Assessing the Magnitude and Societal Impacts of the April 25-28, 2011 Tornado Outbreak in the Southeastern U.S.

Charles Konrad II, Margaret Kovach, Jordan McLeod, Hillary Fox, Christopher Fuhrmann, William Schmitz, and D.J. Perkins

Southeast Regional Climate Center, Department of Geography, University of North Carolina at Chapel Hill

The April 25-28, 2011 tornado outbreak affected a large region of the southeastern U.S. and produced an extraordinary number of strong tornadoes. Preliminary reports have suggested that the intensity of this outbreak may be greater than any other outbreak observed in recent history, including the April 1974 "Super Outbreak".

Research Questions

- How does the intensity of the April 25-28, 2011 tornado outbreak rank among other major U.S. tornado outbreaks in the modern record (since 1950)?
- What were the societal impacts of the April 25-28, 2011 tornado outbreak and how do they compare to other major U.S. tornado outbreaks in the modern record? Specifically, how does the population and mobile home density along each tornado track relate to the intensity of the outbreak and the number of deaths and injuries?

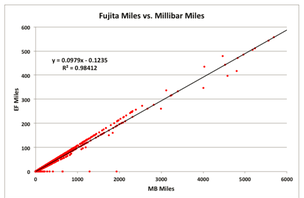
Data and Methods

Tornado Reports and Outbreak Classification

- Tornado data from 1950 to 2010 were obtained from the Storm Prediction Center (SPC) using the online *SeverePlot* tool. Tornado data from April 2011 were obtained in segmented form from the SPC. These segments were then connected to form individual events. This procedure was done in consultation with SPC and the National Climatic Data Center. Only events east of the Rocky Mountains were used in this project.
- Individual tornado events were aggregated into "outbreaks" using the definition from Grazulis (1993, 1997) (i.e. a sequence of tornado events with no more than a 6 hour period between consecutive events in the sequence). Daily weather maps were also examined to determine if individual events in the sequence were associated with the same synoptic-scale weather system.

Intensity Metrics

- Three metrics were developed to provide a quantitative estimate of the intensity of the outbreaks:
  - ***Millibar miles:*** the force of the wind (i.e. median wind speed by F/EF scale) multiplied by the distance over which the wind acts (i.e. track length)
  - ***Fujita miles:*** the F/EF level of the tornado multiplied by the track length; a simpler measure that is highly correlated with millibar miles (*see Figure*)



F/EF level (0-5) * track length (miles) = Fujita miles

- Because the reported F/EF level represents the *maximum* level assigned along each tornado track, these metrics overestimate the true intensity of the tornado. To account for this, an adjustment factor was applied for each F/EF level using tornado segment data from the National Weather Service Verification Database (*see Table*)

Correction Factor Statistics for All Tornadoes			
EF-Level	Mean Adjusted EF-Level	Standard Deviation Range (-1 -> +1)	Sample Size
1	0.981	0.912 - 1.05	60
2	1.818	1.456 - 2.18	32
3	2.769	2.514 - 3.024	31
4	3.544	3.064 - 4.024	30
5	4.43	3.83 - 5.03	

  - ***Density:*** the number of strong tornadoes (F/EF-2 and greater) per unit area across a range of circular regions (1,000,000 km² to 1,000 km²)

Assessment of Societal Impacts and Vulnerability

- Population and mobile home data at the census block group level were retrieved from the 1990 and 2000 U.S. Censuses. The 1990 census was the first census to survey both urban and rural regions of the U.S. and was used for outbreaks prior to 2000. More recent outbreaks utilized the 2000 Census.
- A Geographic Information System (GIS) was utilized to create a raster of population and mobile home density (1 km by 1 km spatial resolution) across the central and eastern sections of the U.S. Estimates of population and mobile home density (i.e. exposure) within 1 km of each tornado track were computed by overlaying these rasters on the tornado tracks and aggregating by outbreak. These numbers were then compared with the number of reported fatalities and injuries in each outbreak as a preliminary measure of vulnerability.

Results

The Most Intense Tornado Outbreaks on Record: How Does April 25-28, 2011 Compare?

