Online Damage Report

The 2015 Christmas Tornado Outbreak

View from Rockwall, TX looking towards the I30/I-90 interchange as a strong tornado passes over (via Todd Ward)

University of Florida's Wind Hazard Damage Assessment Team
http://windhazard.davidoprevatt.com/

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29 December 2015

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Wind Hazard Damage Assessment Team
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Executive Summary

2015 has been a reasonably active year for tornadoes but as of mid-December tornado-related fatalities was extremely low, at only 10 deaths - five less fatalities than the record low 1986 yearly total. All that changed in this past week that saw 38 tornadoes, 47 weather-related fatalities and 2,000 damaged or destroyed structures spread over five states. This report by University of Florida's Wind Hazard Damage Assessment Team remains focused on ascribing causes and effects for structural damage and deaths due to tornadoes. Our thoughts go to the communities and families directly affected by these tornadoes, for whom sadly the Christmas holidays may never be quite the same.

The structural damage from an engineering perspective was not unexpected, with the vast majority of damage occurring to single-family residences, structures that are nominally designed for wind load magnitudes just a quarter to one-third as strong as any tornado. We see the same structural deficiencies known to be vulnerable in high winds and the resulting damage patterns are similar. The demographics of community buildings are also the same, and the profound sense of loss remains. The disasters beg the question have we done enough to protect our communities?

The tornado damage from this tornado outbreak could have been much worse. Had the Texas tornado outbreak shifted two to three miles to the west, it would have affected more densely populated communities rather than passing as it did mainly over Lake Ray Hubbard and the outskirts of the towns. And, although two Mississippi tornadoes were on the ground for nearly 150 miles combined, they fortunately traversed over a sparsely populated region with few small towns and so damage was limited.

As engineers we understand that the 23-27 December 2015 tornado damage is the product of both the strength of the hazard (the tornado) and the vulnerability of the buildings. It is clear that, barring some future scientific invention or unforeseen influences of climate change, hazard risk from tornadoes will not be reduced. However, the structural vulnerability can be mitigated by building stronger, retrofitting existing homes and by providing more protection for occupants. Therefore, communities confront an economic decision to determine the acceptable level of engineering for protecting life and property, and all communities make that choice, whether implicitly by accepting the status quo or explicitly by adopting tornado-resilient building practices.

Without a doubt, more buildings and urbanization is increasing the tornado vulnerability of communities, by enlarging the size of potential tornado "targets". Indeed, had the Garland/Rowlett tornado occurred 30 years ago, only 876 homes would have been within the damage path as opposed to the 2250 homes in 2015. But more importantly, continuing to build future communities in accordance to existing building codes that lack tornado-resilient provisions for stronger buildings will exacerbate the damages. The cost to retrofit structures for tornado-resilience is much more than the cost of building tornado-resilient structures in the first place, so putting off the decision to strengthen our communities now guarantees high costs later – either through future tornado damage or costs of retrofitting.

How much longer is it prudent for us to continue playing this game of chance with tornadoes? We have better knowledge of the tornado strengths and distribution of wind speeds (Lombardo et al, 2015), and our studies show that much of the damage is not inevitable (Prevatt et al, 2012), buildings can be made to resist the forces at reasonable costs, as is the case for hurricane-resistant structures in Florida (Gurley and Masters, 2011). Engineers will need to lend voice along with other community leaders to advocate for more resilient residential infrastructure. Investing in better infrastructure now will save money by reducing the level of rebuilding, repairing, and debris removal otherwise needed after the next tornado (Simmons et al, 2015).

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About the Wind Hazard Damage Assessment Team

This report was prepared from online sources by University of Florida civil engineering students in Prof. David O. Prevatt's Research Group. The study is done in parallel to our experimental research seeking to understand and quantify the strength of tornadoes and their impact on vulnerable wood-framed residential structures. Compilation of this information is part of student learning objectives in forensic engineering and post-disaster damage investigation.

