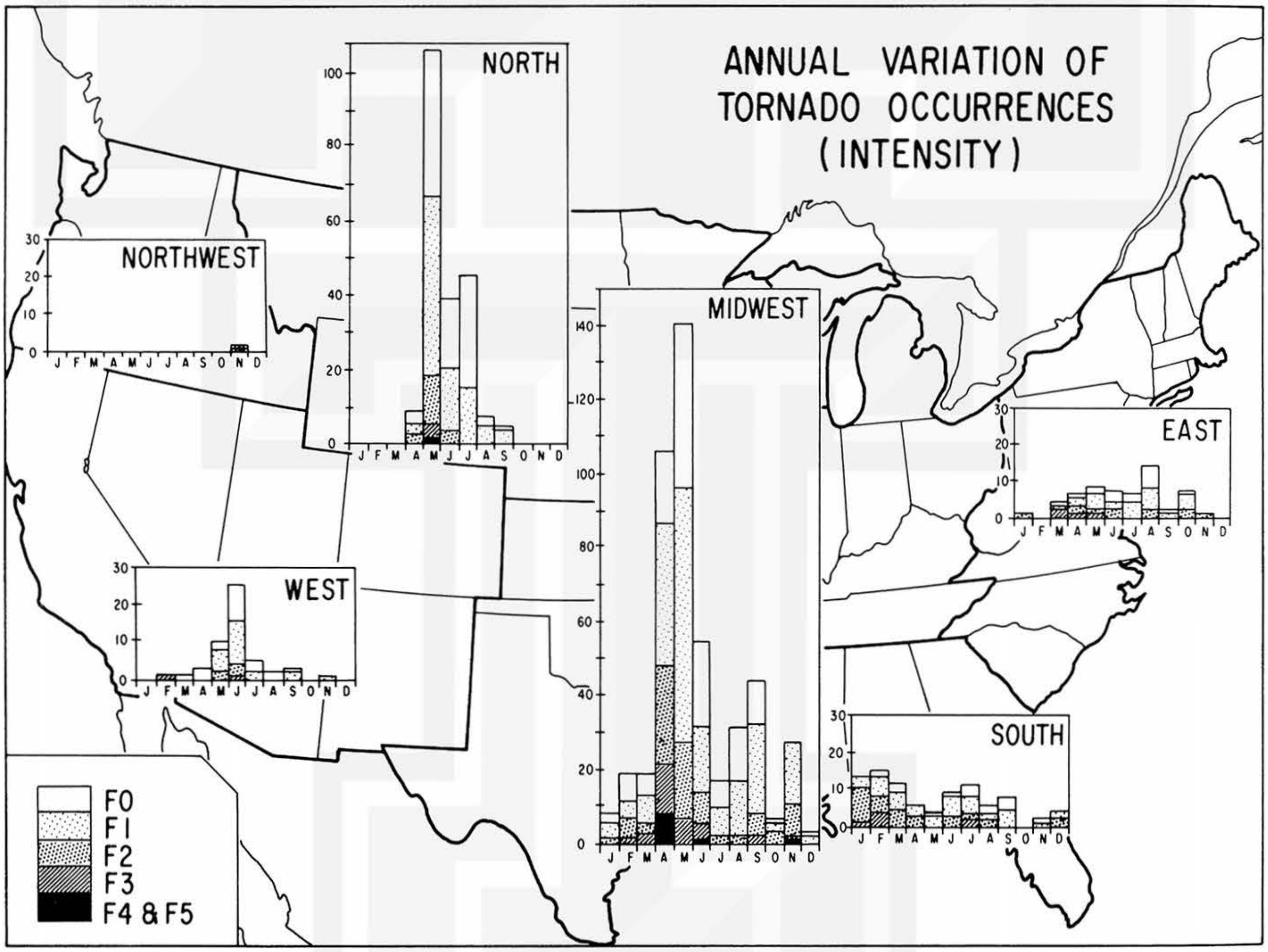

Fig. 10b. Annual variation of tornado occurrences by geographical region according to intensity of damaging winds.

