AN EXAMINATION OF TORNADO ENVIRONMENTS, EVENTS, AND IMPACTS FROM 2003-2012

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Environments

•Tornado reports are taken from *Storm Data*, with individual county segments being treated as separate reports.
•Environment data is taken from SPC's archived hourly objective analysis system.
•Severe weather reports are placed onto the analysis grid, then the environmental parameters at that grid point (for the hour prior to the report) are assigned as the representative environment.

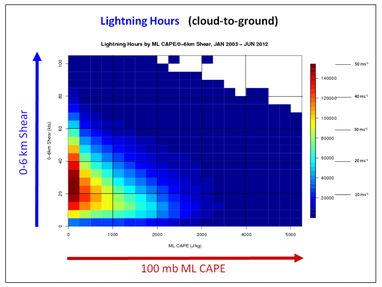

Fig. 1: Lightning hours binned by ML CAPE/0-6km bulk shear, valid from JAN 2003-JUN 2012.

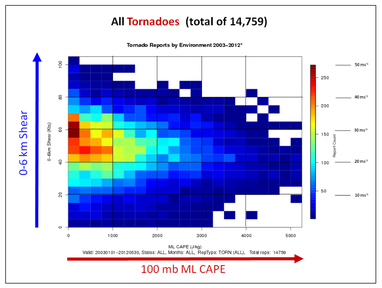

Fig. 2: Tornado counts binned by ML CAPE/0-6km bulk shear, valid from JAN 2003-JUN 2012

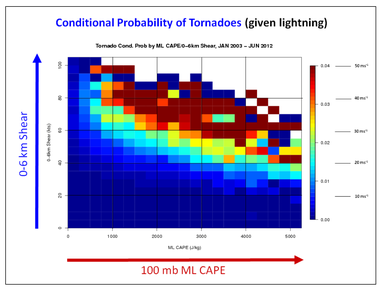

Fig. 3: Conditional probability of tornadoes, given lightning, in ML CAPE/0-6km Shear space

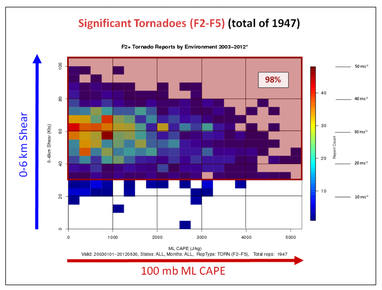

Fig. 4: F2+/EF2+ tornadoes binned by ML CAPE/0-6km shear. 98% of these events occurred with 0-6km shear ≥ 15 m s^{-1}, as indicated by shaded area.

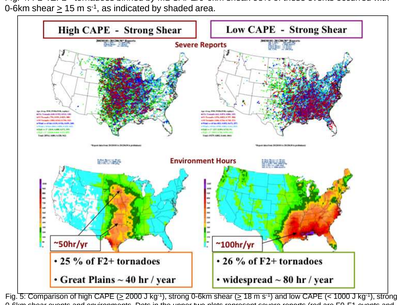

Fig. 5: Comparison of high CAPE (≥ 2000 J kg^{-1}), strong 0-6km shear (≥ 18 m s^{-1}) and low CAPE (< 1000 J kg^{-1}), strong 0-6km shear events and environments. Dots in the upper two plots represent severe reports (red are F0-F1 events and purple are F2+), while color shading in lower plots represent number of hours spent in such an environment.

