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Tornado Climatology of the Contiguous United States

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inconsistent with distance between the beginning and end points of the segment, the latitude and longitude of the beginning point, and the length were assumed to be correct. Overall, the database is in reasonably good condition and acceptable for use in this climatology.

2.1 Tornado Intensities

Most of the statistics in the database related to tornadoes are self-explanatory. The exception is the tornado intensity. The tornado database does not include estimates of the maximum wind speeds in tornadoes. However, it does include an estimate of tornado intensity in the form of an intensity scale that is based on the damage caused by the tornado. The most common tornado intensity scale developed by Fujita (1971, 1978) classifies tornado intensity in six F Scale classes, F0 to F5. Wind speeds are rarely measured by meteorological instruments. Instead, they are estimated from damage associated with the tornado. The range of wind speeds assigned to classes by Fujita is listed in Table 2-1. This range been extended from F5 through F12, which has the speed of sound as its upper limit (NCDC 2004). However, no tornado has been assigned an intensity of F6 or greater, and, because of the imprecision in estimating F-scale and wind speeds in tornadoes, there is some question whether an F6 or greater tornado would be identified if it did occur. According to NCDC (2004), the strongest tornadoes are in the F5 range.

Table 2-1. Fujita Tornado F Scale Intensity Wind Speed Relationships

Intensity	Description	Original Fujita Scale (Fastest quarter mile, mph)	Fujita Scale (3-s gust, mph)	Operational Enhanced Fujita Scale (3-s gust, mph)
F0	Light damage	40 to 72	45 to 78	65 to 85
F1	Moderate damage	73 to 112	79 to 117	86 to 110
F2	Considerable damage	113 to 157	118 to 161	111 to 135
F3	Severe damage	158 to 206	162 to 209	136 to 165
F4	Devastating damage	207 to 260	210 to 261	166 to 200
F5	Incredible damage	261 to 318	262 to 317	>200

It should be noted that the maximum wind speed associated with a tornado occurs for only a small fraction of the footprint and at any location for only a short period of time. Depending on the translational velocity of the tornado, a location might experience wind speeds near the maximum for 5 to 10 seconds.

The problems of tornado intensity from damage are well known. It is a subjective process. For example, damage estimates are limited by the nature of the area where the tornado strikes. If there is nothing to damage, there is no way to assign an F Scale. Similarly, where there are structures, the damage will depend on the nature of the construction.

In 2001, Texas Tech University Wind Science and Engineering Research Center organized a forum of scientists and engineers to consider alternatives to the Fujita Scale (TTU 2006). The Enhanced Fujita

In addition, treating (u + v/2) as a random variable, w, the variance of w, V[w] is approximately

$$V[w] \approx v / n + \frac{v^2}{2(n-1)} \tag{2-8}$$

where n is the number of tornado events used to estimate u and v. For sufficiently large n, perhaps as small as 20, the 90 percent confidence interval for the expected value is approximately

$$\exp\{w - 1.645(V[x])^{1/2}\} < E[x] < \exp\{w + 1.645(V[w])\} \tag{2-9}$$

Equations (2-2) through (2-9) provide the bases for estimation of strike probabilities and the 5th and 95th percentile limits on the 90 percent confidence interval for the expected values.

Table 2-2 lists the characteristics of tornado segments in the contiguous United States, derived from the NCDC tornado data. The table shows that the 90 percent confidence interval in the expected values increases as the intensity increases. This increase is associated with the decrease in the number of segments as the intensity increases. Tables 2-3 through 2-5 list the distributions of tornado dimensions for all tornadoes and for tornadoes by reported tornado intensity.

The geographical distribution of tornado events in the United States between the beginning of 1950 and the end of August 2003 is shown in Figure 2-1. A tornado event is defined as a tornado occurrence within a defined area. A tornado segment in the NCDC database may be counted as an event in more than one area. However, for the boxes shown in Figure 2-1, fewer than 5 percent of the tornadoes contribute to events in more than one box. For larger boxes, this percentage decreases. For the 2° and 4° boxes that form the basis for the analysis in Chapter 5, the percentages of segments contributing to events in more than one box decrease to about 2.3 percent and 1.1 percent, respectively.

Each number in Figure 2-1 represents the number of tornado events occurring in a box that covers 1° of latitude by 1° of longitude. The latitude and longitude labels shown in the figure represent the latitude and longitude of the southeast corners of the boxes. The area covered by each box is a function of latitude. Along the southern border of the country, the area is approximately 4,000 mi^2; in the middle of the country, it is about 3,600 mi^2; and along the northern border, it is about 3,200 mi^2. Figures 2-2 and 2-3 show the geographical distributions of more intense tornadoes, with Figure 2-3 showing only the most intense tornadoes, i.e., those having F Scales of F4 and F5.