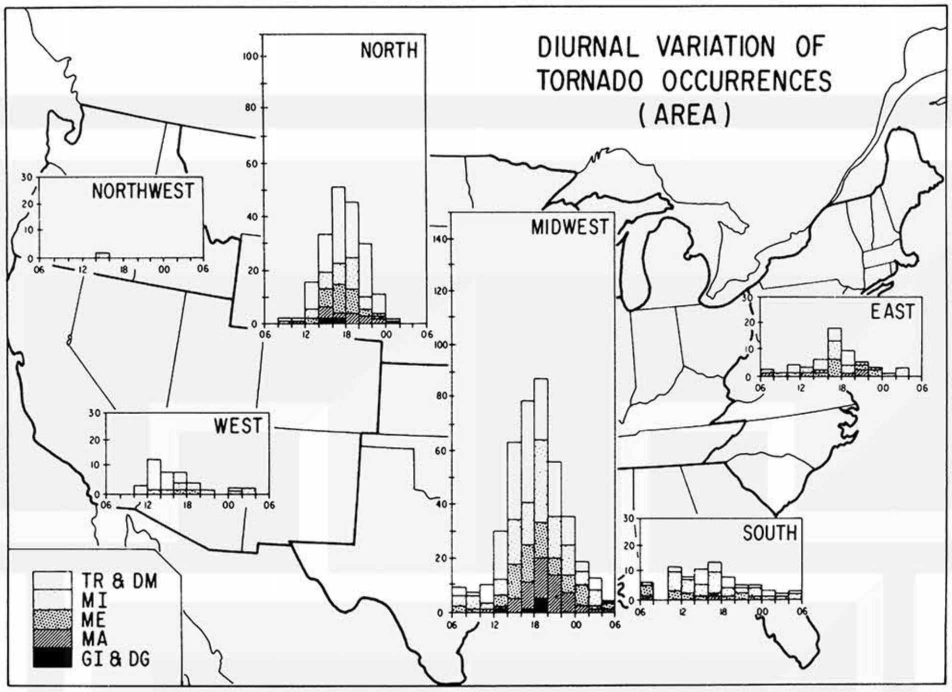

Fig. 11a. Diurnal variation of tornado occurrences by geographical region according to individual damage area.

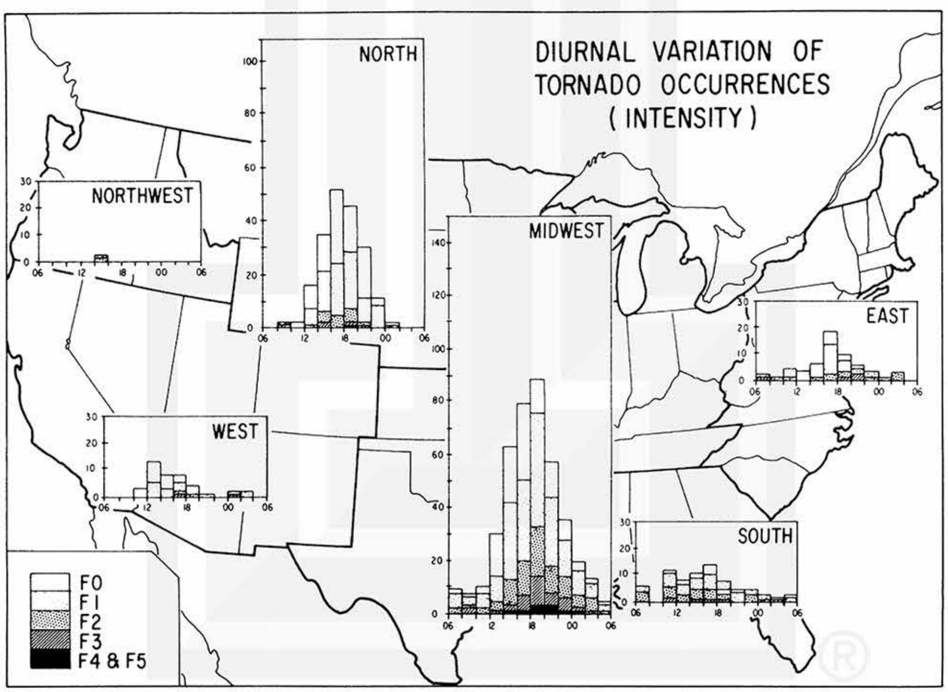

Fig. 11b. Diurnal variation of tornado occurrences by geographical region according to intensity of damaging winds.

