Online Damage Report

# The 25 September 2015 Johns Island Tornado

Courtesy of the Charleston County Government
(https://www.youtube.com/watch?v=HVsn49XLVgQ&feature=youtu.be)

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

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28 September 2015

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## Executive Summary

An isolated tornado occurred on 25 September 2015 on Johns Island, Charleston County, SC, and the resulting damage presents interesting evidence of the influence of building construction quality on the performance of residential homes in tornadoes. This rare late night tornado – it was recorded at 12:38 AM – completely destroyed one single-family wood-framed house within a suburb, while all surrounding homes received only minor damage and roofing loss. Preliminary evidence discounts the theory that the tornado was so narrow that it missed the surrounding homes or that it skipped over the undamaged homes. A more plausible explanation is that the destroyed home which was built in accordance to the 1995 CABO Building code, was more vulnerable to wind damage that the neighboring houses that were constructed more recently following IRC's post-2000 residential building code. It is reasonable to expect that a few of the surrounding buildings experienced similar wind loading as did the destroyed one. However, the newer construction likely incorporated better engineering features that resulted in less damage. The savings (as prevented losses) to the community from this is invaluable, and may be attributable to the enhancements in the building code.

The National Weather Service rated the Johns Island tornado as an EF2. It was about 7 miles long and ½ mile wide – much larger and longer than are typical-sized EF2 tornadoes in South Carolina. However, less than 80 structures were damaged, and only one house completely destroyed. The thousands of downed trees identified the tornado's path. The affected area of Johns Island is a lightly populated coastal region, located in Charleston County, and the buildings may have benefited from hurricane-resistant construction, which limited the damage, preventing more catastrophic building failures. The 1989 Hurricane Hugo is a living memory for many of Johns Island's current residents and the design wind speed for the buildings is 145 mph for Risk Category II structures based upon ASCE 7-10 Minimum Design Loads for Buildings and Other Structures.

We contend that if communities in other parts of the country were built to wind-resistant standards, it would be more common to see limited damage like this despite direct impacts of up to EF2 tornadoes, as was likely the case here.

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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 the Johns Island Tornado**

There was no expectation for tornadoes in the Charleston, SC area on the 25 September 2015. The Storm Prediction Center's (SPC) 9:00 pm 9/24/2015 convective outlook indicated less than 2% probability of tornadoes throughout the US, while mentioning that "a few thunderstorms may occur tonight…in the southern Atlantic seaboard where…moderate instability may develop." This indeed proved to be the case, as a supercell formed within a convective band that moved ashore in the early morning hours of September 25th. The local Charleston, SC National Weather Service (NWS) office posted the following explanation of the atmospheric conditions that led to the tornado on their Twitter account after the event.

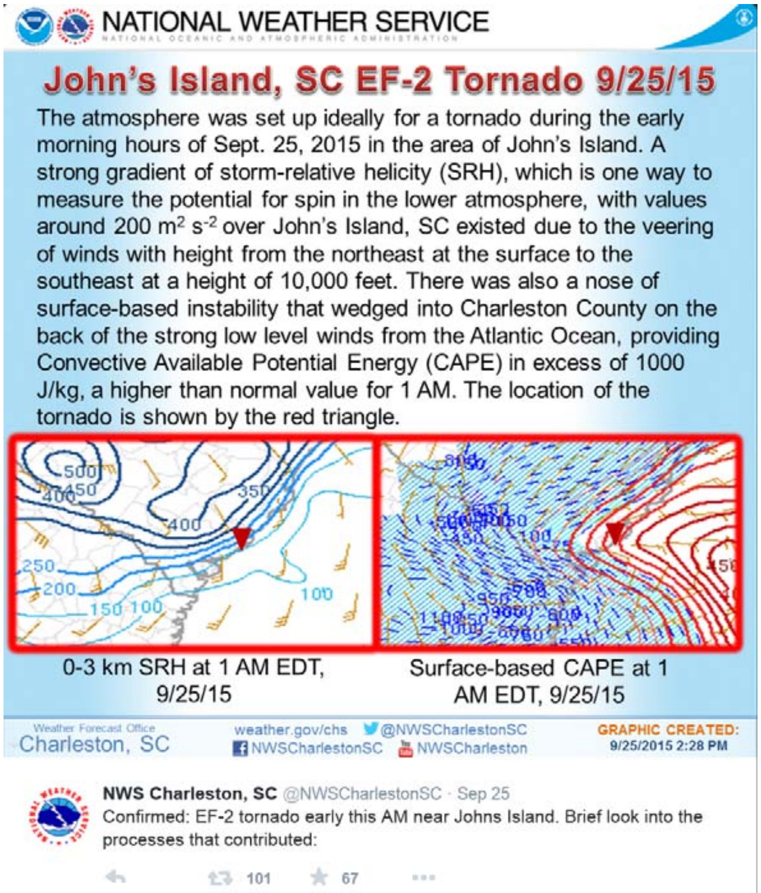


Figure 1: Tornado Probability for September 25, 2015 as issued by NWS SPC at 9:00 PM EDT. No tornadoes or significant thunderstorm activity was expected.

