StEER: Structural Extreme Event Reconnaissance Network

19 JANUARY 2019 TORNADOES IN THE SOUTHEASTERN US: FIELD ASSESSMENT TEAM EARLY ACCESS RECONNAISSANCE REPORT (EARR)

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Executive Summary

A tornado outbreak on January 19, 2019 produced ten tornadoes across the southeastern United States, including an EF2 (estimated wind speeds of 135 mph) that caused considerable damage in Wetumpka, AL. The First Presbyterian Church, an historic landmark in the central part of the city since 1857, was completely destroyed, and many recently constructed buildings also experienced severe damage. This report provides a preliminary summary of the damage and impacts of these tornadoes, and details on-site investigations conducted by researchers from Auburn University. The on-site investigations were jointly funded by a NOAA VORTEX-SE research grant, focused on vulnerability of mobile homes to tornadoes (PI Strader at Villanova University), and the Structural Extreme Events Reconnaissance (StEER) network. Founded under an NSF EAGER grant, StEER's seeks to build societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities.

StEER conducted on-site investigations in Wetumpka, AL and in a rural community just north of Booth, AL that was also struck by a tornado. Using a combination of door-to-door forensic engineering assessments and an Unmanned Aerial Vehicle (UAV), this scout Field Assessment Team (FAT-1) directly investigated 35 buildings impacted by the tornadoes, focusing on the structural systems, observed damage (or lack thereof), and context of the observed damage in relation to the building attributes, surrounding terrain, and proximity to the tornado path.

Preliminary observations from the FAT investigation include the following:

1. Structural load paths in all of the buildings investigated were not sufficient to withstand an EF2 tornado (wind speeds up to 135 mph) without major structural damage. Assuming similar construction throughout the downtown area of Wetumpka, the impacts of the tornado were only limited by its relatively narrow width of approximately 700 yards.
2. Tree-fall in outer regions of the tornado path caused severe structural damage, and heightened potential for loss of life, in buildings that otherwise would have likely performed adequately. Fortunately, no fatalities occurred in any of the tornadoes.
3. Vulnerability of existing mobile homes continues to be a critical issue, driven in part by poor anchorage practices as was observed in several mobile homes in this study.

StEER recommends further investigation into the unique aspects of the tornado vulnerability of urban clusters and rural communities (as defined by the US Census Bureau) and particularly for mobile homes. Careful reconsideration should also be given to current codes and regulations which deem such disasters as acceptable, despite the evidence to the contrary that disasters from tornadoes of this magnitude are unnecessary and avoidable.

All observations and findings provided in this report should be considered preliminary and are based on the limited scope of FAT-1. Specific recommendations of areas worthy of further investigation are offered at the conclusion of this report.

Introduction

On January 19, 2019, a storm system moving through the southeastern United States produced at least ten tornadoes, the strongest rated an EF2 (maximum wind speed of 135 mph) by the National Weather Service based on damage in Wetumpka, AL. While the overall impact of these events was small relative to other natural hazard events (likely less than a hundred buildings damaged in total), the impact to these individual communities cannot and should not be ignored. This is particularly true in Wetumpka, AL, a city with a population of 6,528 per the 2010 US Census, which in many ways represents the dozens, and some years hundreds, of rural communities in the US that are impacted by tornadoes on an annual basis and are left with difficult decisions in the days and years ahead. In Wetumpka, the EF2 tornado damaged or destroyed approximately 35 buildings, a number which tragically included the First Presbyterian Church, a 163 year old landmark in the historic downtown district of Wetumpka, in addition to several buildings on the First Baptist Church of Wetumpka campus, the police station, the senior center, several industrial buildings, and a number of residences.

Thankfully, no fatalities occurred in Wetumpka or elsewhere due to the tornado outbreak, a testament in large part to the tireless work of the National Weather Service employees in issuing timely warnings, whose efforts are commended here. The efforts of the state emergency and governors' offices in executing a timely response are also recognized and commended, along with the hundreds of volunteers who provided meals and other essential needs to those impacted and worked quickly to organize and dispose of debris.

Commentary: Yet the inspiring heroism, selflessness and human resiliency displayed by Wetumpka and other communities following these tornadoes is accompanied by the disconcerting realization that the very real disaster that such communities are left to cope with, is deemed **acceptable** and **unavoidable** by the regulations and policies (or lack thereof) still in place today for buildings in most tornado-prone regions. This persists despite the existence, for decades, of engineering knowledge and practice that can prevent tornadoes of this intensity from becoming disasters (e.g., the Fortified program[1] and peer-reviewed studies[2]) that demonstrate the economic feasibility and benefit of mitigation strategies implemented in tornado-prone regions. We must recognize that society's continued choice to build to minimum, life-safety standards with no consideration of tornadoes equates to a choice to accept preventable deaths and impacts to human life and property.

The objective of this **Early Access Reconnaissance Report (EARR)** by the Structural Extreme Events Reconnaissance network is to:

1. Provide an overview of the tornadoes that were reported;
2. Introduce the StEER event strategy in response to the tornadoes;

[1] https://disastersafety.org/fortified/fortified-home/

[2] Simmons, K. M., Kovacs, P., & Kopp, G. A. (2015). Tornado damage mitigation: Benefit–cost analysis of enhanced building codes in Oklahoma. *Weather, climate, and society*, *7*(2), 169-178.

3. Summarize the activities, methodologies, engineering perspectives and preliminary findings of the scout Field Assessment Team (FAT-1) following on-site deployments.

It should be emphasized that all results herein are preliminary and based on the rapid assessment of data within 24 hours of its collection. As such, the records have not yet been processed by the StEER Quality Assurance protocol. Damage ratings discussed herein are based largely on the judgement of the field investigator on the ground and will be updated when the full dataset is released on DesignSafe under Project ID PRJ-2197. The raw data is now available for viewing in the Fulcrum Community page:
https://web.fulcrumapp.com/communities/nsf-rapid .