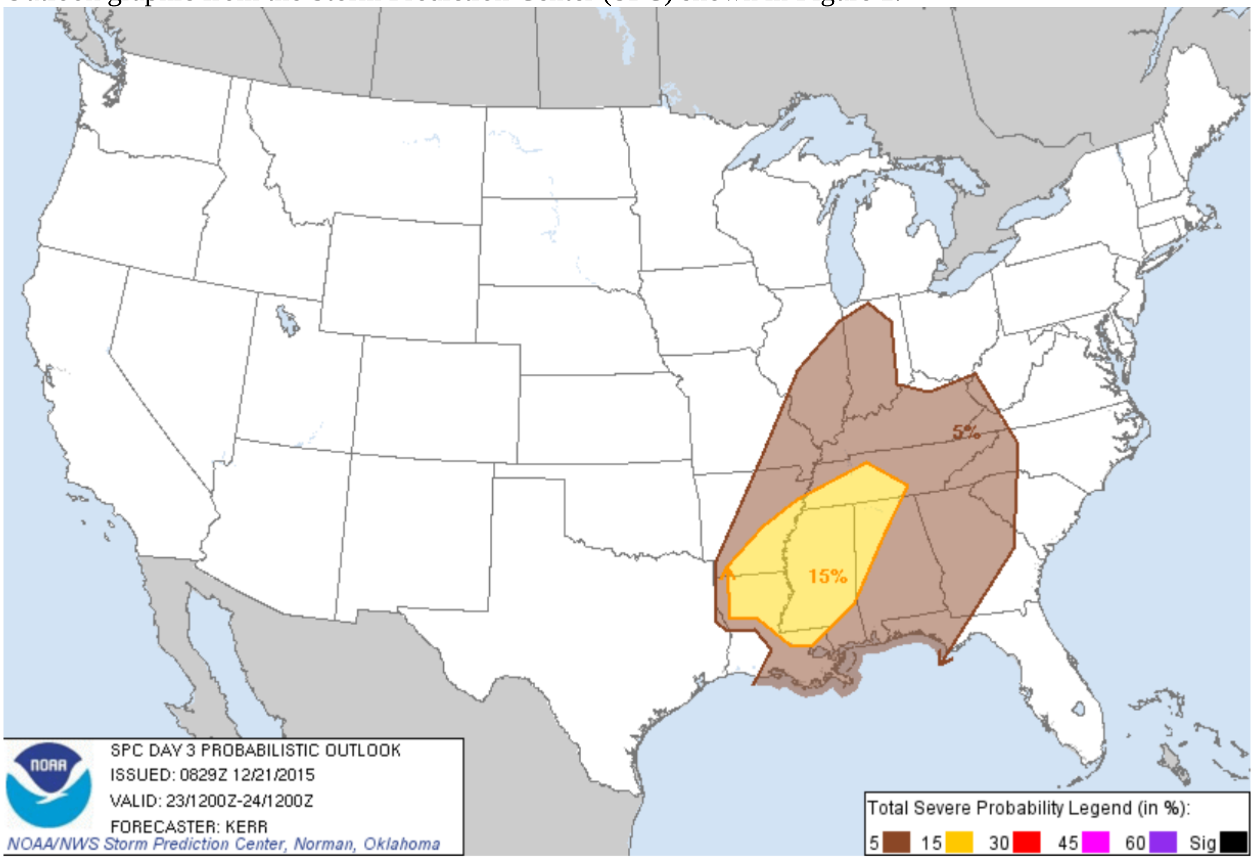
The students gathered the information from reliable online sources, such as the National Weather Service, Accuweather, the US Census Bureau and the national media. Photographs were also obtained from publicly available Twitter feeds.

Please visit our website, http://windhazard.davidoprevatt.com, for additional information, and to download previous damage reports, and filed survey results conducted by our group. Dr. Prevatt and his colleagues have published several papers on recent violent tornadoes that struck Tuscaloosa, AL, Joplin, MO, and Moore, OK. His group has also inspected damaged structures and compiled reports on tornadoes that occur in Florida. Information is also available on the research at www.davidoprevatt.com. Your questions and comments on any aspects of our work are most welcome. Please direct your enquiries to PhD Graduate Student, Mr. David B. Roueche, NSF GRFP Fellow, who can be reached at david.roueche@ufl.edu. The Group is seeking to a Webmaster to manage the website and Recruitment Leader for the upcoming year. Interested UF students (in any field) should contact Dr. Prevatt.

The Wind Hazard Damage Assessment Team was created through support from the NSF Award #1150975. *Its mission is to train university students interested in building construction, engineering and architecture in the forensic engineering and techniques for post-hazard damage surveys and data collection. The team has surveyed damage after several Florida tornadoes and continuously monitors the prevalence of tornadoes worldwide. Ultimately the Damage Assessment Team hopes to inspire upcoming engineers and building professionals in hopes to change the paradigm of widespread catastrophic damage to houses in tornadoes and other extreme wind events.*

FORECASTS AND PREDICTIONS FOR SEVERE WEATHER

The unusually warm weather across the Eastern US this winter led to conditions being favorable for severe weather, including tornadoes, during 23-24 December 2015. The NWS noted as early as 20 December 2015 that the models were suggesting the potential for severe weather, as indicated by the Day 3 Convective Outlook graphic from the Storm Prediction Center (SPC) shown in Figure 1.



Probability of severe weather within 25 miles of a point.
Hatched Area: 10% or greater probability of significant severe within 25 miles of a point.

Day 3 Prob. Risk	Area (sq. mi.)	Area Pop.	Some Larger Population Centers in Risk Area
15 %	102,460	7,007,292	Memphis, TN...Jackson, MS...Huntsville, AL...Tuscaloosa, AL...Jackson, TN...
5 %	306,386	38,524,283	Indianapolis, IN...Nashville, TN...New Orleans, LA...Atlanta, GA...St. Louis, MO...

Figure 1: Day 3 convective outlook as issued by the NWS on 20 December 2015.

As the days approached, confidence in the predictions increased, with the NWS even issuing a Particularly Dangerous Situation (PDS) tornado watch at 11:55 AM CST, indicating that long-lived, intense tornadoes were likely. This was only the second time in the last ten years that a PDS was issued in December, and the first time in 2015. Forecasts for the 24-26 of December continued to show potential for tornadoes to occur, as a new storm system moved through from west to east.

TIMING OF OUTBREAK

The first tornado watch was issued on 23 December 2015 at 12:05 AM CST for SW Arkansas, NW Louisiana, SE Oklahoma, and E Texas until 7:00 AM Central Standard Time (http://1.usa.gov/1Pv77vk). The PDS issued at 11:55 AM CST was effective until 8:00 PM CST for portions of Arkansas, Louisiana, Mississippi and Tennessee. The first tornado warning on the 23rd was issued at 10:15 AM CST, when radar indicated a tornado was on the ground near Ellsinore, MO. A total of 175 tornado warnings were issued between the 23rd and 27th of December, each of which is shown in Figure 2.