	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	
48	0	0	2	0	0	3	5	3	3	0	1	0	3	7	3	6	2	7	21	18	11	24	36	77	36	52	60	45	34	15	7	6	3	4	0	0	0																							48
47	0	1	12	1	1	3	6	10	2	1	1	0	3	15	17	19	7	10	9	9	23	13	26	45	56	51	67	73	59	50	20	11	18	11	2	0	3	0																			0	6		47
46	1	7	5	0	4	3	7	4	6	0	4	1	7	2	4	12	5	4	9	5	18	22	37	47	63	50	84	72	88	46	51	39	15	18	10	10	9	8	6	8	3	1														0	0	9	5	46
45	0	10	19	0	1	2	4	1	3	0	0	7	4	6	1	1	17	8	4	12	9	12	37	22	44	48	101	57	53	85	87	71	71	47	42	55	17	30	5	7	17	13												1	2	1	7	6	2	45
44	2	9	5	4	0	0	0	4	7	0	0	1	5	0	0	2	23	14	13	57	35	56	31	31	38	38	62	121	78	88	104	134	90	81	65	67	71	36	3	34	45	35	0						0	6	5	14	11	5	20	19	5	2	44
43	0	1	0	0	2	2	2	6	23	1	8	5	20	18	2	2	9	9	14	27	31	39	15	45	52	71	107	142	140	120	93	137	115	61	63	97	159	12	19	61	71	79	29			0	5	4	18	16	13	12	18	28	20				43
42	2	0	0	2	0	1	0	1	0	2	17	12	19	3	7	5	4	3	18	27	65	64	60	31	45	53	113	133	146	100	120	138	158	133	99	91	99	38	36	104	116	127	23		6	22	28	13	22	30	26	59	76	81	11				42
41	6	0	0	1	0	2	0	1	0	3	1	2	13	10	5	8	3	7	9	30	123	155	74	67	72	112	152	179	128	109	112	163	116	140	166	94	134	113	139	134	97	90	75	60	89	47	32	23	59	35	33	56	41	14	9				41
40	1	0	4	0	0	1	0	1	3	5	2	2	10	17	2	7	1	4	2	29	207	136	142	88	97	147	250	179	137	128	106	86	76	114	142	178	175	101	148	138	101	77	104	57	58	71	45	37	77	83	78	16	9						40
39		2	4	8	1	12	4	0	0	1	6	0	2	10	3	0	4	1	1	25	310	112	85	155	103	121	135	141	119	183	159	88	74	66	82	139	145	103	138	159	117	80	48	30	26	39	28	83	69	86	27								39
38		2	11	15	2	1	0	1	1	0	1	2	5	4	8	3	2	0	3	15	55	53	128	96	89	150	179	179	136	146	111	88	124	53	149	141	97	116	80	113	78	48	38	14	6	11	42	63	64	50	1								38
37			11	14	19	2	0	0	1	4	1	5	2	0	0	0	3	4	6	11	23	12	63	91	158	114	158	219	120	134	154	111	74	59	83	138	80	83	60	74	87	33	5	12	15	21	25	64	43	13										37
36			1	8	7	32	1	0	2	5	6	1	3	3	1	1	5	2	1	4	16	21	88	134	110	127	156	256	142	227	134	63	94	79	105	130	96	66	131	67	52	19	20	21	38	34	46	50	87	15										36
35				0	1	4	3	2	0	1	6	4	10	7	4	1	0	2	22	12	10	32	67	223	161	170	214	344	229	193	133	89	154	198	146	121	93	65	104	62	55	23	26	79	90	49	88	121	52	29										35
34					2	4	16	21	7	0	4	1	15	2	8	2	0	2	8	11	13	88	226	225	127	244	191	195	201	115	76	82	171	133	93	83	120	113	170	77	92	88	104	79	69	99	76	71	36										34
33							19	32	4	5	2	1	25	29	3	0	0	3	4	5	32	34	183	198	75	122	128	152	188	126	149	113	76	95	144	105	121	141	149	107	125	55	49	91	89	50	23	1										33
32								9	0	2	8	3	4	18	9	4	6	4	12	2	41	76	93	118	158	190	132	246	192	148	202	195	145	177	210	176	97	70	97	78	102	101	51	70	37	16												32
31												0	0	1	6	4	1	1	6	8	6	49	89	35	85	92	81	158	65	82	139	90	94	91	139	183	73	74	98	128	109	123	80	43	0														31
30																				0	10	29	30	14	16	19	66	155	114	113	134	154	202	130	136	163	124	179	132	137	83	73	64	90														30
29																					0	6	1	15	35	30	116	91	139	302	129	74	25	39	91	27				25	30	6	110	137	21												29
28																									7	26	44	108	95	19													225	214	107												28
27																										5	42	130	0														302	129	100												27
26																										4	32	60															66	125	231												26
25																												8																13	135												25
	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	