Meteorological Background

The storm system responsible for the January 19, 2019 tornadoes developed west of the Mississippi Valley on Friday, January 18, and by early Saturday morning became a convective line with greatest organization over Mississippi and Louisiana[3]. As the system entered Alabama, southerly winds raised surface dew points above 60 °F in the southern and central parts of the state[4]. Significant wind shear was observed in the system, as high as 40 to 60 knots of effective bulk shear, providing a favorable environment for the development of severe thunderstorms and tornadoes.[2]

The National Weather Service Storm Prediction Center issued an outlook on Saturday morning—approximately six hours before the tornadoes appeared—which placed central Alabama, Mississippi and parts of Louisiana and Florida at a “slight risk of severe thunderstorms,” with probabilistic ratings of 5% for tornado formation as shown in Figure 1, noting that “enlarged low-level hodographs will support some embedded mesovortices capable of a few tornadoes.” [2] Ultimately, at least 10 tornadoes touched down in the morning and early afternoon hours across the southeast including four in Alabama, four in Mississippi, and one each in Louisiana and Florida. Aside from the tornadoes that formed, the storm system felled numerous trees in the area and generated damaging straight-line winds.

[3] National Weather Service Storm Prediction Center, Norman, Oklahoma, “Day 1 Convective Outlook, January 19, 2019, 1300 UTC.” https://www.spc.noaa.gov/products/outlook/archive/2019/day1otlk_20190119_1300.html

[4] National Weather Service, Birmingham, Alabama, “Tornadoes of January 19, 2019—Event Summary for Central Alabama.” https://www.weather.gov/bmx/event_01192019

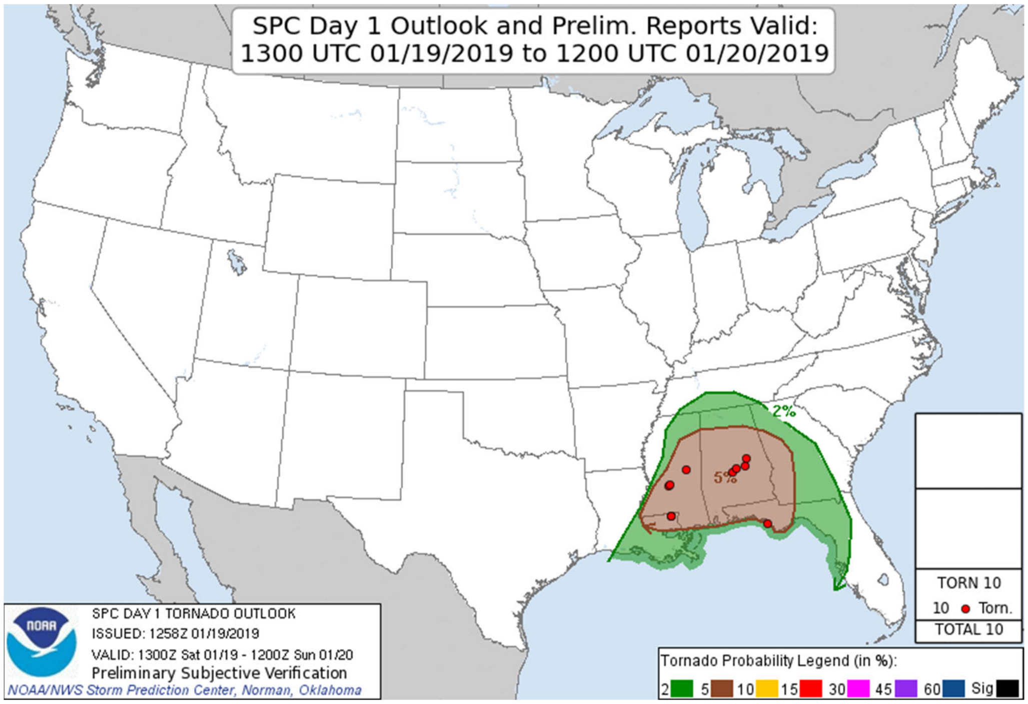

Figure 1. Tornado outlook probabilities issued by the Storm Prediction Center at 1300 UTC (0700 CT) and preliminary tornado verification.

StEER Response Strategy

Following the tornadoes on 19 January 2019, a StEER Field Assessment Team (FAT-1), consisting of Team Lead David Roueche and Brett Davis from Auburn University, deployed to capture perishable data regarding building performance. FAT-1 conducted on-site assessments at two communities impacted by the tornadoes - Wetumpka, AL on 21 January and a rural community just north of Booth, AL on 22 January. The locations of the deployments were guided by public media reports and data (including photographs and estimated tornado path) collected by the Birmingham National Weather Service Forecast Office that was made available through the Damage Assessment Toolkit.

FAT-1 conducted targeted door-to-door forensic assessments using the Fulcrum data collection platform, supported by high-resolution aerial imagery captured via a DJI Mavic Pro. The aerial imagery is intended to provide 3-dimensional views of structures included in the door-to-door assessments and holistically capture the entire damage swath over larger areas. A complementary goal of the aerial imagery is to document the location and direction of tree-falls, used in conditioning theoretical translating vortex models. In addition, information was solicited from survivors to provide context on the tornado path and intensity as well as structural and historical characteristics of certain buildings. This included requesting and receiving security camera footage of the tornado from multiple angles of one building - the First Baptist Church in Wetumpka, AL.

Following the field deployment, the curation process was initiated on raw field reconnaissance data, culminating in publication on the NSF DesignSafe Cyberinfrastructure. Additional Field Assessment Teams are not anticipated, but analysis of the data and extraction of information and knowledge will continue through Virtual Assessment Teams (VATs).

Local Codes & Construction Practices

Tornadoes are not considered in the wind design of typical structures in any of the states impacted by the storms described in this report (ASCE, 2016). Notwithstanding, building codes and regulations are important to broadly understanding the wind vulnerability of impacted regions. This section will focus primarily on local codes and construction practices in the state of Alabama. General information on the status of building codes and standards in other states can be found in the *Rating the States*[1] report by the Insurance Institute for Business and Home Safety.