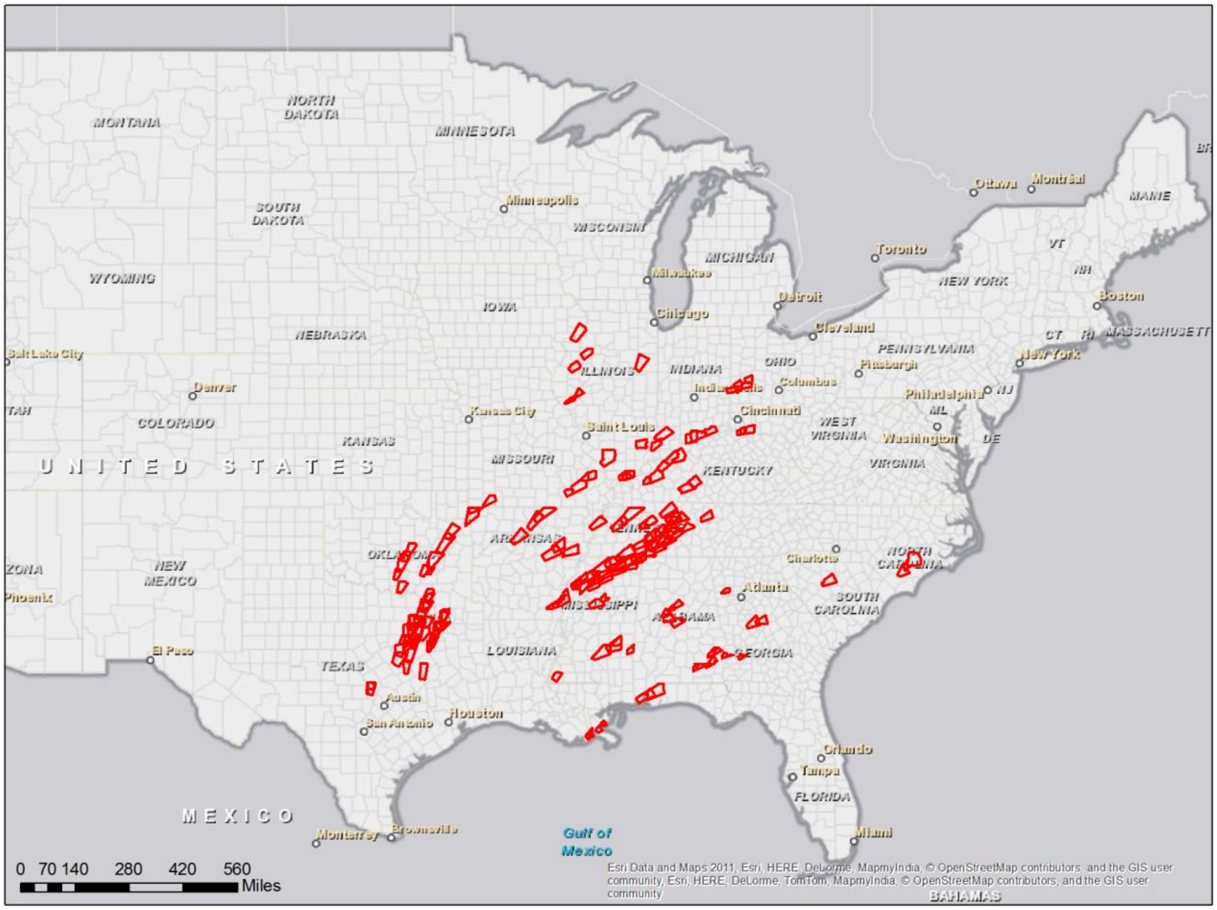


Figure 2: All tornado warnings issued by NWS offices on 23-27 December 2015.

SUMMARY OF DAMAGE

At the time of this report, there have been 87 tornado reports representing at least 38 confirmed tornadoes. The location of the tornado reports relative to the NWS identified area of greatest tornado risk is provided in Figure 3 and Figure 4 for the 23rd and 26th of December. A summary of the most significant impacts is provided in

Table 1.

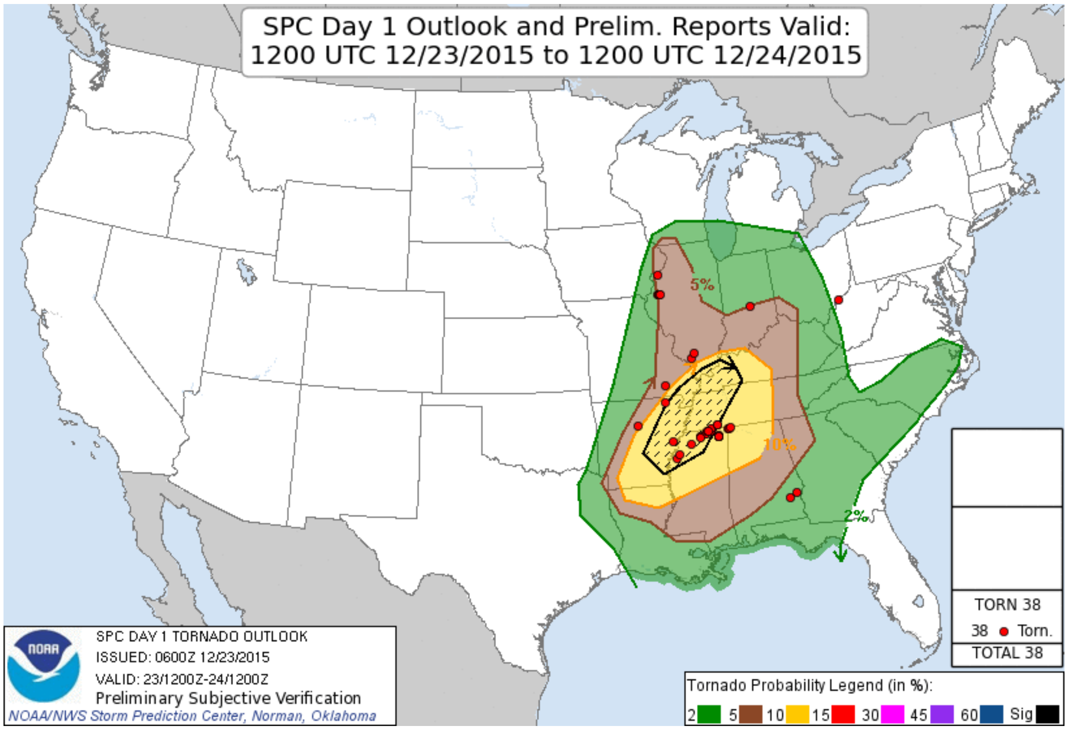


Figure 3: SPC Tornado Outlook as issued at 6 AM CST for 12/23/2015 with unfiltered tornado reports overlaid