Considering again the combined classes of the large-area and the more-intense tornadoes, the monthly distribution by state per 100,000 square miles for Meso Tornadoes and larger tornadoes is shown in Fig. 12a. A comparison of the same distribution for the F 2 and more-intense tornadoes, Fig. 12b, indicated that there were very few occurrences west of the Rockies, if at all, for 1965. The numerous outbreaks in April in Indiana, Michigan and Ohio were attributed to the Palm Sunday Tornadoes. Fig. 12a shows that large-area tornadoes appeared most in May in the adjacent northern states of North and South Dakota, Nebraska and Minnesota but which did not show too well in Fig. 12b for more-intense tornadoes, suggesting that more-intense storms were not necessarily large-area ones, or vice versa, in these states. Nothing signifi-

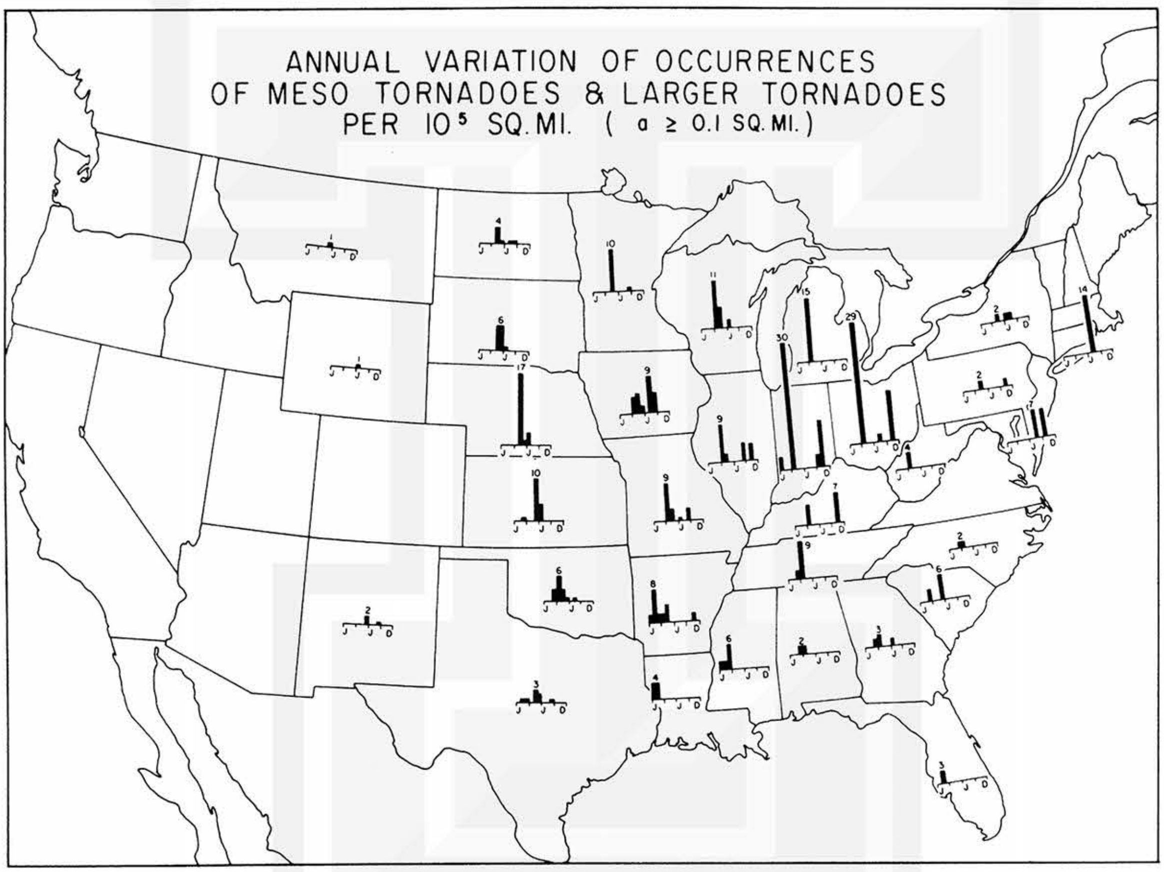

Fig. 12a. Annual variation of occurrences of Meso Tornadoes and larger tornadoes per 100,000 square miles. (Note: The following states are grouped together: Conn., Mass. and R. I.; N. H. and Vt.; Pa. and N. J.; and Md. and Del.)

cant appeared noticeable with the rest of the states. For the more-intense tornadoes, Fig. 12b, peak outbreaks occurred during the first three months of the year for the southern states of Louisiana, Arkansas and Mississippi while during the month of May along an imaginary north-south line covering the states of South Dakota, Nebraska, Kentucky, Oklahoma and Texas including Minnesota.