Construction for buildings in Alabama is not regulated by a mandatory statewide code unless it is a state owned/funded building or if it is a hotel, motel, theater, or school[5]. Although the state government has published an amended version of the 2015 International Residential Code (IRC) for voluntary adoption by municipalities, under current law, local jurisdictions are permitted to continue using any residential code adopted prior to issuance of the state-amended code.[6] Any jurisdiction without a previously-adopted residential code must, if it chooses to adopt one at any time in the future, adopt the state-amended code.

The absence of a required statewide code complicates the process of identifying the applicable code for a particular site. It is possible that some municipalities, particularly in rural areas, have no formally adopted code for residential construction. At least two city governments in the tornado-affected area have adopted residential codes—Prattville in Autauga County and Wetumpka in Elmore County—and in both cases the code is the 2015 IRC[7-8].

Taking the 2015 IRC as normative for purposes of estimating current design wind speeds, it is found, based on the map shown in Figure 2, that the design wind speed in the four affected counties is approximately 115 miles per hour for a typical building (i.e., Category II), and 120 mph for a building that would pose substantial risk to human life in the event of failure (i.e., Category III). From this, then, the design wind speed for residences built to the current code in Wetumpka is 115 miles per hour. Thus, the Wetumpka-Eclectic Tornado—the most damaging of the four, classified as an EF-2 according to the National Weather Service, with estimated maximum wind

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[5] https://stage.iccsafe.org/wp-content/uploads/Code-Adoption-Process-by-State-.pdf
[6] Insurance Institute for Business and Home Safety, “Rating the States: 2018—An Assessment of Residential Building Code and Enforcement Systems for Life Safety and Property Protection in Hurricane-Prone Regions, Atlantic and Gulf Coast States,” March 2018. http://disastersafety.org/wp-content/uploads/2018/03/ibhs-rating-the-states-2018.pdf.
[7] City of Prattville, Alabama, “Building Codes, Permits, and Inspections.” https://www.prattvilleal.gov/departments/building-permits.html.
[8] City of Wetumpka, Alabama, “Building Department.” http://www.cityofwetumpka.com/Default.asp?ID=190

speeds of 135 miles per hour—was an above-design-level wind event for homes in Wetumpka. The other three tornadoes, with maximum wind speeds between 90 and 100 miles per hour were near-design-level events based on 115−120 mile per hour design wind speeds.

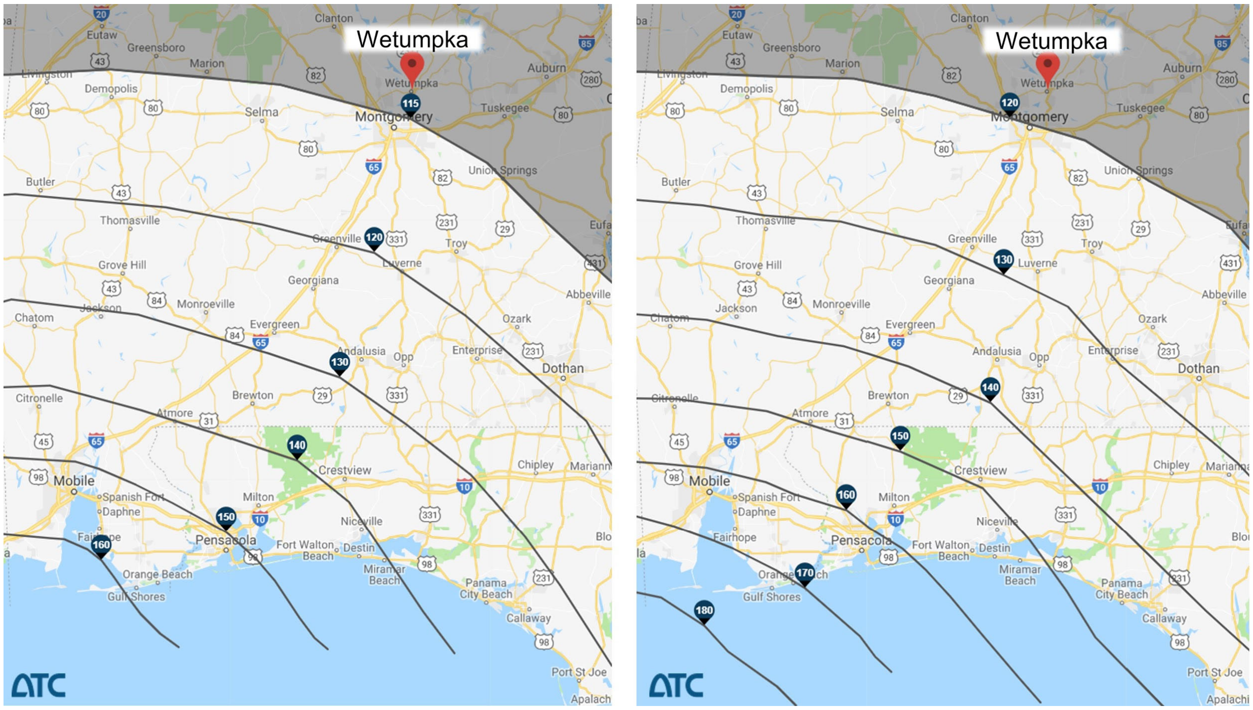


Figure 2. ASCE 7-10 design wind speeds for Category II (left) and Category III (right) buildings in the study region. ASCE 7-10 is referenced in the 2015 International Building Code. Graphics are obtained from ATC Hazards by Location.

Construction and installation of mobile (manufactured[9]) homes is governed in Alabama by the Alabama Manufactured Housing Commission Administrative Code, which includes regulations for design, installation, and anchorage of mobile homes. These statewide provisions were effective October 1, 1981[10]. All counties within the State of Alabama except Baldwin and Mobile counties fall within Wind Zone 1, which has an equivalent ultimate strength design wind speed of 110 mph.[11]

Reconnaissance Methodology

Due to the relatively narrow damage paths of the two tornadoes that impacted Wetumpka and outer limits of Booth, the scout FAT-1 sampled across the full damage width for specific segments

[9] Although there are slight differences between mobile and manufactured homes, we use the more prevalent "mobile home" term for either those factory-built and/or capable of being moved (single or double-wide).