**Timing of Outbreak**

The timeline of the tornado outbreak as it formed is given below. All times are Eastern Standard Time on 25 September 2015.

12:38 AM – NWS Charleston issues a tornado warning (shown in Figure 2) for Johns Island and nearby communities until 1:15 AM.
12:42 AM – A tornado formed just off Cane Slash Rd in Johns Island, SC.
12:45 AM – An off duty NWS employee reported several trees down near the intersection of Maybank Highway and Walter Drive.
12:47 AM – A trained spotter reported numerous trees reported down near Swygert Landing.

12:50 AM – The Johns Island fire department reported at least 12 homes were damaged along Sonny Boy Lane.
12:50 AM – Local residents reported several homes damaged with windows blown out along Sonny Boy Lane.
12:54 AM – Local media relayed pictures of trees down near the intersection of Main Rd and River Rd.
12:55 AM – Local media relayed pictures of trees and power lines down near the Limehouse Bridge.
12:59 AM – A trained spotter reported siding off a home in Bolton's Landing apartments in the West Ashley region of Charleston, SC.

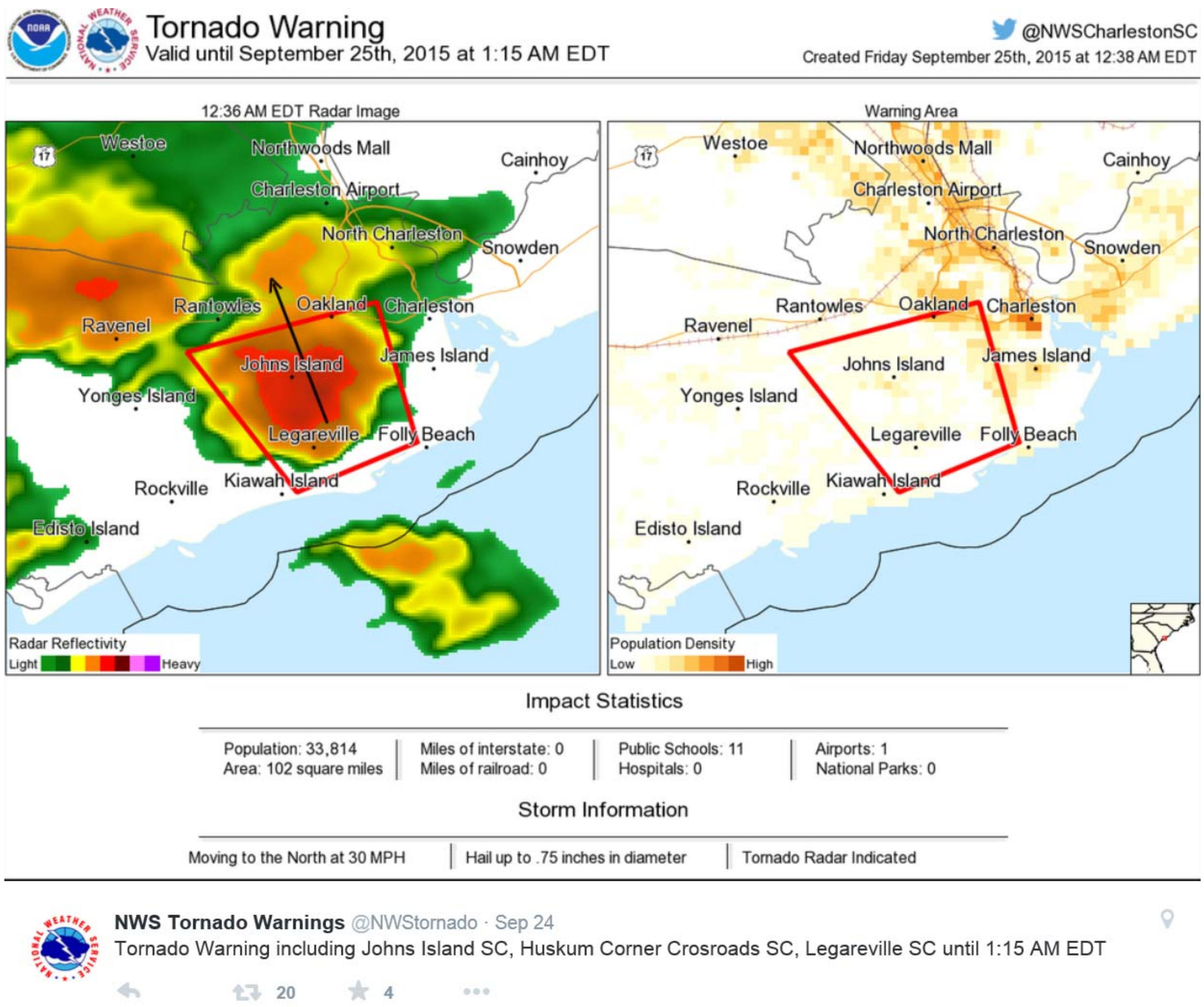


Figure 2: Tornado warning graphic issued by the NWS Charleston office at 12:38 AM EDT on 25 September 2015. Radar indicated a tornado was moving north at 30 mph into Johns Island, SC.

**Summary of Damage**

A survey team from the NWS Charleston office concluded that the tornado had a maximum intensity of EF2 on the Enhanced Fujita (EF) Scale, with a path length of 6.9 miles and a maximum path width of 0.5 miles. Between 70 and 80 homes were estimated to have been damaged by the tornado, with one home completely destroyed. Most of the damage was light, limited to sheathing and siding removals, broken windows and loss of roof cover. Thousands of trees were reportedly snapped or uprooted throughout the tornado's path (Post and Courier).

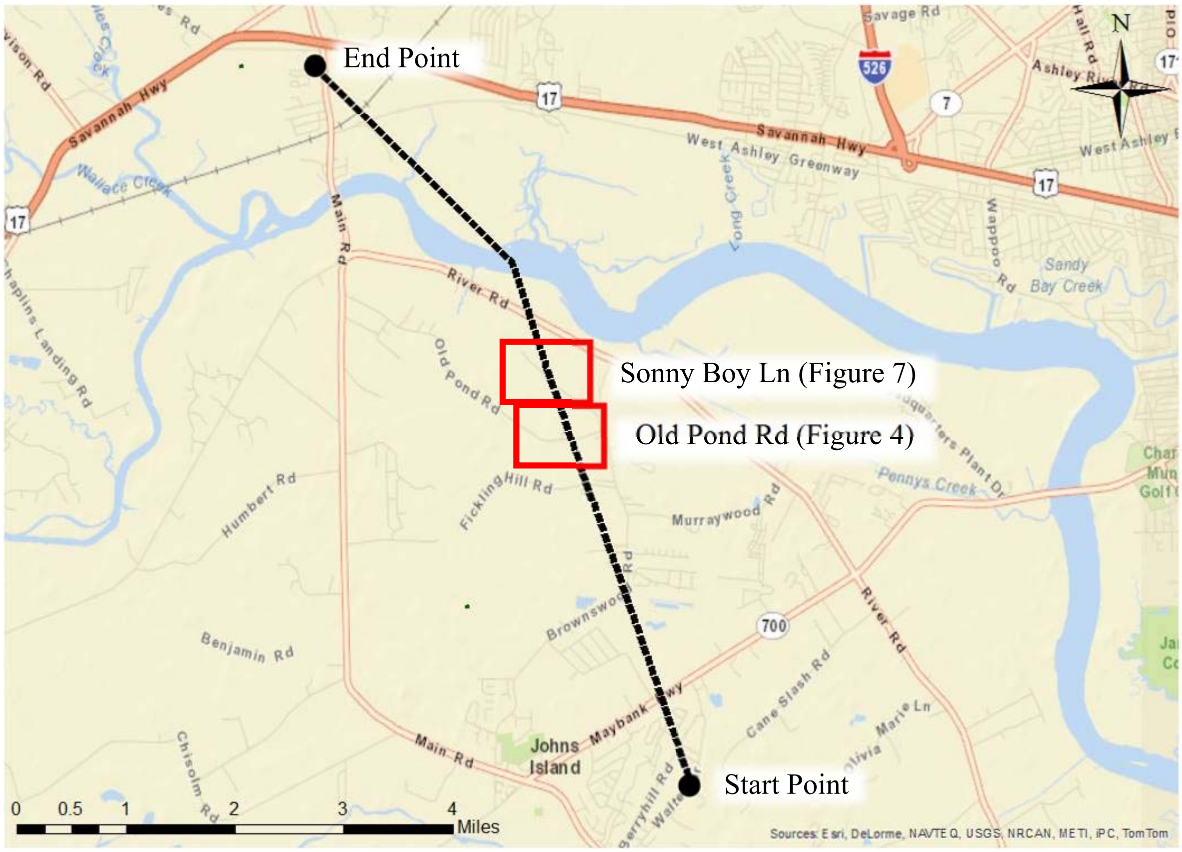


Figure 3: Overview of approximate damage path (dashed black line) through Johns Island, SC with areas of major damage shown in red outlines.