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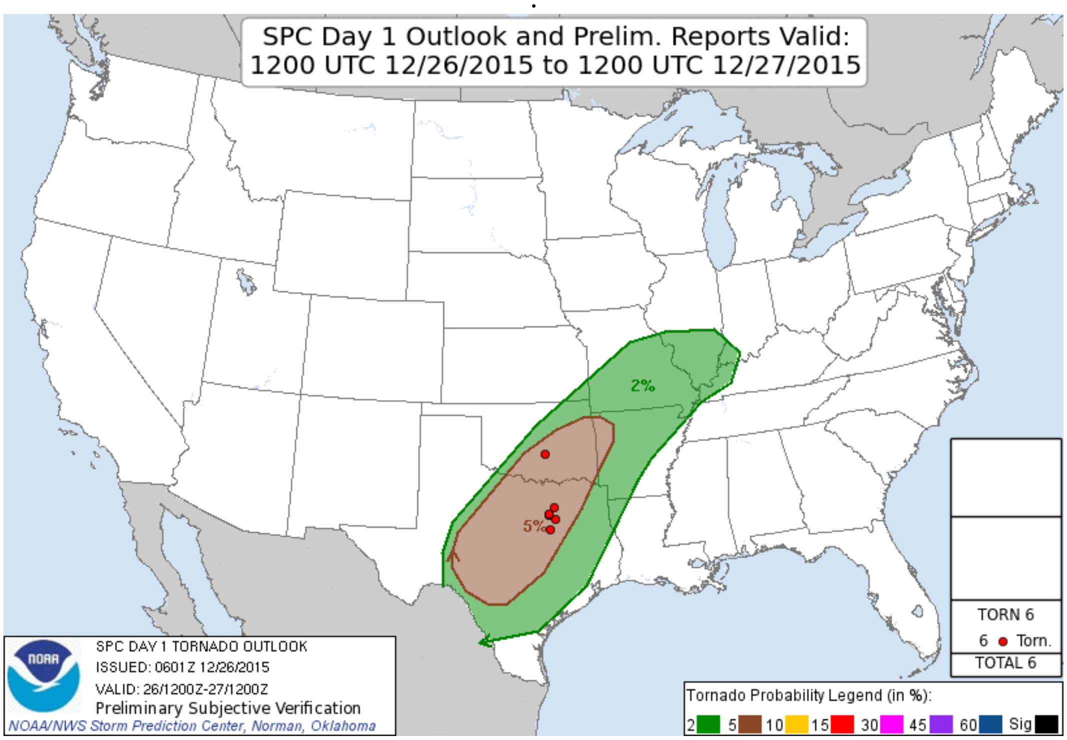

Figure 4: SPC Tornado Outlook as issued at 6 AM CST for 12/26/2015 with unfiltered tornado reports overlaid

Table 1: Summary of Impacts from Tornado Outbreak

23 DECEMBER 2015						
Town/City	**County**	**State**	**Population**	**Number of Homes**	**Impacted Buildings**	**Fatalities**
Clarksdale	Coahoma	MS	17,962	7,214	16 [1]	0
Como	Panola	MS	1310	506	9 [1]	0
Holly Springs	Marshall	MS	7,699	2,636	183 [1]	2
Ashland	Benton	MS	569	239	57 [1]	4
-	Quitman	MS	8,223	3,597	29 [1]	0
-	Tippah	MS	22,232	9,718	139 [1]	1
Selmer	McNairy	TN	4,513	2,205	15 [2]	0
Linden	Perry	TN	908	491	5+[3]	2
Lutts	Wayne	TN	17,021	7272	N/A	0
-	Perry	IL	22,350	9,439	10 [4]	0
Waterloo	Lauderdale	AL	203	95	6 [5]	0
25 DECEMBER 2015						
Town/City	**County**	**State**	**Population**	**Housing Units**	**Impacted Buildings**	**Fatalities**
Birmingham	Jefferson	AL	212,237	111,233	72[6]	0
26 DECEMBER 2015						
Town/City	**County**	**State**	**Population**	**Number of Homes**	**Impacted Buildings**	**Fatalities**
Garland	Dallas	TX	226,876	80,168	600[7]	8
Rowlett	Dallas/Rockwall	TX	56,199	19,203	600[7]	0
Ovilla/Glen Heights	Ellis	TX	149,610 (county)	55,628	100[7]	0
-	Collin	TX	782,341	313,254	91[8]	3

[1] http://www.msema.org/two-additional-deaths-storm-damage-reported-to-mema/
[2]http://www.jacksonsun.com/story/news/local/2015/12/24/community-begins-cleanup-selmer/77887266/
[3]http://valleywx.com/2015/12/24/nws-nashville-ef-3-tornado-touched-down-in-wayne-county-wednesday-night/
[4] https://nwschat.weather.gov/p.php?pid=201512242331-KPAH-NOUS43-PNSPAH
[5] https://nwschat.weather.gov/p.php?pid=201512242242-KHUN-NOUS44-PNSHUN
[6] http://www.wbrc.com/story/30836573/preliminary-field-damage-assessment-reveals-72-structures-damaged-by-birmingham-tornado
[7]http://fremonttribune.com/news/national/the-latest-officials-say-homes-damaged-in-dallas-suburb/article_920d2e25-2c3e-59b0-9c60-1ebaae807f28.html
[8]http://www.nbcdfw.com/news/local/Tornadoes-Leave-3-Dead-in-Collin-County-363612181.html?partner=nbcnews

23 December 2015 Damage Summary

Much of the damages and fatalities on the 23rd of December were caused by an intense tornado that tracked an estimated 150 miles through Mississippi into Tennessee. At the time of this report, NWS Memphis is estimating that the long-track damage path consisted of two separate tornadoes, an EF4 that tracked for 73 miles and an EF3 that tracked for 63 miles. The original estimated tornado path in relation to the reported fatalities and other nearby tornadoes is provided in Figure 5.