[10] http://www.amhc.alabama.gov/PDF/Rules/11MFCH.pdf

[11] Equivalent to 50-year return period, 70 mph fastest mile wind speed from AMHC wind map converted to 50-year 3-second gust wind speed of 85 mph and then to ultimate wind speed of 110 mph per the Manufactured Housing Institute Fact Sheet - Wind Speeds and Building Codes.

of the tornado in downtown Wetumpka and the tornado near Booth, AL. The segments were chosen based on the availability and type of structures within the tornado path, with priority given to downtown Wetumpka, where building density was highest, and to Booth, where a community of mobile homes (the focus of a separate project by FAT-1 Team Lead Roueche) was impacted.

D2D Assessments

D2D Damage Assessments enable a detailed construction classification and evaluation of condition/component damage levels. These were recorded using a Fulcrum mobile smartphone application acquiring geotagged photos and other relevant metadata from the surveyor's mobile device. The App development was informed by the experience of the 2017 Hurricane Season and reorganized into a Fulcrum project, allowing FAT-1 members to select assessment forms customized for buildings, non-buildings, or hazard indicators.

FAT-1 emphasis is placed on documenting the performance of as many buildings as possible in a short amount of time, while still capturing the critical, perishable information in the field that is needed for a useful assessment. This information includes 1) collecting clear photographs from multiple perspectives, 2) accurately geo-locating the assessments, 3) defining site-specific characteristics which require on-site forensic investigation, 4) noting unique features of structures that would affect windstorm performance and not be otherwise visible from the photographs or aerial imagery.

A large portion of D2D data enrichment comes from Virtual Assessment Team members working to post-process and analyze the data submitted by FATs, once the file synchronizes with the cloud-based Fulcrum database. VATs are charged with 1) creating uniform damage rating standards from the variable assessments of individual FAT investigators, 2) conducting a detailed QA/QC process, 3) enriching each entry with more detailed classification of the structure and assessments of overall/component damage due to wind and storm surge, and 4) overseeing the migration of this data into DesignSafe in accordance with uniform data standards.

Unmanned Aerial Surveys

Five UAS flights were conducted in Wetumpka and two near Booth. Locations of photographs taken in each flight are summarized in Figure 3. Flight parameters are shown in Table 1. Flight and image acquisition parameters for flights 1 and 2, encompassing the First Baptist Church, were chosen with the intention of developing a 3D point cloud of the damaged structures and vehicles on the campus. Parameters for the other flights were chosen with the intention of developing 2D map products, e.g., orthomosaics and digital surface models (DSMs). Flight altitudes were adjusted as necessary to account for towers, trees and other obstacles within the flight domain.

After the flights were completed, the raw imagery was processed using the commercial software Pix4Dmapper to generate preliminary Structure-from-Motion 3D models and orthomosaics of the damaged regions.

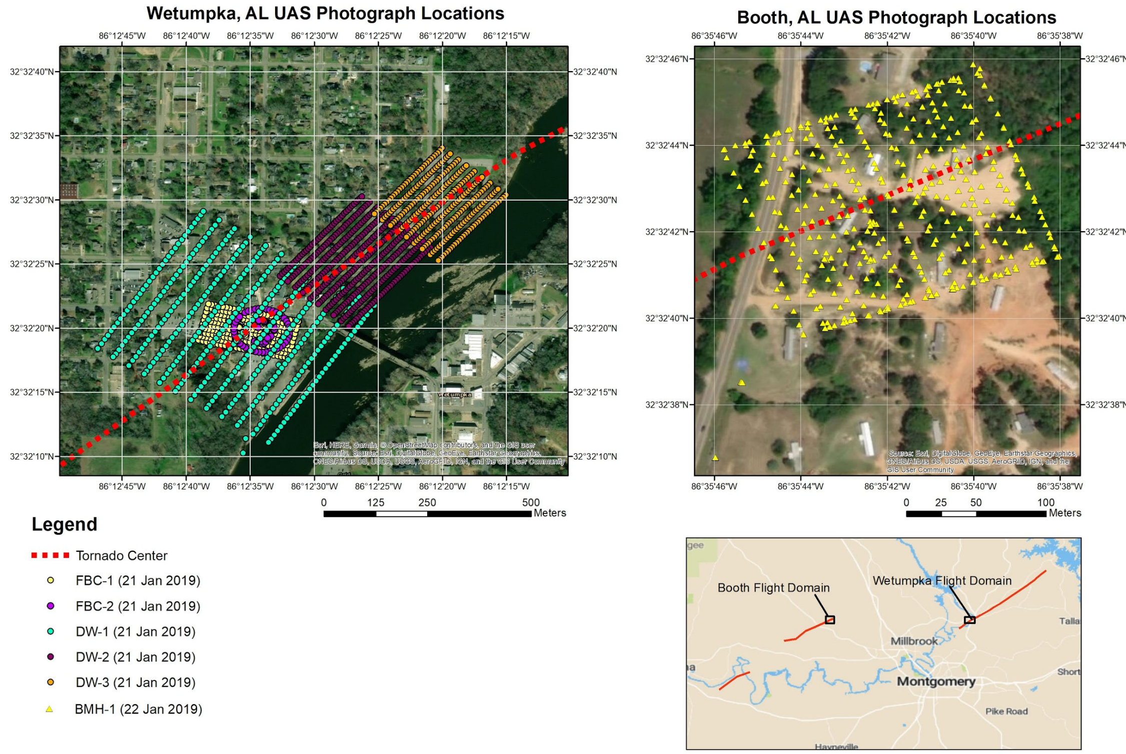


Figure 3. Grid of imagery captured by UAV flights over Wetumpka and Booth.