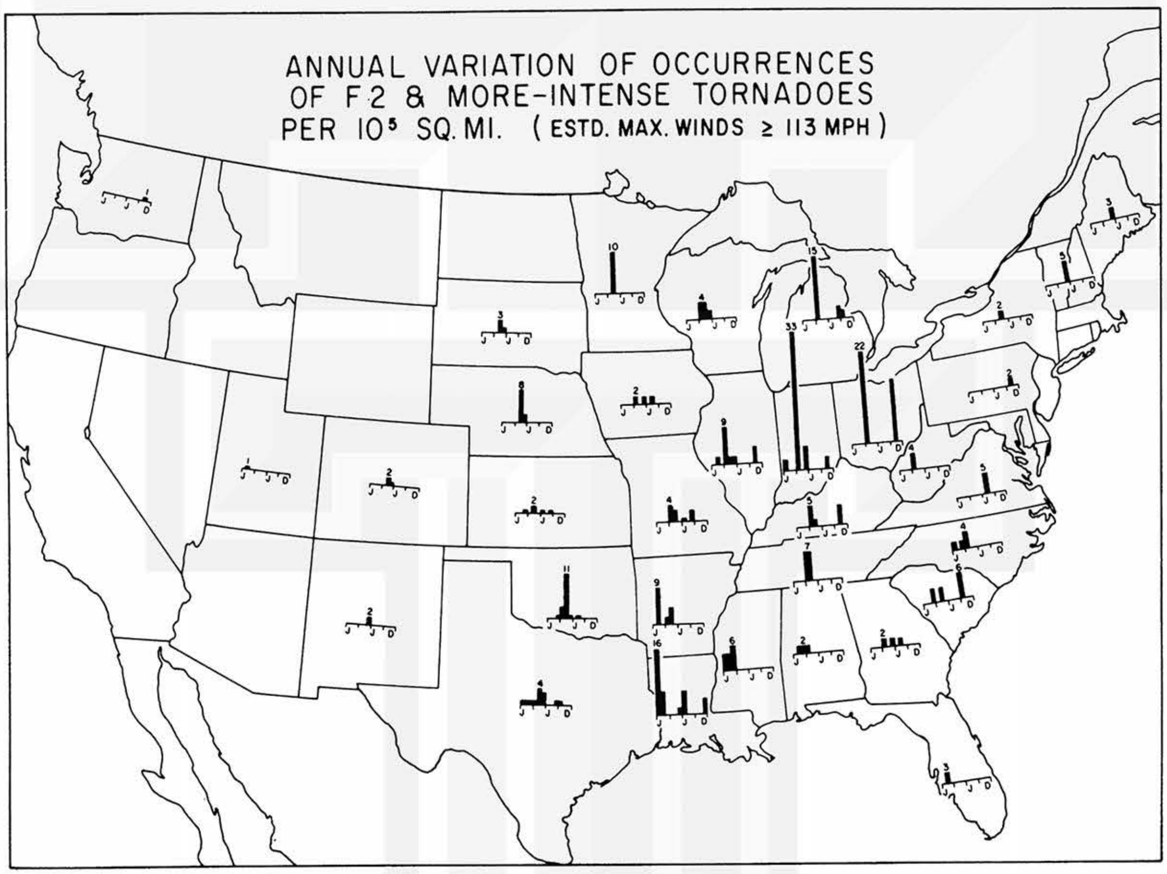

Fig. 12b. Annual variation of occurrences of F 2 and more-intense tornadoes per 100,000 square miles. (See note in Fig. 12a)

The diurnal distribution of occurrences of Meso Tornadoes and larger tornadoes by state per 100,000 square miles appears in Fig. 13a. There seemed to be no clear-cut time range of appearances of the large-area tornadoes. Peak occurrences were spread out between 1400 H and 0000 H of the following day for the majority of the states east of the Rockies and west of the East and the South regions. Fig. 13b shows the same distribution for F 2 and more-intense tornadoes. Comparing this with