Events

Tornado Tracks and Population Density

Valid JAN 2003 – JUN 2012

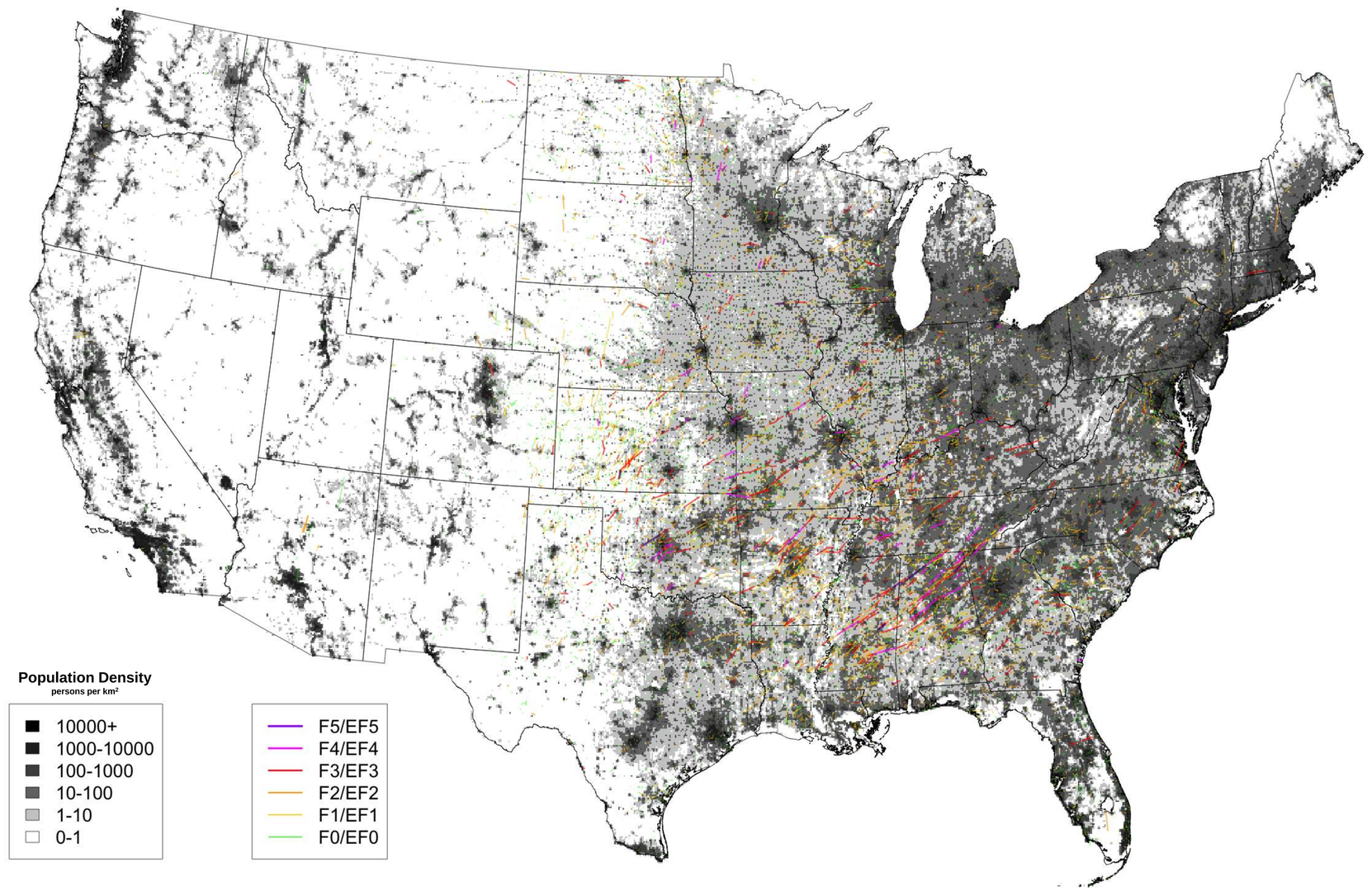

Fig. 8: Tornado tracks and population density, valid JAN 2003 – JUN 2012. Tornado county segments are plotted on this map and color-coded by F-/EF-Scale rating. Population density is on a ~5 km grid.

Tornado Watch Verification

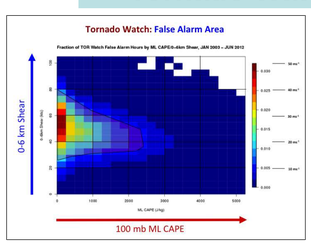

Fig. 6: Fraction of false alarm (FAR) area in Tornado Watches as a function of ML CAPE/0-6km shear. Transparent shading highlights the area where false alarms are most common.

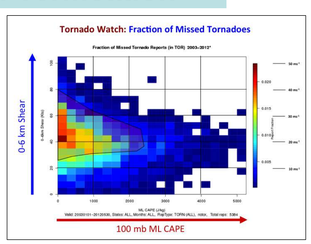

Fig. 7: Fraction of missed tornado events (events not in a Tornado Watch) in ML CAPE/0-6km shear parameter space. Transparent shading shows where most false alarms tend to occur (Fig. 6), which has significant overlap with where missed events tend to occur.

Discussion

•As expected, conditional probability of tornadoes rises with increasing CAPE/Shear. (Fig. 3)
•Most tornadoes occur in low ML CAPE (< 1000 J kg^{-1}), moderate/high 0-6 km shear (>= 15 m s^{-1}) environments (Fig. 2). While the conditional probability (Fig. 3) is relatively low in these environments, thunderstorm frequency (Fig. 1) is much higher, resulting in more events.
•Strong tornadoes are very rare when shear is weak: 98% of F2+ events (Fig. 4) and 99.6% of F3+ events (not shown) have 0-6km bulk shear >= 15 m s^{-1}.
•Low CAPE/strong shear events are more common in the Southeast (Fig. 5), while high CAPE/strong shear events are more common across the Plains, in the traditional "Tornado Alley."
•Over the last 10 years, many tornado fatalities have occurred in low CAPE environments (Fig. 13), where the conditional probability is relatively low and forecasting can be a challenge in terms of both POD and FAR (Figs. 6 and 7).
•Similar-sized outbreaks in areas with vastly different population density can result in very different outcomes with respect to tornado-related injuries and fatalities (Fig. 10).
•A very large tornado outbreak over a relatively dense populated area (as on 27 April 2011) can result in a catastrophe, but so can a more isolated violent tornado event occurring in a densely populated area of a town, as in Joplin, MO on 22 May 2011 (Figs. 11 and 13).