Table 1. Flight parameters for the imagery captured via UAV

Flight	Start Time	Flight Duration	Flight Pattern	Camera Angle	Side Overlap	Front Overlap	Altitude
FBC-1	10:31 AM	22:05	Double Grid	70°	70%	70%	27.4 m
FBC-2	11:09 AM	5:21	Circular	45°	8°[12]	8°[12]	27.4 m
DW-1	12:27 PM	18:44	Single Grid	80°	50%	80%	61 m
DW-2	3:34 PM	16:09	Single Grid	80°	50%	80%	32 m
DW-3	3:56 PM	13:11	Single Grid	80°	50%	80%	33.5 m
BMH-1	11:24 AM	13:20	Single Grid	90°	72%	80%	40 m

Observations by Region

Table 2 provides a summary of all confirmed tornadoes that occurred on 19 January (as of 24 January). The strongest storm was the Wetumpka/Eclectic tornado, which was given a maximum intensity of 135 mph[13], just shy of EF3 strength. Of the remaining nine tornadoes, seven were rated EF-1, with wind speeds between 85-105 mph, and the other two were rated EF-0, with maximum wind speeds estimated to be less than 85 mph. Relatively few structures were impacted by the tornadoes as the tornadoes tracked predominately over largely undeveloped land. Thankfully no fatalities occurred, although six persons were injured.

Observations of damage and conditions in the regions assessed by FAT-1 are now summarized.

[12] For circular flight types, side overlap and front overlap refer to the angle between photographs, meaning photographs are taken at the starting point, and in 8° increments up to 352° along a circular path around the object of interest.
[13] All wind speeds are assumed to be 3 second gust, in open terrain, at 33 ft height above ground level following the assumptions of the Enhanced Fujita (EF) Scale (ref).

Table 2. Confirmed tornadoes from 19 January 2019 by the National Weather Service

Tornado Name (State)	**County**	**City(ies) Affected**	**Path Length**	**Path Width**	**Injuries Reported**	**Fatalities Reported**	**Max intensity**
Tyler (AL)	Dallas/ Autauga	Selma, Tyler White Hall	6.18 miles	75 yards	0	0	100 mph (EF-1)
Booth (AL)	Autauga	Autaugaville Independence Booth Prattville	9.29 miles	400 yards	2	0	90 mph (EF-1)
Wetumpka/Eclectic (AL)	Elmore	Wetumpka Eclectic	18.18 miles	700 yards	4	0	135 mph (EF-2)
Coosa County Road 101 (AL)	Coosa	Rockford Goodwater	1.80 miles	112 yards	0	0	100 mph (EF-1)
Leake (MS)	Leake	Redwater	1.39 miles	250 yards	0	0	90 mph (EF-1)
Rankin (MS)	Rankin	Florence	2.72 miles	150 yards	0	0	75 mph (EF-0)
Rankin (MS)	Rankin	Brandon	2.45 miles	150 yards	0	0	88 mph (EF-1)
Neshoba (MS)	Neshoba	Philadelphia	0.26 miles	50 yards	0	0	75 mph (EF-0)
Washington Parish (LA)	Washington Parish	Franklinton	1.2 miles	75 yards	0	0	105 mph (EF-1)
Tyndall Air Force Base (FL)	Bay	Panama City	0.81 miles	50 yards	0	0	90 mph (EF-1)
Sources: https://www.weather.gov/bmx/, https://www.weather.gov/jan/, https://www.weather.gov/lix/, https://www.weather.gov/tae/							

Wetumpka, AL

The Wetumpka/Eclectic tornado tracked for approximately 18 miles, but the majority of the structural damage occurred within a 1.25 mile segment of the tornado path that passed through downtown Wetumpka, just west of the Coosa River. Several buildings on the First Baptist Church campus were damaged or destroyed, and the historic First Presbyterian Church was also destroyed. Emergency management officials estimated 35 homes sustained damage. The police station was also severely damaged, and a senior center collapsed. It should be noted that the majority of the buildings within the tornado path in Wetumpka were historic, with an average year of construction of 1932. The exception was the iMPACt center on the First Baptist Church campus, which was constructed in 2013 based on information provided by members on-site following the tornado.

First Baptist Church

The First Baptist Church Wetumpka consists of multiple buildings, including the main sanctuary (constructed in 1858 according to county records, though it is unclear if all sections of the building were constructed at the same time), the iMPACt center (constructed in 2013), and two detached garage structures. Figure 4 shows a Microsoft Bing Bird's Eye view of the campus pre-tornado, and a snapshot of the campus post-tornado reconstructed from the UAS photographs.

The main campus building MC1 was a 50 ft by 75 ft gable roof building with 30 ft eave height. It was constructed of multi-wythe brick masonry walls (7 wythes thick according to conversations with a member of the church) with heavy timber roof trusses spaced at 10 ft, assembled using mortise and tenon joinery. Spanning the heavy timber roof trusses were dimensional wood planks overlaid with asphalt shingles, which had been installed within the last couple years according to members. The building sustained heavy damage to the roof, with the roof cover and diaphragm completely missing (Figure 5a). Four of the eight heavy timber trusses were fully or partially collapsed/disassembled, with the east slope (closest to the tornado) sustaining the worst of the damage. The large, stained glass windows in the walls did not appear to sustain any damage and the brick walls also lacked significant damage.

Figure 4. Pre-tornado birds-eye view of the FBC campus with individual buildings annotated (top); post-tornado birds-eye view of the FBC campus based on preliminary processing of UAV photos using Structure-from-Motion techniques. Approximate direction and location of tornado path centerline is indicated by the red arrow.

(a)

(b)

Figure 5. (a) Damaged roof structure on main campus building MC1 campus and (b) loss of steeple on main campus building MC2 at the First Baptist Church Wetumpka campus. It is clear the steeple lacked structural connections because the remaining structure is lightly damaged.

Main campus buildings MC2 and MC3 did not suffer any obvious structural damage; however, the top half of the steeple on MC2 was lifted off and destroyed (Figure 5b). A few shingles on MC3 were lifted off, all on the west-facing slopes of the roofs, which were subjected to the radial inflow into the tornado vortex. Structural details of these buildings are not available at this time.