The damage reports available online focused on damage to homes along Sonny Boy Ln and Old Pond Rd. Tree damage and minor structure damage was also reported on several other roads, including Brownswood Rd, Fickling Hill Rd and River Rd, which were closed for portions of time while crews cleared the debris. Figure 4 through Figure 8 illustrates some of the damages observed along Old Pond Rd and Sonny Boy Ln.


Figure 4: Aerial view of damage along Old Pond Rd. Roof damage was observed to two commercial buildings and a nearby home suffered damage to a bay window, garage door and roof covering. A camper was flipped in the same property. Approximate direction of tornado is indicated by white arrow. (Photo from ABCNews4.com)

Figure 5: Toppled camper on property along Old Pond Rd (Photo Courtesy of Karla Mata).

Figure 6: Bay window breached and garage door blown out in home along Old Pond Rd. Photo courtesy of Stephanie Maxwell, WSOC Channel 9)

The worst damage caused by this tornado occurred along Sonny Boy Lane where a one-story home was completely destroyed (Figure 8). The roof and attic structure were ripped away and the debris deposited throughout the neighborhood. The aerial view shows several downed trees around nearby homes, but no other major damage on them. Roof covering loss is observable in several homes and there were also many reports of broken windows in these homes. The extent of the damage to the destroyed home is apparent from a ground view photograph, showing the front elevation with the partially removed roof structure resting on the ground (Figure 8.) Our report draws sharp focus on this home to answer questions regarding the size of the tornado, strength of construction and effectiveness of building codes.

Figure 7: Aerial view of damage to homes along Sonny Boy Ln. The red arrow indicates the approximate location and direction of the photo shown in Figure 8. Photo taken from Charleston County Government aerial survey.

Figure 8: Ground view of destroyed home along Sonny Boy Ln. Photo courtesy of Bryan Luhn, WCBD Channel 2.

**Disproportionate Damage to Residential Structure at 727 Sonny Boy Ln, Johns Island, SC**

The destroyed home shown in Figure 7 and Figure 8 was located at 727 Sonny Boy Ln. While the other houses suffered EF0 or EF1 damage, this structure exhibited quite severe damage (DOD 6 - large portions of roof structure removed), making it an EF2 level damage. By this context, estimated wind speed would be between 111 and 135 mph.

The level of damage this home sustained is starkly greater than that occurring on the surrounding homes – making one consider whether the tornado vortex was shortlived on the ground or that it skipped over other homes. No other homes along the road had any significant structural damage, there were only reports of roof cover loss and a few cases of windows or doors failing (Post and Courier). An overview of the damaged area given in Figure 9 shows large areas of tree damage both to the east and to the west of the destroyed home, with relatively consistent tree-fall orientations along both sides of Sonny Boy Ln. If a tornado had passed down Sonny Boy Ln, we would have expected to see fallen trees pointing in opposite directions on opposite sides of the tornado path. An aerial video of the damage shows that this was not the case and indeed, looking at the overall patterns and locations of damage, it appears implausible that any sized vortex could have passed directly over the destroyed home without encountering at least some of the other homes. This leads us to consider other explanations.