Challenges

•Low CAPE/high shear events pose a difficult challenge in terms of both POD and FAR. These events tend to be more common in the eastern U.S., where population density and resulting aggregate risk to life and property is generally higher. How can forecast performance be improved for these types of events?

•Major tornado outbreaks still claim many lives. From a forecast perspective, what can be done in advance of these events to raise awareness and minimize the impact?

Impacts

•Population data is derived from the 2010 Census at the census block level.
•Population density calculated on 5km NDFD grid.
•F3+/EF3+ path length was used to rank outbreak days.
•Shaded outbreak areas below are defined by the 10% contour of the "practically perfect" F2+ tornado coverage, which is designed to encompass an area where coverage of events was relatively high.

Tornado Outbreaks (2003-2012)

Date	F3+ PL	∑ Pop.	> 10 km^{-2}	> 100 km^{-2}	Deaths	Injuries
27 Apr 2011	1694 km	49,680,374	44.7%	8.0%	313	2753
4 May 2003	563 km	14,589,932	28.4%	3.8%	38	346
5 Feb 2008	411 km	19,204,988	36.7%	4.9%	57	425
2 Mar 2012	378 km	28,102,835	49.4%	8.2%	40	309
12 Mar 2006	309 km	10,013,368	22.5%	3.7%	8	163
2 Apr 2006	307 km	14,687,696	26.9%	4.1%	27	348
24 May 2011	287 km	7,212,195	18.4%	2.9%	18	375
24 Apr 2010	267 km	7,954,992	35.3%	4.8%	10	199
16 Apr 2011	230 km	17,686,983	48.3%	9.6%	26	480
14 Apr 2012	223 km	5,288,056	6.0%	1.4%	6	73

Top 10 Outbreaks Ranked by summed F3+ Path Length

Fig. 9: Table showing top 10 tornado outbreaks from 2003-2012 ranked by path length (PL) of F3+/EF3+ tornadoes. Population numbers are calculated inside of the 10% "practically perfect" contour for F2+/EF2+ events on the given day. Percent values indicate the percent area affected by the outbreak with population density of 10 km^{-2} and 100 km^{-2}.

Outbreaks: 14 Apr. 2012 vs. 16 Apr. 2011

Date	F3+ PL	∑ Pop.	> 10 km^{-2}	> 100 km^{-2}	Deaths	Injuries
14 Apr 2012	223 km	5,288,056	6.0%	1.4%	6	73
16 Apr 2011	230 km	17,686,983	48.3%	9.6%	26	480

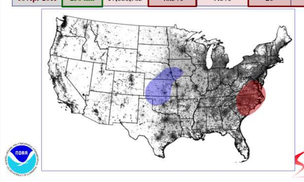

Fig. 10: Comparsion of 14 April 2012 (blue) and 16 April 2011 (red) outbreaks. Grey shading indicates population density using the same scale as Fig. 8 (large center map). The table shows the same information as seen in Fig. 9.

Outbreaks: 22 May 2011 vs. 27 Apr. 2011

Date	F3+ PL	∑ Pop.	> 10 km^{-2}	> 100 km^{-2}	Deaths	Injuries
22 May 2011	43 km	10,883,176	26.3%	4.3%	159	1218
27 Apr 2011	1694 km	49,680,374	44.7%	8.0%	313	2753

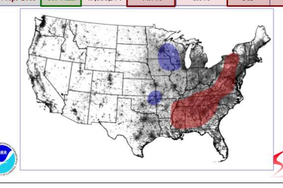

Fig. 11: Comparsion of 22 May 2011 (blue, including EF5 in Joplin, Mo) and 27 April 2011 (red) outbreaks. Grey shading indicates population density using the same scale as Fig. 8. The table shows the same information as seen in Fig. 9.

Tornado Deaths: Top 20 Outbreaks (611 or 56.3%)

Top 20 Outbreaks Ranked by summed F3+ Path Length

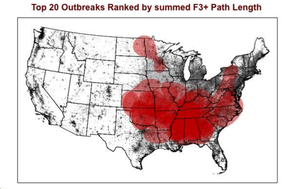

Fig. 12: Overlay of top 20 tornado outbreaks ranked by F3+/EF3+ tornado path length. Shaded regions indicate area encompassing events of F2/EF2 or greater on these days. Darker shading indicates areas affected by multiple outbreaks.

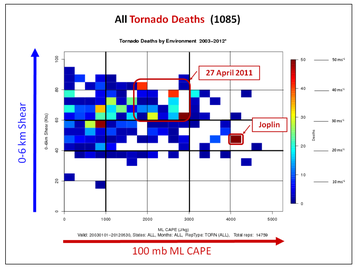

Fig. 13: Tornado deaths in ML CAPE/0-6km shear parameter space, valid from JAN 2003 – JUN 2012. The single bin indicating the Joplin event is outlined, as is the representative part of the parameter space from 27 April 2011 (though the outlined area does not contain all fatalities from that day). Note that many fatalities have occurred in the low CAPE (< 1000 J kg^{-1}) part of the parameter space.