Few structural details are available about the administrative wing of the main campus. It is a flat roof building with brick veneer standing 20 ft in height. A porte cochere on the east side of the building was destroyed. A window and casing on the east side of the building was also pulled out of the wall due to apparent suction forces. An entry door on the south side of the building was also sucked open, shattering the glazing inside the door upon impact with the wall. Two air handler units on the roof were dislodged from their supports.

The iMPACt Center was constructed in 2013 and appears to be a steel moment-frame building with cold-form steel infill walls overlaid with brick veneer on the north, south and west walls and corrugated metal panels on the east wall. The roof diaphragm consisted of z-purlins (span length of 12 ft, spacing of 5 ft) supporting a standing seam metal roof. Interior layout of the building was not apparent during the on-site assessment. The building measures approximately 100 ft by 100 ft with a 35 ft eave height on the north wall and 26 ft eave height on the south wall. Design wind speeds and other details of the structural design have been requested, but are not available at the time of this report. **Assuming a Category III structure per ASCE 7-10, the minimum design wind speed is 120 mph, meaning the wind loads induced by the tornado may have been 27% higher ($135^2/120^2 = 1.27$) than design.**

Nearly 50% of the cladding on the east wall was destroyed, and all openings except one window were also destroyed (Figure 6). On the north wall, an overhang collapsed inward into the building, with two of the three center columns underneath the overhang left resting on the building. Structural details of the columns or anchorage were not visible. Multiple windows were broken on all sides of the building. The southwest corner of the building also experienced partial collapse inward towards the center of the building. Many of the roof purlins were also observed to have developed plastic hinges. Approximately 25% of the standing seam metal roof cover was also removed, all on the east side of the building, which would have been the leading edge of the roof relative to the tangential and radial velocity components of the vortex as it approached the building.

Figure 6. View from the east of the iMPACt center on the First Baptist Church Wetumpka campus.

Analysis of Surveillance Video

Multiple surveillance cameras were set up covering different zones of the campus. This data is still being processed and will be made available with the full data set on DesignSafe (see Project PRJ-2197). The locations of these cameras and approximate viewing angles are shown in Figure 7. The vortex itself is not directly visible in any of the videos due to the amounts of rain and debris wrapped around the vortex, but it's motion and location is apparent. A few preliminary observations can be made, but further analysis is ongoing:

- The strong radial inflow into the vortex is obvious. In each video, the rain indicates the wind is initially moving southwest to northeast - following the general motion of the storm system. At a specific point in each video, the wind rapidly changes direction and flows from northeast to southwest towards the approaching tornado.
- The duration of the tornado over a given location is approximately 30 seconds, based on the time from the videos when wind speeds begin to rapidly increase to the time when the winds return to calm. Assuming a storm translation velocity of 45 mph (based on archived radar of the storm), this gives the width of the tornadoes impact as roughly 660 yards, which agrees with the NWS estimate of 700 yards. The width of EF0+ winds and width of the actual vortex core (i.e., radius to maximum winds) would necessarily be less than 660 yards.
- As the tornado approaches, a glass entry door on the south wall of the administrative building (adjacent to Camera 2 in Figure 7) fails outward, indicative of strong suction forces on the surface of the building facing the oncoming tornado. This could perhaps be indicative of the strong radial component inducing leeward wall pressures on the south wall as the tornado approached.

Figure 7. Locations and viewing angles of security camera footage obtained by the FAT overlaid on the post-tornado aerial imagery. Red arrow indicates the approximate centerline of the tornado path based on the damage in this area.

First Presbyterian Church

The First Presbyterian Church was a historical landmark for Wetumpka, with the original building (the center of the T-shaped building footprint) having been constructed in 1856, and the east and west wings added in the mid 1950s according to public records (Figure 8) (https://www.hmdb.org/marker.asp?marker=67943). The construction was all wood-frame, but details of the load path in the original building were no longer discernible at the time the on-site assessment was conducted due to ongoing cleanup.

Figure 8. Before and after views of the historic First Presbyterian Church in Wetumpka, AL. Source: First Presbyterian Wetumpka.

Inspection of the east wing indicated the building consisted of wood wall studs with diagonal wood planks, constructed atop 2x10 wood floor joists (spaced approximately 10 inches on center) and diagonal wood floorboards (Figure 9). The floor structure rested atop an unreinforced brick masonry stem wall. No positive anchorage of the floor system to the stem wall was discernible; however, the presence of a positive anchorage would not have significantly affected the outcome given that the stem wall was not reinforced. The roof consisted of a wood rafter system, toe-nailed to the wall top plate with (3) ~16d nails with diagonal wood planks and an asphalt shingle roof. If the west and east wings were constructed around the same time, it is expected that construction would be similar.

Figure 9. Looking upward at the floor structure of the First Presbyterian Church east wing after it had been shifted off the masonry stem wall on which it originally rested.

The roof on the east wing was completely removed and the entire building shifted off the foundation. The west wing generally fared better than the east wing, but still sustained roof damage in several areas. The east wall of the west wing, where a corridor connected to the main sanctuary, was destroyed. The historic sanctuary was completely destroyed. Debris from the bell tower was scattered to the southwest of the original location (Figure 8), generally in the direction of the oncoming tornado (confirmed by early UAV video[14] prior to cleanup).

Police Station

The police station was also composed of multiple building wings, with the original building constructed in 1900 according to county records. Conversations with officers on-site indicated additional wings were added around the 1960's, but no dates could be confirmed. The back wings consisted of concrete masonry unit block walls of unknown reinforcement, with a steel roof structure. The station was partially destroyed by the tornado, with 20% of the roof structure removed, all in the back wings of the building, along with partial wall collapse in the same (Figure 10b). The front wing of the building, facing west and closest to Marshall St., remained mostly intact, even retaining most of the asphalt shingles (Figure 10a).

[14] https://www.youtube.com/watch?v=0zcTxDm1MQQ

(a)
(b)
(c)

Figure 10. View of the Wetumpka police station from the (a) northwest, (b) southeast and (c) overhead (north is up).