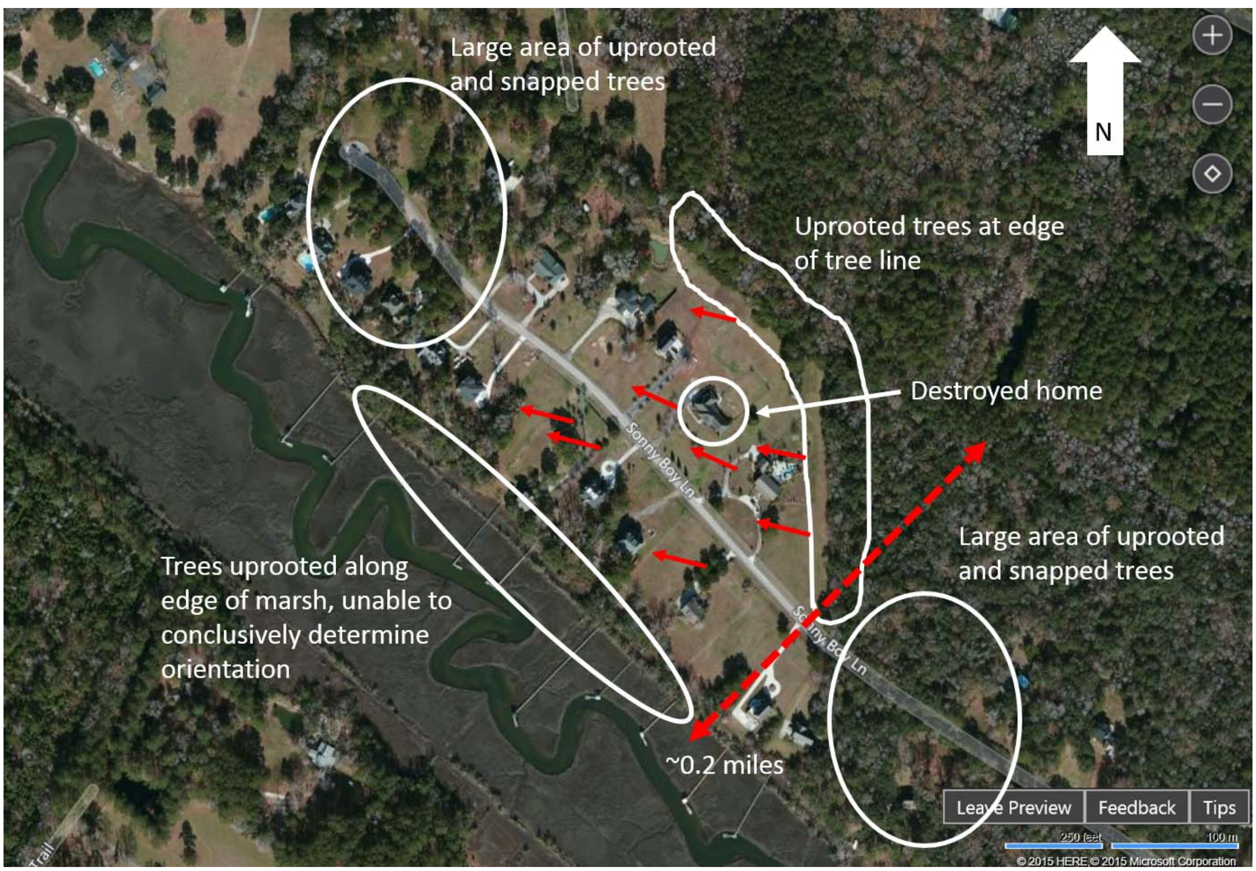


Figure 9: Overview of Sonny Boy Ln showing major areas of fallen or snapped trees and general tree-fall orientations (red arrows) along Sonny Boy Ln.

*Possible Explanations for Disproportionate Damage*

The destroyed home was built in 1999, and we learned from ABCNews4.com that it was designed by the homeowner. The house was a wood-frame structure, having plywood sheathed exterior walls, plywood roof sheathing and a brick façade. The hip roof structure was constructed with long-span rafters and had an approximate 8:12 roof slope (36°) based upon the damage photos. Hurricane straps connected the rafters to the horizontal double wall plate as shown in Figure 10. The top plates remained attached to the rafters as the roof failed, cleanly separating from the wall structure beneath. The roof ridge (rafter-to-rafter) connection at the peak appears to be toe-nailed – no metal straps were observable in the available photos which showed this connection.

Figure 10: Hurricane straps present between rafters and wall top plate. However, the wall top plate separated cleanly from the wall structure and failed along with the roof, indicating the load path between the wall plate and vertical studs may have been the critical failure point resulting in the observed damage to this home (Photo courtesy of ABCNews4.com).

The question as to why this home sustained such heavy damage while surrounding homes experienced very little damage is an interesting one. A similar case to this was observed in the 2011 Tuscaloosa, AL tornado, and the evidence there pointed to large overhangs on the windward side of the home initiating the roof damage, resulting in the complete failure of the roof and ensuing wall collapse (Prevatt and Roueche, 2015). This does not appear to be the case here in the Johns Island tornado, as the dominant wind direction, based upon the orientation of debris and fallen trees around the home, would have been from the side and back of the house. A bird's eye view of the home provided in Figure 11 does not show large overhangs to abnormally increase the wind uplift loads or obvious weak points relative to that wind direction.

A common explanation that is sometimes heard for such seemingly random damage is the damage was caused by presence of a sub-vortex, or a smaller satellite tornado rotating around the primary vortex at higher wind speeds. But the tree-fall and debris patterns around the house are consistent with those found along the entire street, indicating that the wind speeds were likely due to a single vortex. Deterioration or rotting of the wood framing can also cause disproportionate failure, as we observed in a 2013 tornado in

Palm Coast, FL. However, the photographs we were able to see showed no such evidence, as generally the wood framing appeared to be in good condition.