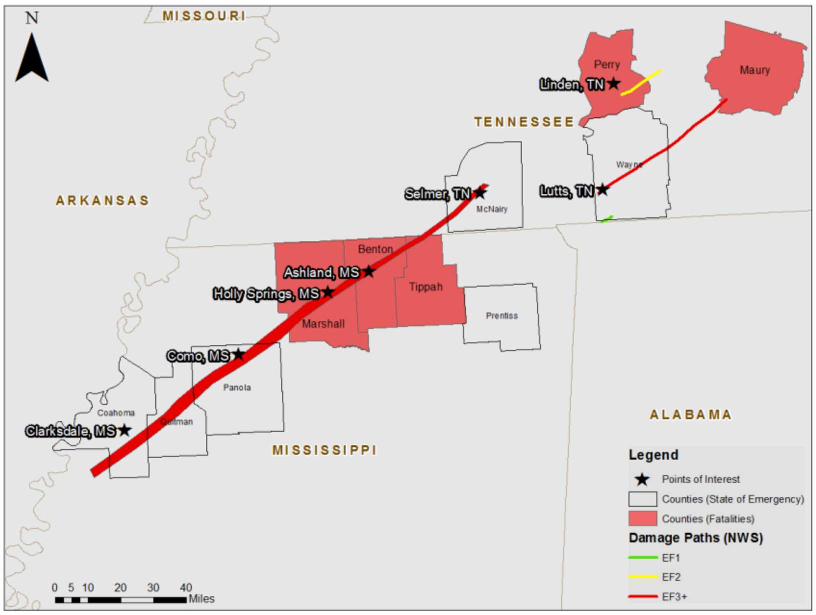

Figure 5: Damage path of long-track tornadoes that combined had an estimated path length of 150 miles and maximum path width of ¾ mile. Counties which were declared as being in a state of emergency are shown in black outline. Counties with fatalities are filled red. Map was generated using data from the National Weather Service. On the following pages, a few illustrative photos of the damage are provided.

Figure 6: A home in Jumperstown, MS (~5 miles East of Ashland, MS) that was lifted and spun around off its foundation before resettling to the ground (Twitter.com). Note the complete lack of positive anchorage to a foundation necessary to resist the strong uplift pressures caused by the tornado.

Figure 7: The remnants of a home in Perry County, TN where two fatalities occurred (WSMV). The home appears to have been supported on CMU block piers, with no real uplift capacity.

Figure 8: The Post Office in Lutts, TN in Wayne County destroyed by the tornado (WKRN).

Figure 9: The remnants of a destroyed home between Sardis and Como, MS, with another severely damaged home in the distance. Source: Noah Donahou via Twitter.

In general, the damage is unfortunately as expected for these regions of the country. Wind-resistant building codes are not in effect in these counties and as a result most homes are highly vulnerable to the winds of a tornado, even the EF0 to EF2 wind speeds (up to 135 mph). The continued use of toe-nail connections to fasten the roof to the exterior walls makes the roofs highly susceptible to blowing off during a tornado. The lack of lateral support for the walls means there is little capacity to resist the wind loads once the roof has been removed. When walls collapse, the residents are exposed to even more danger with the falling objects and wind-borne debris, increasing the risk of injury and even death.

25 December 2015 Damage Summary

Four tornadoes were confirmed by the National Weather Service on Christmas Day, including two in Alabama, one in Mississippi, and one in Tennessee. An EF2 (maximum winds speeds of 135 mph) tornado struck Birmingham, AL in the Brownville area. One residential structure was completely destroyed with a church and several industrial buildings also suffering damage. All other damage was minor as the tornado was only on the ground for less than a mile. The other three tornadoes on Christmas Day were all EF1 (maximum wind speeds of 110 mph) or less.

Figure 10: EF2 damage in Birmingham, AL where the exterior walls of a residential structure collapsed (NWS).

26 December 2015 Damage Summary

The National Weather Service has confirmed 9 tornadoes on 26 December 2015, although surveys are still pending. The NWS Fort Worth office posted the summary graphic shown in to their Twitter page. The heaviest damage was due to an EF4 tornado that tracked 13 miles through Garland and Rowlett, just northeast of Dallas, TX. This tornado impacted dense residential areas, damaging or destroying over 1200 homes. A closer view of the estimated damage path is provided in Figure 13. Thankfully only 65% of the estimated damage path was over land. If the path had been shifted to the left by 2-3 miles, the damage could have been far worse. However, using the damage path estimated by the NWS survey and Dallas County parcel data, if the tornado had occurred 30 years ago, only 876 homes would have been exposed to the tornado as opposed to the 2,250 that were exposed in 2015 (Figure 12).