Wetumpka Senior Center

The Wetumpka Senior Center was a single story building with wood-frame and unreinforced concrete masonry unit (CMU) block walls supporting a wood truss roof structure. The roof diaphragm consisted of approximately ¾-inch by 8-inch wood planks spanning across the wood trusses, overlaid with 15/32-inch plywood. The roof cover consisted of 3-tab asphalt shingles atop a roofing felt paper. The roof structure was connected to the CMU block walls via ½-inch anchor bolts embedded in grouted cells of the CMU block spaced approximately 8 feet on center. However, grout was not continuous through columns of the CMU block wall and no steel reinforcement was observed, meaning the wind uplift load path relied upon the mortar joints in tension to resist the forces. The exact age of the building is unknown, but the roof truss joints and other structural details indicate the original building was likely built prior to 1950, with several alterations or additions made over the years.

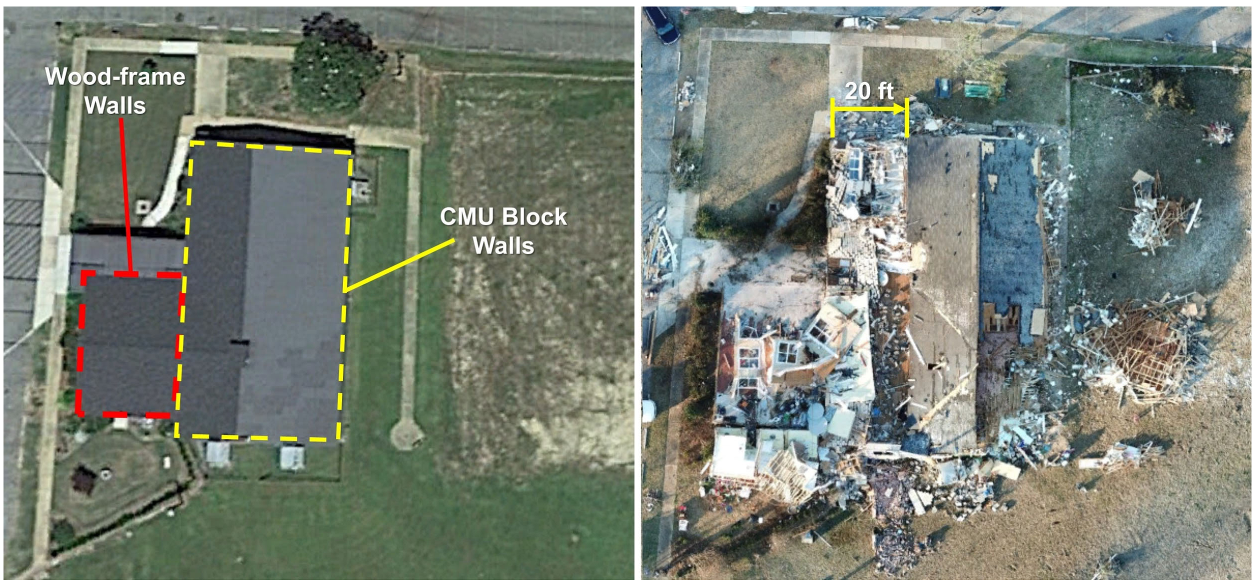


Figure 11. Before (left) and right (after) views of the Wetumpka Senior Center showing removal of the gable roof structure on the west wing and collapse (from east to west) of the roof structure over the north-south oriented portion of the building. North is up in both pictures.

The entire center was destroyed by the tornado (Figure 11), with the north-south oriented portion of the building racking and collapsing towards the northeast, following the direction of the tornado movement (Figure 12). The lack of reinforcement in the CMU block wall appeared to be the primary cause of failure. Several of the grouted cells containing the anchor bolts for the roof-to-wall connection simply separated from the remainder of the wall as shown in Figure 13; however, the majority of the roof structure remained largely intact and in place. The roof structure on the north-south oriented portion of the building was displaced 20 ft from west to east, while the roof structure on the west wing of the building was completely lifted off.

Figure 12. View from the back of the building looking northwest showing the collapsed, unreinforced CMU block walls and damage to roof structure.

Figure 13. Roof-to-wall connection at the Wetumpka Senior Center, showing wood top plate anchored to grouted CMU block with ½-inch anchor bolt. Lack of reinforcement in the CMU block wall allowed the grouted cell to easily separate from the rest of the wall structure.

Single-Family Residential Structures

All single-family homes investigated by FAT-1 were wood-frame, and varied in age of construction from 1890 to 1960. Two were single story and twelve were two story (above ground). Foundations typically consisted of CMU block or brick masonry stem walls with unknown attachment between the wood floor structure and the stem wall. Where the vertical load path was visible, connections relied upon nails, including toe-nails for roof-to-wall connections. Diagonal wood planks were commonly used for the wall diaphragm. The roof diaphragm also typically consisted of diagonal wood planks, in some cases with plywood overlaid atop the wood planks. Most homes had asphalt shingle roof cover.

Removal of the complete roof or large sections of the roof was observed in eight buildings, but in all but two the walls remained standing, albeit with significant debris impact such as most windows shattered (Figures 14-15). The frequent use of diagonal planks in the walls and roofs results in a heavier, more rigid diaphragm relative to modern homes[15], which may have prevented wall collapse in several homes that lost most sections of their roof. Tree-fall was also a primary source of damage in a number of the homes investigated (Figure 16).

Figure 14. Partially collapsed single family home in Wetumpka, AL.

[15] Prevatt, D. O., and D. B.Roueche. 2015. "A tale of two houses: Investigation of disproportionate damage in 2011 Tuscaloosa, AL Tornado." *Wood Des. Focus* **25** (**1**): 11–22.

Figure 15. Multi-family residential structure with failure of the roof structure on the west-facing slope of the exterior hip roof, and partial uplift of the ceiling joists as viewed from inside the structure. The additional dead weight of the roof from the wood plank ceilings and wood plank roof diaphragm may have prevented complete lift-off of the roof structure.

Figure 16. Tree damage (removed before photo was taken) to a facility nearby the Wetumpka Senior Center.