We concluded there was nothing unusual in shape and orientation of the house, topographic or exposure effects, or special meteorological phenomena to account for the mode of failure, and we are left to suspect there may be a structural deficiency in the vertical load path. The evidence for this is visible in the "clean" separation of the wall double-top plate from the vertical studs Figure 10. That is, neither the rafter nor the studs themselves were fractured, the connection merely separated. The common construction of the stud walls is to nail it into the end of the vertical studs – nails are installed into the end grain of the wood members and the withdrawal capacity of this connection is very low. Thus, while the metal hurricane straps provide a robust connection of the rafters to the top plate (using a nail group of 3-4 nails, loaded in shear), if the vertical studs are not directly engaged by the metal tie, the weak connection between horizontal wall plate to vertical stud remain in the load path and lead to this failure. Common design practices for addressing this connection can be found here. A far stronger connection for attaching the horizontal top plates to the vertical wall studs is by using through metal straps and/or through overlapping the wall sheathing on to the top plates such that the sheathing and its fasteners form the connection.

Another failure initiation point could have been at the ridge of the roof. For a steep sloped roof like this was, high suction pressures would have been observed on the leeward roof surface. When rafters span the roof slope rather than metal-plate connected wood trusses, the meeting point of the rafters at the ridge can be a critical (low capacity) connection. Photos of this connection indicated that the rafters at the peak were toe-nailed together, and in portions of the roof the rafters separated at the peak. It cannot be ascertained from the available photographs whether this was indeed a failure mechanism. A more detailed forensic investigation would be necessary to confirm that assertion.

Regardless of the exact cause of failure in this home, the lack of damage to surrounding homes is still surprising. The Charleston County tax assessor database indicates that the destroyed home was built in 1999. The year built of surrounding homes are shown in Figure 11. The destroyed home was the oldest home on the street, and one of two (out of 8) that were built prior to South Carolina's adoption of the International Building Code in 2001. The second-oldest home, located immediately north-west of the destroyed home, was built in 2000 and had a roof span approximately half that of the destroyed home. Assuming these homes had similar construction, the shorter roof span would result in much lower wind uplift loads (suction) on the roof structure. This alone could explain the difference in structural performances of these two homes.

Additionally, according to the 1995 CABO building code, the design wind speed for Charleston County was a 100 mph fastest mile (i.e. 115 mph 3-second gust, Exp. C)[1]. The 1995 CABO also states that one-story homes in this wind speed zone, and in Exposure B (suburban or wooded areas) terrain, do not need engineering design but instead could be built using the prescriptive requirements of the code. For homes located in Exposure C, engineering design is required, assuming a roof uplift pressure of 32 psf. If the home was properly designed then, the estimate of EF2 (3-second gust wind speeds between 111 and 135 mph) is reasonable.

[1] Table R301.2.1.3, 2009 International Residential Building Code (IRC)


Figure 11: Birds eye view of the destroyed home. Solid red arrows indicate the range of wind directions the home was exposed to during the passage of the tornado based on the debris and treefall patterns (see Figure 7). The white arrow with red outline indicates the approximate direction of travel of the tornado as it passed this area. The exact path of the tornado center is not known however.

The other houses that suffered minimal damage constructed in accordance to the 2000 International Residential Code, or more recent code, and the design wind speed would be at least 130 mph (3-sec gust). At this design wind speed, the prescriptive design provisions would not be applicable and instead the homes must be designed to resist the wind pressures given in Table R301.2(2), adjusted for height and exposure by the factors in Table R301.2(3). For Exposure C, a one-story home should be designed to withstand roof uplift pressures of 30.5 psf, similar but actually lower than the 32 psf required by the 1995 CABO building code.

The following points summarize the observations regarding the destroyed home at 727 Sonny Boy Ln:

- Multiple homes surrounding the destroyed home all had similar design requirements, yet none of the surrounding homes suffered major structural damage.
- The orientation of the fallen trees and debris give no indication that a narrow tornado passed directly over the destroyed home. Further, the NWS estimated 6.9 miles and 0.5 miles for the path length and path width respectively, which places this tornado in the 70$^{th}$ percentile for length, and 90$^{th}$ percentile for width, of all EF2 tornadoes reported in South Carolina between 1950 and 2014 (Figure 12).
- Structural deficiencies were noted in the damaged house from available photos of the debris, specifically the following:

- The top rafters were connected to the top plate with hurricane straps but there is no evidence of positive attachment of the horizontal top plate to the vertical wall studs, either through metal straps or overlapping of the exterior sheathing.
- Rafters meeting at the peak of the roof were toe-nailed together rather than connected with metal plates or straps.

These observations lead to two possible explanations for the contrasting level of damage to the home at 727 Sonny Boy Ln based on the evidence we have:

1) The tornado had a highly irregular travel path and/or was very narrow, or was not continuously on the ground, allowing it to strike the destroyed home only while leaving nearby homes untouched, or.
2) The oldest home on Sonny Boy Lane was built in accordance to the 1995 CABO building code, and critical details resulted in a weak roof-to-wall connection and/or weak ridge connection that initiated the failure and partial removal of the roof structure. The adjacent houses on the street were built to the International Residential Code, which mandated more stringent structural designs and wind-resistant details, and thus those houses suffered little damage despite experiencing the same or nearly the same wind speeds.