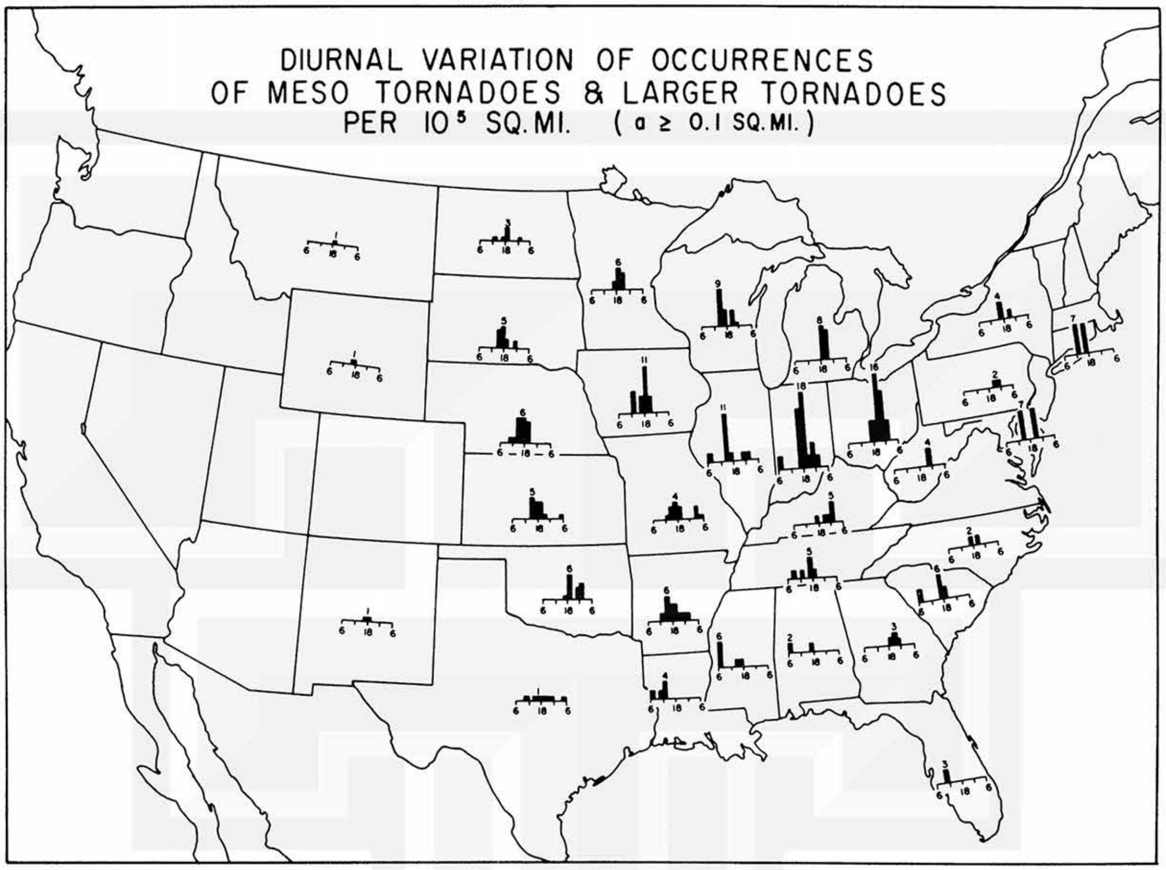

Fig. 13a. Diurnal variation of occurrences of Meso Tornadoes and larger tornadoes per 100,000 square miles. (See note in Fig. 12a)

Fig. 13a, it may be noticed that there were less peak occurrences of F 2 and more-intense tornadoes than the large-area ones. It may also be interesting to note the 0600 H outbreaks observed in Louisiana, Mississippi and Oklahoma in 1965 persisted for both the strong-intensity and the large-area tornadoes.

5. CONCLUSIONS

During the year 1965, there were a total of 893 tornadoes in the United States that were "characterized" simultaneously into two classes according to individual damage area and intensity of damaging winds. The source data consisted mainly from reports compiled in the STORM DATA publication of NOAA.