Tornado Outbreaks	Geographic Region	# of F/EF-0s	# of F/EF-1s	# of F/EF-2s	# of F/EF-3s	# of F/EF-4s	# of F/EF-5s	Total Tornadoes	Total Track Length (miles)	Adjusted Fujita Miles	Ranking
April 3-4, 1974	Midwest, Southeast	11	37	34	33	23	7	145	2,489.8	7,060.6	1
April 25-28, 2011	South-Central, Southeast, Mid-Atlantic, Northeast	119	140	62	20	13	4	345	3,208.2	6,859.0	2
March 13-14, 1990	Great Plains	10	21	13	10	2	2	58	1,218.6	3,903.4	3
November 21-23, 1992	South-Central, Southeast, Midwest	12	36	26	15	6	0	95	1,219.8	2,871.9	4
April 11-12, 1965	Midwest	0	15	10	5	17	0	47	901.1	2,550.5	5
May 4-8, 2003	Great Plains, South-Central, Southeast	130	82	25	13	6	0	256	1,351.9	2,442.1	6
April 29-30, 1954	Great Plains, South-Central	3	14	15	5	1	0	38	946.8	2,185.6	7
May 26-29, 1973	Great Plains, South-Central, Southeast	20	39	33	10	3	0	105	999.1	2,084.7	8
May 31, 1985	Northeast	2	8	5	8	6	1	30	534.9	1,589.2	9
May 8, 1965	Great Plains	5	9	9	4	2	1	30	572.1	1,444.1	10
May 5-6, 1960	Great Plains, South-Central	3	10	19	6	2	1	41	581.1	1,443.2	11
April 16, 2011	Southeast	16	22	10	6	0	0	54	444.7	857.4	12

Table 1. **Ranking of the most intense tornado outbreaks on record across the contiguous U.S. by adjusted Fujita Miles** (1950 to 2011). The frequency of tornadoes by F/EF scale and total track length is provided for each outbreak. The maximum value in each category is highlighted.

Area (km²)	1,000	100,000	500,000	1,000,000
April 3-4, 1974	7	40	81	95
April 25-28, 2011	5	37	70	77
May 4-8, 2003	2	15	34	43
April 11-12, 1965	2	18	30	31
May 26-29, 1973	3	13	25	35
May 5-6, 1960	4	19	25	27
November 21-23, 1992	3	12	21	30
May 31 1985	4	19	20	20
March 12-14, 1990	2	11	22	25
April 16 2004	2	15	16	16
May 8 1965	3	7	14	15
April 29-30, 1954	1	5	10	15

Table 2. Frequency of strong tornadoes (F/EF2 and greater) by spatial scale for the most intense outbreaks on record, ranked according to the aggregate frequency across all four scales (not shown)

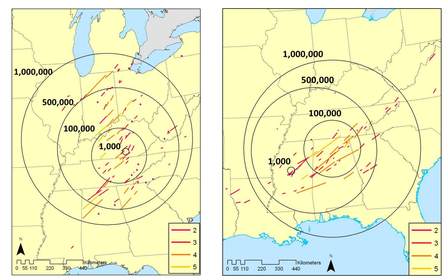


Figure 1. Tracks of strong tornadoes (F/EF2 and greater) associated with the April 3-4, 1974 Super Outbreak (left) and the April 26-28, 2011 Outbreak. The circles circumscribe regions in which the greatest frequency of tornadoes were identified over four different spatial scales (km²).

Societal Impacts of Major Tornado Outbreaks: How Does April 25-28, 2011 Compare?