Based upon the preliminary evidence available to us, the second explanation is more probable, which could be confirmed through a more detailed forensic investigation of the damaged home and the adjacent construction.

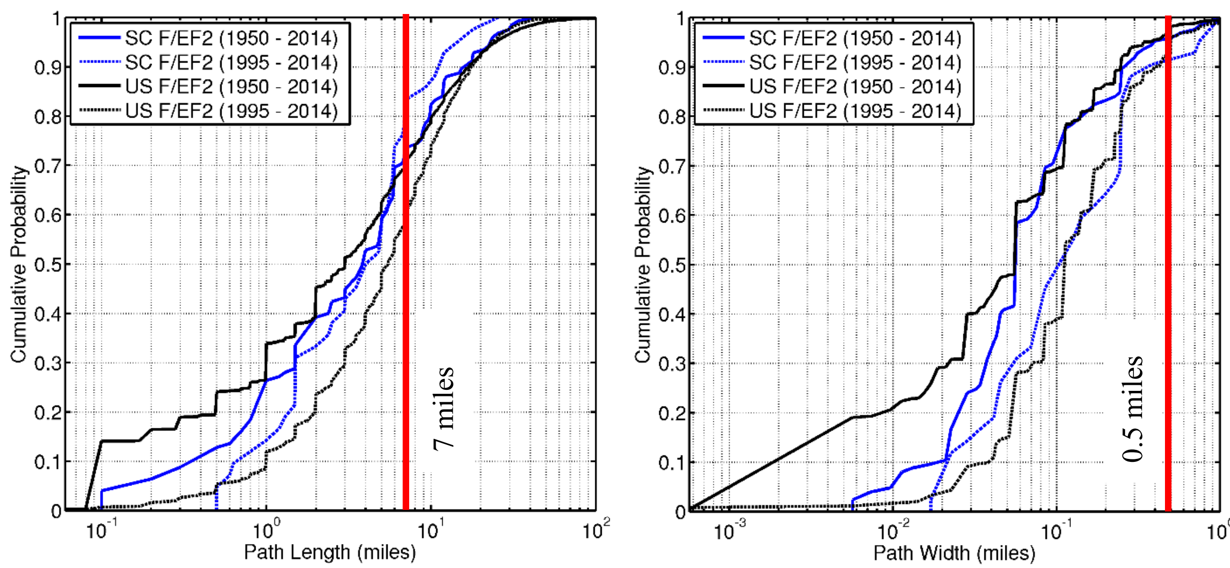


Figure 12: Empirical distributions of EF2 tornado path length and path width for South Carolina (blue lines) and the entire US (black lines). Distributions are shown for the entire SPC record (1950 – 2014) and for 1995 – 2014, since the defintion of tornado path width was changed in 1994 to represent the maximum path width rather than the mean path width. The path length is in at least the 70th percentile, an the path width in at least the 90th percentile, for EF2 tornadoes in South Carolina.

**Summary**

The evidence and analysis presented in this report raise several points of emphasis:

1) The load path in a residential structure consists of more than just the roof-to-wall connection. While this is certainly an important link in the load path, and one that often fails during strong winds, addressing it alone will not necessarily prevent premature roof failure from occurring. It bears repeating that the vertical load chain is only as strong as its weakest link, and the strength of every link must be considered in the design of buildings.
2) Construction quality is critical in assigning EF Scale ratings. If all homes had been designed well to wind-resistant building codes on this street, there may have been no major structural damage. Even if the same wind speeds had occurred, the lack of structural damage would have led the surveyors to select a lower EF rating if the quality of construction of undamaged homes was not carefully considered. The lack of damage to structures in the tornado path can be as important, if not more so in assigning damage ratings. This fact can often be overlooked by non-engineers unfamiliar with post-storm damage survey procedures.
3) The lack of widespread damage from a tornado path that covered nearly 3.5 square miles with as much as 135 mph winds should not be dismissed. It is plausible that if this tornado had struck a town in a non-hurricane zone, the damage would have been substantially higher.

The results of this study suggests that more efforts are needed to develop standard protocol for evaluating strengths of tornado using post-event damage patterns. The observations following the Johns Island tornado suggest substantial economic and social benefits (e.g. eight families are occupying their homes today and they are not seeking private insurance or state support to rebuild) can accrue by implementing an engineering design approach and wind-resistant construction in residential construction. The narrative (and national media attention) could have been substantially greater had all or the majority of these nine homes been destroyed. Focusing singularly on the observed spectacular damage may overlook the many building performance success stories during tornadoes. The good performance of adjacent buildings also tells part of the story, if surveyors are trained to look for it. It is important to share those benefits in order to alter public perception and continue developing tornado-resilient designs.