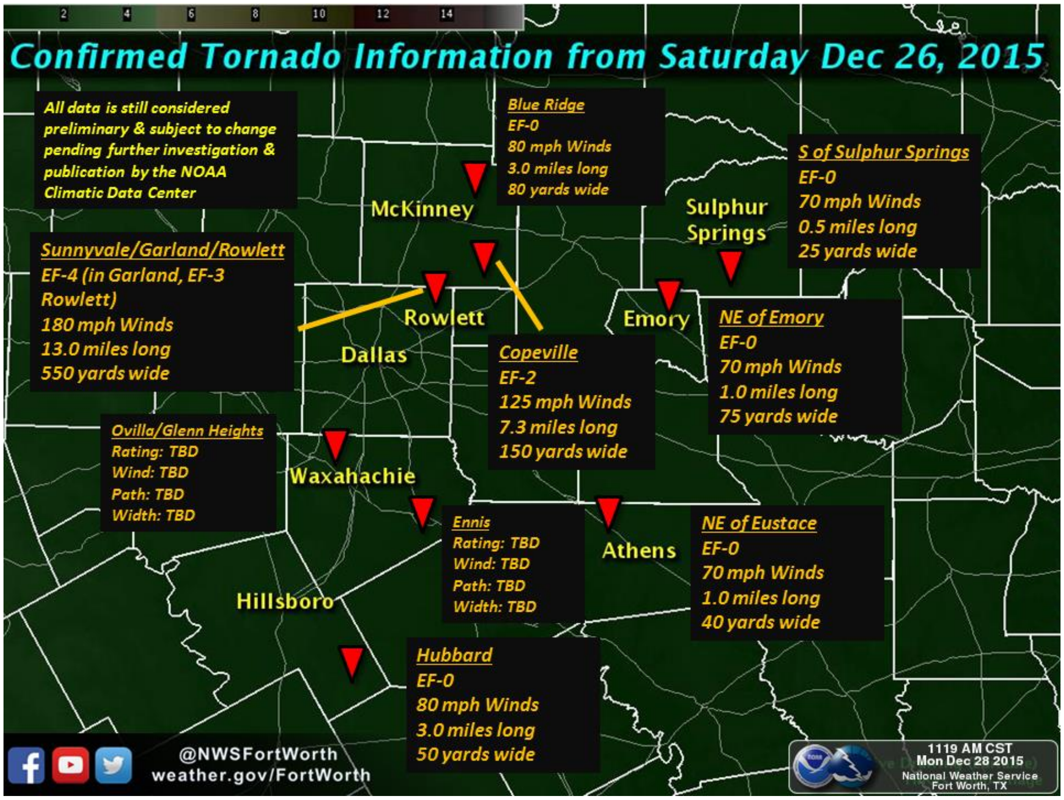

Figure 11: Summary of the 9 confirmed tornadoes in North Texas as of 28 December 2015.

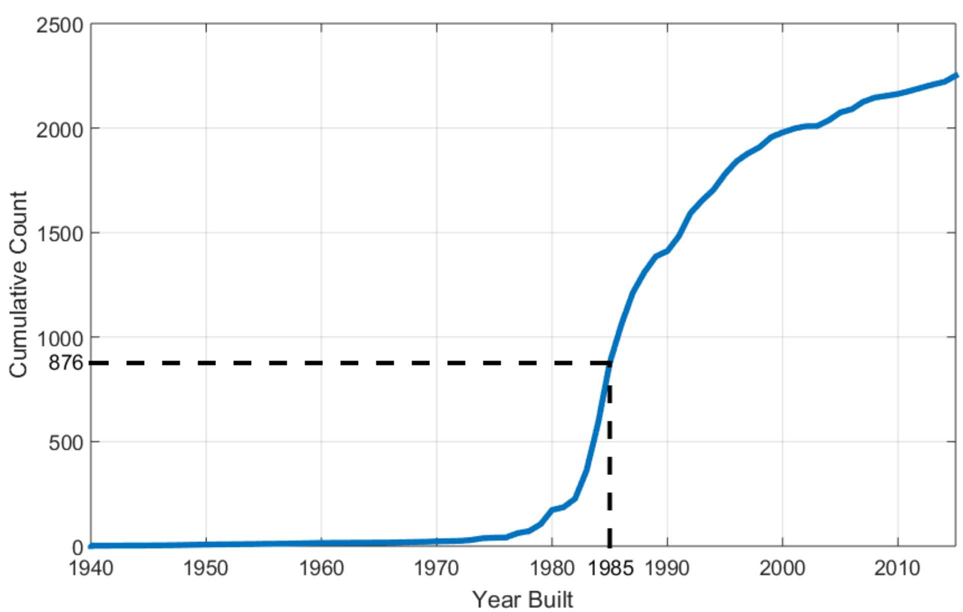

Figure 12: Distribution of the year built for homes in the damage path estimated by the NWS survey.