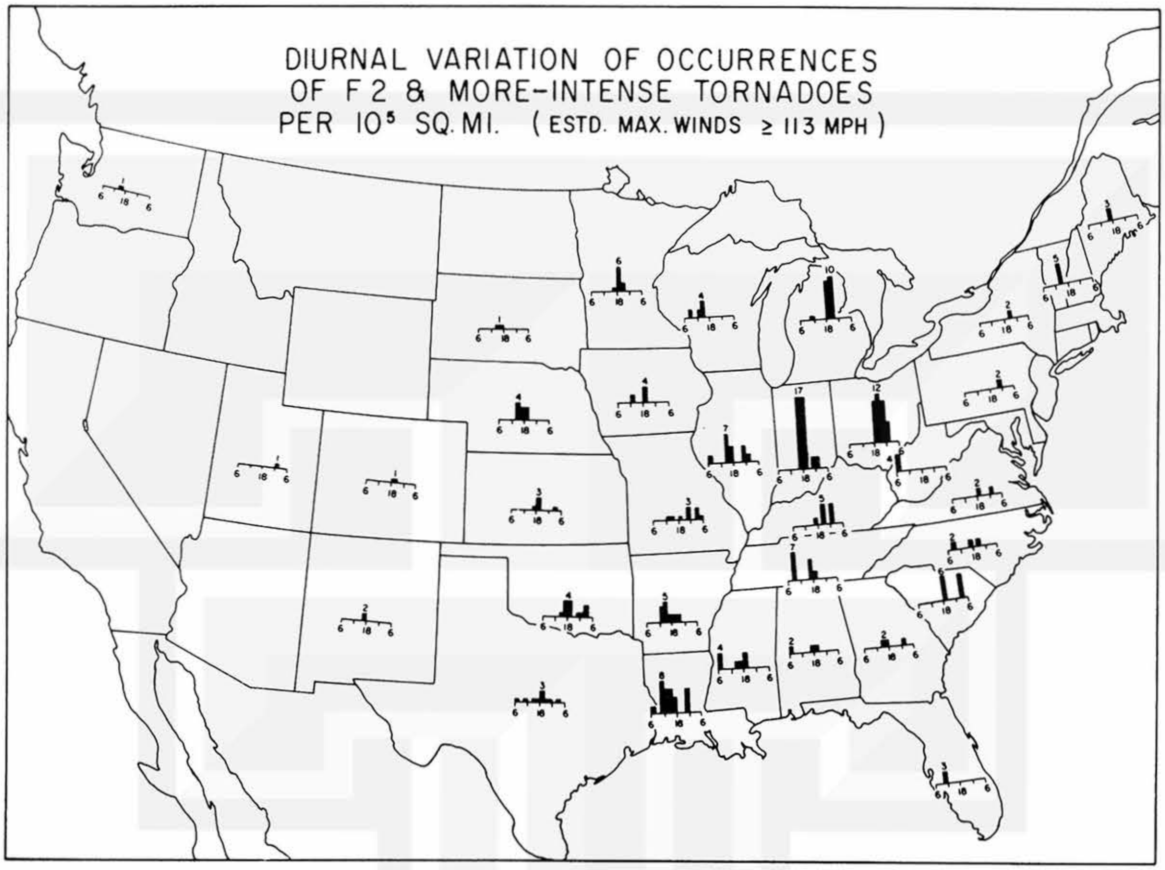

Fig. 13b. Diurnal variation of occurrences of F 2 and more-intense tornadoes per 100,000 square miles. (See note in Fig. 12a)

Based on this classification scheme and being aware that the data was only for one year, it was observed nevertheless that about three-fourths or 77% of the tornadoes had estimated damaging winds of 112 mph or less (F 0 and F 1) and about the same fraction or 74% had individual damage areas of less than .1 square mile (TR, DM and MI). Of these simultaneously classified tornadoes, those of the F 0 and TR, F 1 and MI, and the F 1 and DM categories were the most prevalent with maximum occurrences for all of them during the month of May. The diurnal behavior of tornadoes indicated that the more intense the tornadoes, the later time of day they developed, which, however, did not show up area-wise. In states where tornadoes occurred 5 times or more during the year and which had damaging winds of more than 112 mph (F 2 or greater) or damage areas of 1 square mile or more, it was noted that there were more than 50% occurrences of them in an almost northeast to southwest band below the Great Lakes area extending, in the case of the more-intense tornadoes, to the lower Mississippi Valley. Where tornadoes were grouped into regions, the diurnal distribution pattern for the North and Midwest areas appeared very similar with peak occurrences for the latter to within 2 hours later of the former.

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