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**About the PI**

David O. Prevatt is an Associate Professor of Civil & Coastal Engineering, in the School of Sustainable Infrastructure & Environment, University of Florida, Gainesville, FL. He is a registered professional engineer registered in Massachusetts and in Trinidad and Tobago.

**References**

*Peer-Reviewed Publications*

Prevatt, D. O., Coulbourne, B., Graettinger, A., Pei, S., Gupta, R., and Grau, D. (2013). "Tornado of May 22, 2011 – Structural Damage Survey and Case for Tornado-Resilient Building Codes", 47 p. ASCE/Structural Engineering Institute, Reston, VA.

Prevatt, D. O., Roueche, D. B., et al. (2011c). "Building damage observations and EF classifications from the Tuscaloosa, AL and Joplin, MO tornadoes." *Proc., 2012 Structures Congress*, ASCE, Reston, VA, in press. Prevatt, D. O., van de Lindt, J. W., Graettinger, A., et al. (2011a). *Damage study and future direction for structural design following the Tuscaloosa tornado of 2011*. University of Florida, Gainesville.

Prevatt, David. O., van de Lindt, J.W., Back, E., Graettinger, A.J., Pei, S., Coulbourne, W., Gupta, R., James, D., Agdas, D.; (2012) Making the Case for Improved Structural Design: The Tornado Outbreaks of 2011, October 2012 ASCE's Leadership and Management in Engineering Journal

Prevatt, D.O., van de Lindt, J.W., Graettinger, A.,Coulbourne, B., Gupta, R., Pei, S., Hensen, S., Grau, D. (2011a) Damage Study and Future Direction for Structural Design Following the Tuscaloosa Tornado of 2011, University of Florida, Gainesville, FL (April 5, 2012).

Prevatt, D. O., van de Lindt, J. W., Gupta, R., and Coulbourne, B. (2011d). "Structural performance—Tuscaloosa tornado." *Structure Magazine*, July, 24–26.

Vo, T. D., Prevatt, D. O., Acomb, G. A., Schild, N. K., & Fischer, K. T. (2012, October). High speed wind uplift research on green roof assemblies. Conference paper presented at Cities alive: 10th annual green roof & wall conference, Chicago, IL. Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2012/12/SUBMISSION-5R-1-Vo-et-al.-High-speed-wind-uplift-research-on-green-roof-assemblies.pdf

Wurman, J., Alexander, C., Robinson, P. & Richardson, Y. (2007, January). Low-level winds in tornadoes and potential catastrophic tornado impacts in urban areas, *Bull. Amer. Meteor. Soc.* American Meteorological Society, DOI:10.1175/BAMS-88-1-31.

*Other Publications and Research Reports*

Prevatt, D. O., Agdas, D., & Thompson, A. (2013). Tornado damage and impacts on nuclear facilities in the united states. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2012/10/Prevatt-2013-US-Nuclear-Power-Plants-and-Tornadoes_dop.pdf

Prevatt, D. O., Doreste, J., & Egnew, A. (2013). Online summary damage from the 31 May 2013 tornado in El Reno, OK. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2012/10/El-Reno-Tornado-31-May-2013-Summary-UNIV-FLORIDA.pdf

Prevatt, D. O., Kerr, A., Peng, X., Vo, T., & Doreste, J. (2012). Damage survey following the August 27th, 2012 tornado in Vero Beach, FL. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2012/10/Damage-Survey-Vero-Beach-Tornado-Sept-7-2012-UNIV-FLORIDA.pdf

Prevatt, D. O., Roueche, D., Thompson, A., & Doreste, J. (2013). Online summary damage from the 20 May 2013 tornado in Moore, OK. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2013/05/Moore-Tornado-20-May-2013-TORNADO-Summary-UNIV-FLORIDA.pdf

Prevatt, D. O., Roueche, D., Vo, T., Kerr, A., Thompson, A., Peng, X., & Egnew, A. (2013). Online/internet damage summary of the 15th May, 2013 North Texas tornado outbreak. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2013/05/Summary-of-North-Texas-Tornado-Outbreak-on-May-15th_Final.pdf

Prevatt, D. O., Roueche, D., Kerr, A., & Peng, X. (2012). Summary of june 24, 2012 Lake Placid tornado. Unpublished manuscript, Department of Civil and Coastal Engineering, University of Florida, Gainesville, Retrieved from http://windhazard.davidoprevatt.com/wp-content/uploads/2012/10/June-24-Lake-Placid-Tornado-Damage-Survey.pdf

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Appendix