Fatalities and Injuries

Frequency of Fatalities Associated with the 12 Tornado Outbreaks									
Tornado Outbreaks	Geographic Region	F/EF-0	F/EF-1	F/EF-2	F/EF-3	F/EF-4	F/EF-5	Total	Ranking
April 3-4, 1974	Midwest, Southeast	0	3	6	35	118	148	310	1
April 25-28, 2011	South-Central, Southeast, Mid-Atlantic, Northeast	0	2	16	21	166	98	303	2
April 11-12, 1965	Midwest	--	1	7	14	238	--	260	3
May 31, 1985	Northeast	0	0	1	18	39	18	76	4
May 4-8, 2003	Great Plains, South-Central, Southeast	0	0	0	21	19	--	40	5
May 5-6, 1960	Great Plains, South-Central	0	0	2	5	21	5	33	6
November 21-23, 1992	South-Central, Southeast, Midwest	0	3	1	4	18	--	26	T-7
April 16, 2011	Southeast	0	0	4	22	--	--	26	T-7
May 26-29, 1973	Great Plains, South-Central, Southeast	0	3	1	3	15	--	22	8
May 8, 1965	Great Plains	0	0	0	0	4	0	4	9
March 13-14, 1990	Great Plains	0	0	0	0	0	2	2	10
April 29-30, 1954	Great Plains, South-Central	0	0	1	0	0	--	1	11

Table 3. The most intense tornado outbreaks on record across the contiguous U.S. by Adjusted Fujita Miles (1950 to 2011) **ranked according to the total number of fatalities**. The number of fatalities by F/EF scale is provided for each outbreak. The maximum value in each category is highlighted.

Frequency of Injuries Associated with the 12 Tornado Outbreaks									
Tornado Outbreaks	Geographic Region	F/EF-0	F/EF-1	F/EF-2	F/EF-3	F/EF-4	F/EF-5	Total	Ranking
April 3-4, 1974	Midwest, Southeast	2	99	210	778	1,920	2,445	5,454	1
April 11-12, 1965	Midwest	--	69	93	134	3,146	--	3,442	2
April 25-28, 2011	South-Central, Southeast, Mid-Atlantic, Northeast	1	13	103	253	2,184	288	2,842	3
May 31, 1985	Northeast	0	5	36	248	277	310	876	4
May 26-29, 1973	Great Plains, South-Central, Southeast	2	38	42	206	513	--	801	5
November 21-23, 1992	South-Central, Southeast, Midwest	1	42	75	220	300	--	638	6
May 4-8, 2003	Great Plains, South-Central, Southeast	2	7	52	173	326	--	560	7
April 16, 2011	Southeast	2	13	44	421	--	--	480	8
May 5-6, 1960	Great Plains, South-Central	0	8	21	45	119	81	274	9
March 13-14, 1990	Great Plains	0	0	17	3	8	60	88	10
May 8, 1965	Great Plains	0	0	8	0	53	1	62	11
April 29-30, 1954	Great Plains, South-Central	0	1	37	22	0	--	60	12

Table 4. Same as Table 3, but outbreaks **ranked according to the total number of injuries**.

Societal Impacts, Continued

Population Exposure

Total Population Exposure Associated with the 12 Tornado Outbreaks								
Tornado Outbreaks	F/EF-0	F/EF-1	F/EF-2	F/EF-3	F/EF-4	F/EF-5	Total	Ranking
April 25-28, 2011	30,700	71,292	38,772	23,476	50,261	11,366	225,866	1
April 3-4, 1974	3,232	67,021	48,042	26,259	19,431	51,297	215,281	2
November 21-23, 1992	15,866	72,041	44,040	4,809	3,363	--	141,119	3
May 4-8, 2003	18,528	26,874	14,132	11,258	35,830	--	106,622	4
April 11-12, 1965	--	16,253	23,575	6,552	54,082	--	100,462	5
May 26-29, 1973	18,444	31,307	30,449	8,197	4,716	--	93,112	6
April 16, 2011	9,282	5,623	13,606	54,581	--	--	83,091	7
May 31, 1985	446	2,021	2,096	5,855	17,491	21,573	49,483	8
April 29-30, 1954	712	1,713	22,257	18,356	1,281	--	44,319	9
May 5-6, 1960	7,068	2,343	16,292	6,568	537	73	32,882	10
March 13-14, 1990	3,175	2,215	8,440	1,604	1,696	1,206	18,336	11
May 8, 1965	33	354	4,158	941	410	101	5,997	12

Table 4. Ranking of the total population exposed (i.e. the number of people within 1 km of the tornado path) in each of the most intense tornado outbreaks from Table 1. The total population exposed by F/EF scale is also provided for each outbreak. The maximum value in each category is highlighted.