Figure 2-1. Distribution of Tornado Events in the Contiguous United States by 1° Latitude and Longitude Boxes (1950 through August 2003)

	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	
48	0	0	2	0	0	0	1	1	1	0	0	0	0	1	0	1	0	0	4	2	2	3	6	7	5	4	9	8	3	1	1	1	0	0	0	0	0																						48
47	0	0	2	0	0	1	1	2	1	0	0	0	1	4	4	7	1	0	0	3	5	2	4	7	8	13	16	13	7	4	1	2	8	2	0	0	0	0																		0	2		47
46	0	0	1	0	1	0	1	2	1	0	1	0	0	0	1	1	1	0	0	1	6	6	4	6	13	18	14	24	30	18	19	17	5	5	1	3	3	2	1	2	0	0													0	0	1	0	46
45	0	0	2	0	0	0	0	1	0	0	0	2	1	0	0	0	4	1	0	3	3	1	6	8	13	15	22	11	8	12	16	25	23	20	22	18	12	14	2	3	4	2											1	0	0	3	5	1	45
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	3	1	6	8	12	2	8	6	7	11	35	20	29	23	40	23	39	39	21	34	12	2	11	12	13	0						0	1	1	4	4	1	3	8	0	1	44
43	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	3	0	4	3	7	11	3	12	10	17	26	42	38	43	24	50	46	23	27	35	58	4	7	18	25	28	6			0	1	0	3	3	1	3	8	9	5				43
42	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	2	0	3	1	4	6	9	10	9	12	15	46	43	31	48	50	60	50	41	30	44	16	17	38	44	47	8		2	11	12	1	6	7	7	23	20	27	2				42
41	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	2	12	23	18	7	17	33	49	45	35	34	40	51	36	50	55	28	37	47	63	53	41	37	29	24	41	26	14	7	12	9	9	15	16	1	3				41
40	1	0	1	0	0	0	0	0	0	0	1	2	1	2	0	0	0	1	0	3	24	16	21	17	26	28	61	60	47	40	47	41	40	40	39	41	45	37	65	61	27	28	40	21	13	32	10	11	27	27	19	4	1						40
39		0	2	0	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	5	20	8	9	27	22	40	33	50	28	82	65	37	27	16	29	38	45	27	53	81	48	34	10	8	7	17	8	13	22	27	8									39
38		1	1	1	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	2	7	9	9	15	29	55	42	60	51	65	43	24	29	17	51	60	46	50	37	63	35	19	13	2	1	3	12	17	10	3	1									38
37			3	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	1	1	3	30	36	22	38	54	36	52	56	37	32	23	39	63	36	47	29	30	37	11	0	4	10	8	6	25	10	2											37
36			0	1	0	3	0	0	0	1	0	0	0	0	0	0	1	0	0	0	3	1	10	28	25	26	41	89	50	86	50	25	38	43	42	43	38	24	52	35	33	4	6	6	7	7	18	18	24	4											36
35				0	0	0	0	0	0	0	0	0	2	2	0	0	0	1	0	0	3	4	7	50	44	36	70	143	112	62	55	46	88	97	68	52	46	32	45	25	28	6	3	22	15	15	33	36	21	3											35
34							3	2	1	0	0	0	3	0	0	0	0	0	1	0	1	11	40	42	17	69	58	76	85	46	33	34	75	60	42	42	70	68	95	39	44	33	33	30	19	43	29	13	5											34
33							5	3	0	1	1	0	2	6	0	0	0	0	0	0	2	3	37	28	10	32	40	47	67	61	72	48	33	43	74	43	61	69	73	44	46	22	14	31	13	9	5	0											33
32								0	0	0	2	2	0	2	0	0	1	0	0	1	3	7	12	10	28	46	21	78	57	60	87	75	48	76	81	95	32	28	35	29	37	38	14	18	4	3													32
31												0	0	0	0	0	0	0	0	0	1	15	12	1	13	27	15	62	24	31	60	38	41	37	58	88	27	30	28	47	37	32	18	11	0															31
30																				0	1	0	7	3	1	8	20	45	43	23	33	29	55	48	31	38	35	38	30	32	31	19	8	12																30
29																					0	0	1	2	6	9	26	20	28	58	32	20	1	11	19	4				3	4	2	28	26	4													29
28																									3	8	9	24	10	1													25	44	24													28
27																										2	6	20	0														42	19	20													27
26																										3	5	7															7	13	27													26
25																												2																2	11													25
	124	123	122	121	120	119	118	117	116	115	114	113	112	111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	

Figure 2-2. Distribution of Tornado Events with Intensities of F2 or Greater in the Contiguous United States by 1° Latitude and Longitude Boxes (1950 through August 2003)