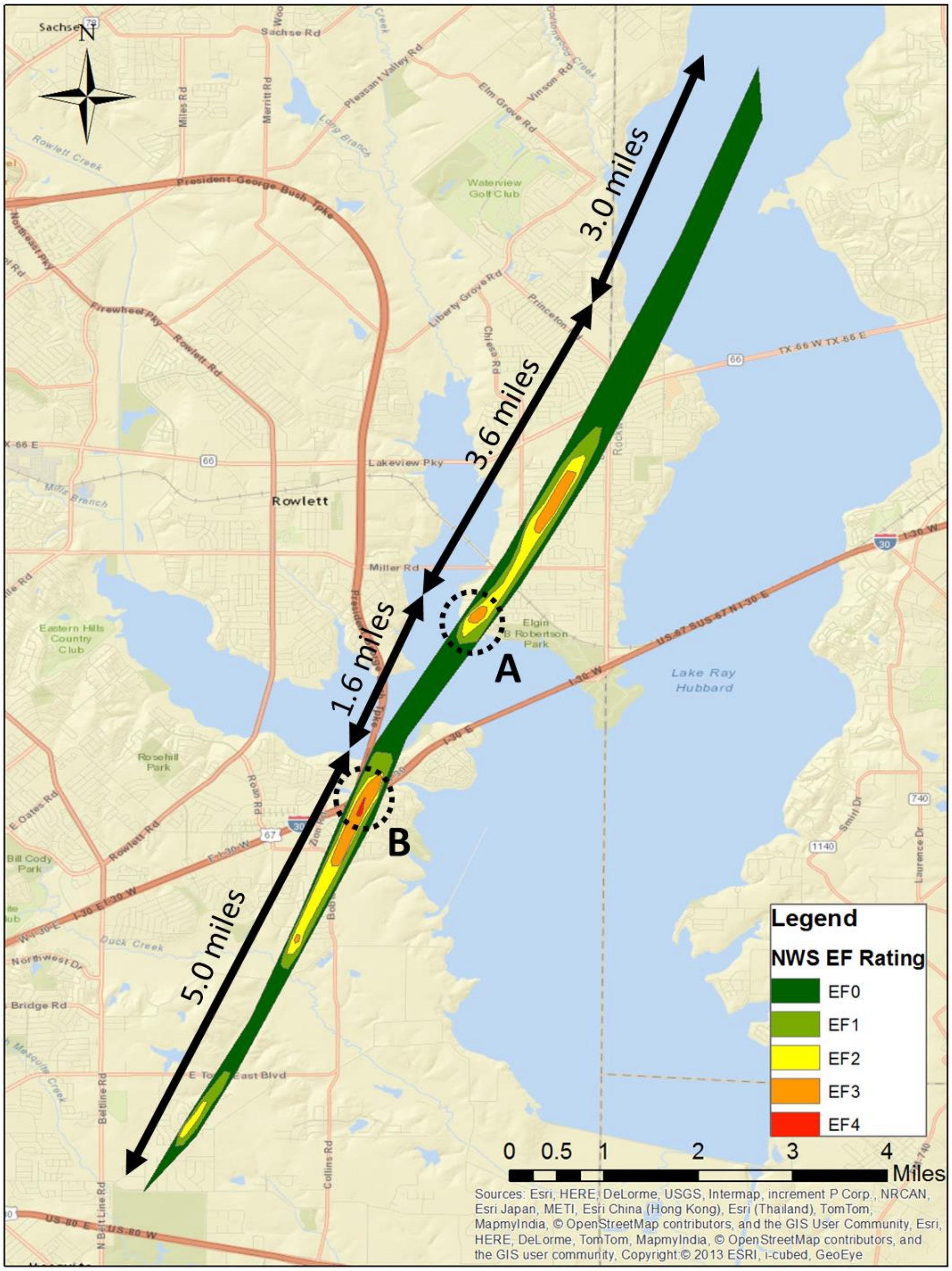

Figure 13: Damage path of EF4 tornado that passed through the cities of Garland, TX and Rowlett, TX. Region A is the general area shown in Figure 14 and Region B is the location of the 8 fatalities at the I-30/I-90 interchange. EF-Scale contours are from the preliminary NWS survey.

A few illustrative photos of the damage are provided in Figure 14 and Figure 15.

Figure 14: After (top, via WFAA) and before (bottom, via Google Streetview) view of Windjammer Way in Rowlett, TX. Location and orientation of the "observer" is indicated by red arrowhead in top photo.

Figure 15: View of the I-30/I-90 exchange overpass where five fatalities occurred in vehicles.

FATALITIES

At the time of this report there have been 24 confirmed fatalities related to tornadoes or high winds between 23rd and 27th of December 2015. The fatalities are summarized as follows:

Table 2: Summary of all wind-related fatalities during the 23-27 December 2015 tornado outbreak

Date	County	State	Event Type	Fatalities	Location of Fatalities
12/23/2015	Pope	AR	Severe T-storm	1	Home
12/23/2015	Benton	MS	Tornado	6	Home (3), Vehicle (3)
12/23/2015	Coahoma	MS	Tornado	1	Mobile Home
12/23/2015	Tippah	MS	Tornado	1	Mobile Home
12/23/2015	Marshall	MS	Tornado	2	n/a
12/23/2015	Perry	TN	Tornado	2	Home
12/26/2015	Dallas	TX	Tornado	8	Vehicle
12/26/2015	Collin	TX	Tornado	3	Gas Station (2), Vehicle (1)

Based on the information available at the time of this report, the chart in Figure 16 summarizes locations at which the reported tornado-related fatalities occurred.

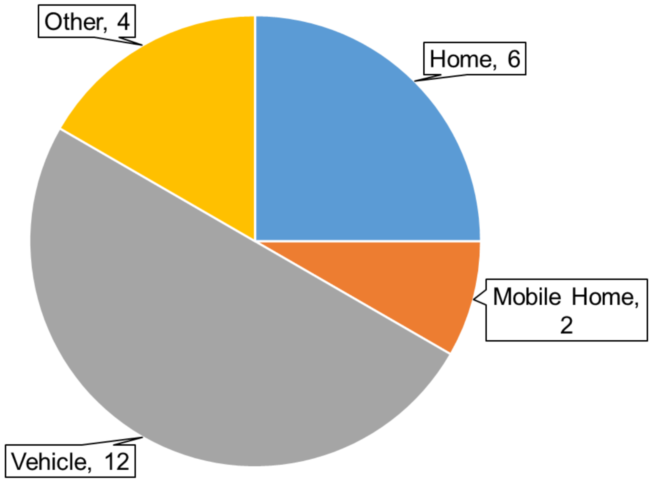

Figure 16: Number of wind-related fatalities by reported location.