April 3-4, 1974 Super Outbreak *April 26-28, 2011 Outbreak*

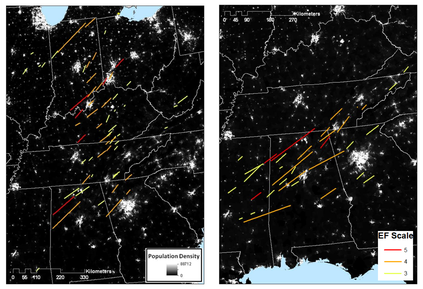


Figure 2. Tracks of strong and violent tornadoes (F/EF 3 and greater) associated with the April 3-4, 1974 Super Outbreak (left) and the April 26-28, 2011 outbreak (right) overlain on population density (per km²).

Mobile Home Exposure

Total Mobile Home Exposure Associated with the 12 Tornado Outbreaks								
Tornado Outbreaks	F/EF-0	F/EF-1	F/EF-2	F/EF-3	F/EF-4	F/EF-5	Total	Ranking
April 25-28, 2011	1,375	3,205	1,899	1,498	2,905	914	11,995	1
April 3-4, 1974	201	1,918	2,774	1,490	1,204	407	7,994	2
May 26-29, 1973	559	1,625	1,380	320	173	--	4,058	3
November 21-23, 1992	1,109	1,430	758	359	221	--	3,876	4
May 4-8, 2003	513	1,101	611	638	865	--	3,728	5
April 16, 2011	109	464	722	1,429	--	--	2,724	6
April 29-30, 1954	1	138	1,646	644	79	--	2,508	7
April 11-12, 1965	--	556	138	130	1,301	--	2,126	8
May 31, 1985	22	78	138	307	834	487	1,867	9
May 5-6, 1960	57	170	364	328	46	6	972	10
March 13-14, 1990	28	63	327	55	38	42	553	11
May 8, 1965	2	16	126	21	14	9	189	12

Table 4. Same as Table 3, but for mobile home exposure (i.e. number of mobile homes within 1 km of the tornado path).

April 3-4, 1974 Super Outbreak *April 26-28, 2011 Outbreak*

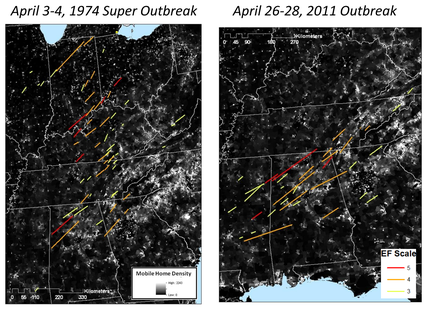


Figure 3. Same as Table 2, but overlain on mobile home density (per km²).

Major Findings

- **The use of adjusted Fujita miles provides an objective and simple metric to assess and compare the intensity of tornado outbreaks. Only three of the top 10 most intense outbreaks since 1950 have occurred over the past two decades.**
- **The April 25-28, 2011 outbreak had more than double the number of tornadoes than the April 3-4, 1974 Super Outbreak. However, the 1974 Super Outbreak had more strong and violent tornadoes (F3 and greater) and had a greater frequency (i.e. density) of tornadoes across a wide range of areas. The aggregate track lengths of the outbreaks are comparable.**
- **According to the number of adjusted Fujita miles, the April 25-28, 2011 outbreak is comparable to, but does not exceed the April 3-4, 1974 Super Outbreak. Nevertheless, these outbreaks clearly stand above all others in the modern record, with the next highest intensity exhibiting only a little more than half of the adjusted Fujita miles.**
- **In terms of fatalities, the April 25-28, 2011 outbreak is comparable to the April 3-4, 1974 Super Outbreak. However, the 1974 Super Outbreak had considerably more injuries, particularly among F5 tornadoes.**
- **The population density along all tornado tracks was slightly higher (~5%) during the April 25-28, 2011 outbreak compared to the 1974 Super Outbreak. More notably, the density of mobile homes along all tornado tracks was 34% higher during the April 2011 outbreak. This was most evident among EF-4 tornadoes, which were responsible for 55% of all fatalities from the outbreak.**

We thank Greg Carbin of the Storm Prediction Center for sharing the 2011 tornado data and for his feedback on preliminary analyses.