Prior to 23 December, there were only 10 tornado-related fatalities confirmed in 2015, which would have been the lowest count on record (1940 – current), beating the previous record of 15 fatalities in 1986. With the recent tornado outbreak however, the number of tornado fatalities in 2015 has risen to at least 34, tied for the 12th lowest year. The number of tornado fatalities per year is shown in Figure 17. The preliminary count of 34 tornado-related fatalities in December 2015 is highest since 1953, the year of the deadly Vicksburg, MS tornado that claimed 38 lives (NWS Jackson, MS).

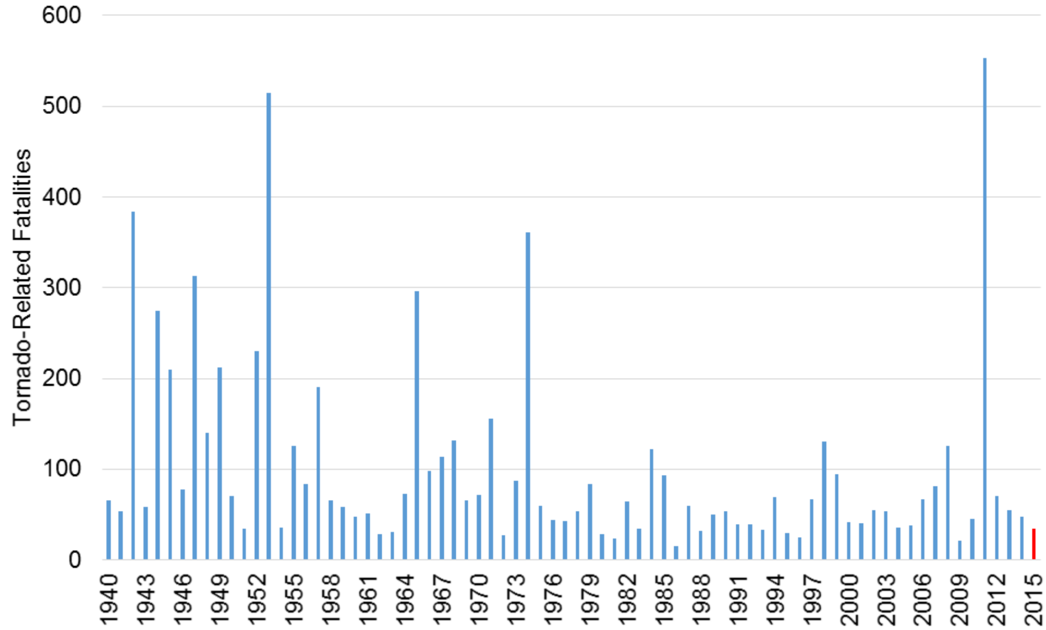

Figure 17: Tornado fatalities by year since 1940. Data obtained from NWS records (nws.noaa.gov). Count for 2015 is preliminary and is shown in red.

CLIMATOLOGY

Tornado outbreaks in December are not uncommon, as described by former American Meteorology Society (AMS) President Marshall Shepherd in a recent news article (Forbes.com/Science). While December on average sees the fewest tornadoes each month, El Nino years tend to increase the chances for tornado outbreaks, with two of the largest December outbreaks, 1957 and 1982, occurring during strong El Nino years. While tornadoes themselves are not uncommon in December, the path lengths of 63 and 73 miles recorded in Mississippi and Tennessee, are the 5th and 6th longest tornadoes ever reported in the US in December, and the 15th and 18th longest tornadoes ever reported in Mississippi at any time of the year (the record being a 198 mile tornado in 1971), since records began in 1950.

SCOURED PAVEMENT NEAR ASHLAND, MS

The long-track tornado that struck Mississippi is reported to have severely scoured sections of pavement near Ashland, MS in Benton County.

Source: https://twitter.com/deanowx/status/679861516376649729/photo/1

Source: https://twitter.com/NWSMemphis/status/680139241997729792/photo/1

Figure 18: Scoured pavement on Lamar Rd near Ashland, MS

Preliminary analysis indicates the scoured pavement was located just past a completely destroyed home at 2643 Lamar Rd in Ashland, MS, as shown in Figure 19. The NWS survey team posted the following picture of the home at this location (Figure 20), showing a slab almost swept clean. No structural details of the home are available at this time, but as the home was built in 1970 (Zillow.com), it would not be expected to have wind-resistant construction. Using the EF-Scale for a One- and Two-Family Residence, the Degree of Damage would be 9 ("All walls collapsed"), which has an expected wind speed of 170 mph and a lower bound wind speed of 142 mph, meaning the wind speeds necessary to cause this damage would be at least 142 mph.

Figure 19: Approximate stretch of road on which the scoured pavement was observed. The destroyed home is shown in Figure 20.

Figure 20: Destroyed home off Lamar Rd near Ashland, MS. Photograph via the NWS damage survey (http://services.dat.noaa.gov/arcgis/rest/services/DamageAssessmentToolkit/DamageFlexViewer/FeatureServer/0/876818/attachments/535328).

Noda et al (2013) performed an analysis of peeled pavement caused by a tornado in the northern Kanto region of Japan and estimated that the wind speeds required to lift asphalt pavement in reasonably good condition would be at least 165 mph (74 m/s). This agrees relatively well with the 170 mph wind speeds expected to have caused the damage to the home in the same area. A more thorough investigation would be necessary to verify these estimates however.

Acknowledgements

The authors gratefully acknowledge the National Science Foundation for the financial support of this study under research grant 1150975. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

About the PI

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Engineering, Vol. 139, No. 2, February 1, 2013. ©ASCE, ISSN 0733-9445/2013/2-251–263. Appendix