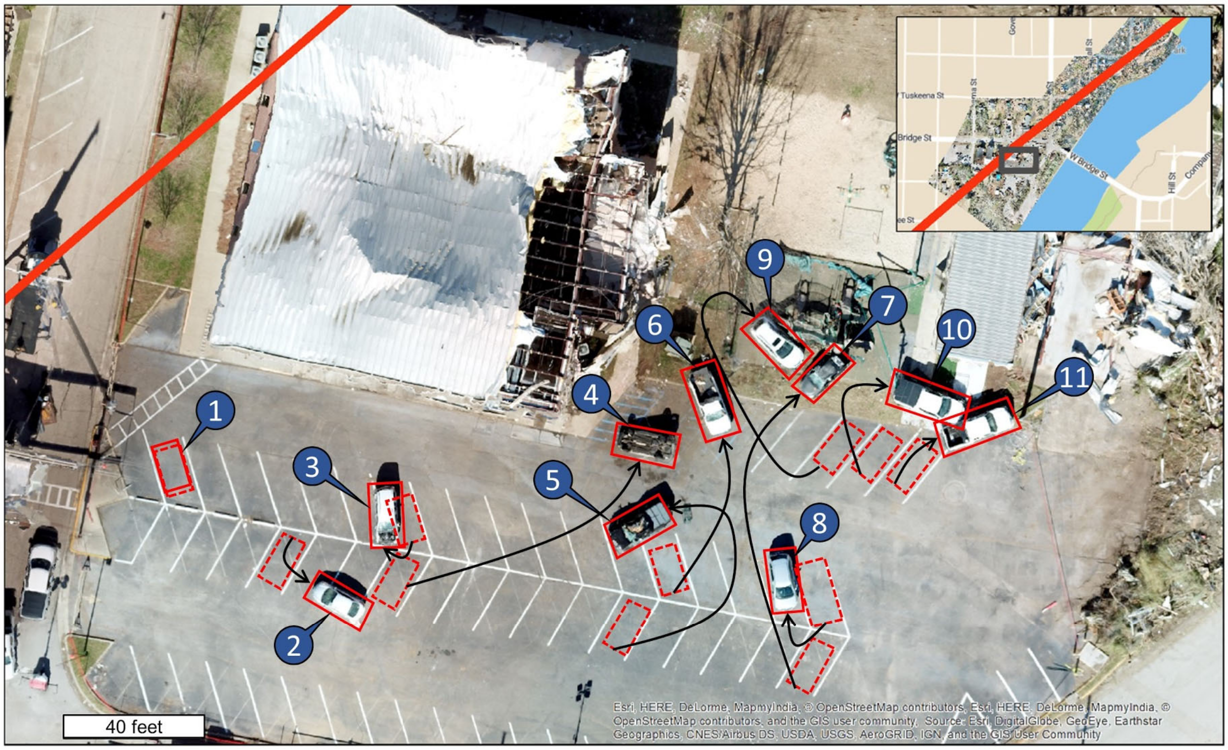
Vehicles

A number of vehicles were encountered during the damage assessment, but the only vehicles that were obviously moved by the tornado were those in the FBC parking lot. According to church members present on-site, a group of church members had left on the morning of 19 January in a bus, leaving their vehicles in the parking lot. Figure 17 shows the original location of the vehicles as best estimated from the security camera footage, along with the final resting place after the tornado. One car was flipped and nine vehicles were shifted laterally (Figure 18). One SUV (Vehicle 8 in Figure 17) only shifted a few feet laterally, but timber debris pierced through the car doors in multiple places (including where a child safety seat was located) and pierced through both walls of one tire (Figure 19).

No other obvious vehicle movements were observed based on publicly available videos from immediately after the tornado[16]. The movement of the vehicles in the FBC parking lot may then be due to the locally unobstructed terrain immediately surrounding the vehicles on three sides. Locally unobstructed terrain is needed for sufficient vertical velocities to develop at such low heights above the ground and either loft the cars, or reduce the friction forces sufficiently to enable lateral movement. Some experimental testing of tornado interaction with vehicles has been performed[17], but more research is needed to better understand the phenomenon and what wind speeds or flow conditions are required for vehicle movement.

[16] https://www.youtube.com/watch?v=0zcTxDm1MQQ&t=49s

[17] Haan Jr, F. L., Sarkar, P. P., Kopp, G. A., & Stedman, D. A. (2017). Critical wind speeds for tornado-induced vehicle movements. *Journal of Wind Engineering and Industrial Aerodynamics*, *168*, 1-8.



1 Midsize truck with cab
2 Hyundai Elantra (car)
3 Nissan Pathfinder (SUV)
4 Nissan Sentra (car)
5 Toyota Tacoma (truck w/ extended cab)
6 Chevy Silverado (truck w/ single cab)
7 Kia Spectra (car)
8 Ford Edge (SUV)
9 Mazda CX-9 (SUV)
10 Midsize truck with cab
11 Midsize truck with cab

Figure 17. Vehicle movements in the First Baptist Church parking lot. Pre-tornado vehicle locations (dashed polygons) are estimated from security camera footage. Vehicle 1 was removed before the aerial imagery was acquired.

Figure 18. Nissan Sentra (Vehicle 4 in Figure 17) flipped by the tornado. Final resting location was approximately 80 ft from origination point in the direction the tornado traveled.

Figure 19. Wind-borne debris pierced doors and windows of this midsize SUV in multiple places.

Booth, AL

FAT-1 conducted additional assessments in the path of a tornado north of Booth, AL. According to the National Weather Service, the tornado was an EF-1 with estimated maximum wind speeds of 90 mph. The tornado traveled approximately 9 miles and was 400 yards wide at its peak width, although the area assessed was near the end of the path and the tornado's width appeared to be much less at that point. It touched down northwest of Autaugaville, just west of County Rd 45, and traveled northeast from there. It crossed over US Highway 82 and lifted just east of County Road 21, where the assessment was performed (Figure 20). Figure 21 provides an orthomosaic of the assessment site with the locations of assessed buildings highlighted. The narrow width of the tornado at this point is clearly seen in the aerial view.

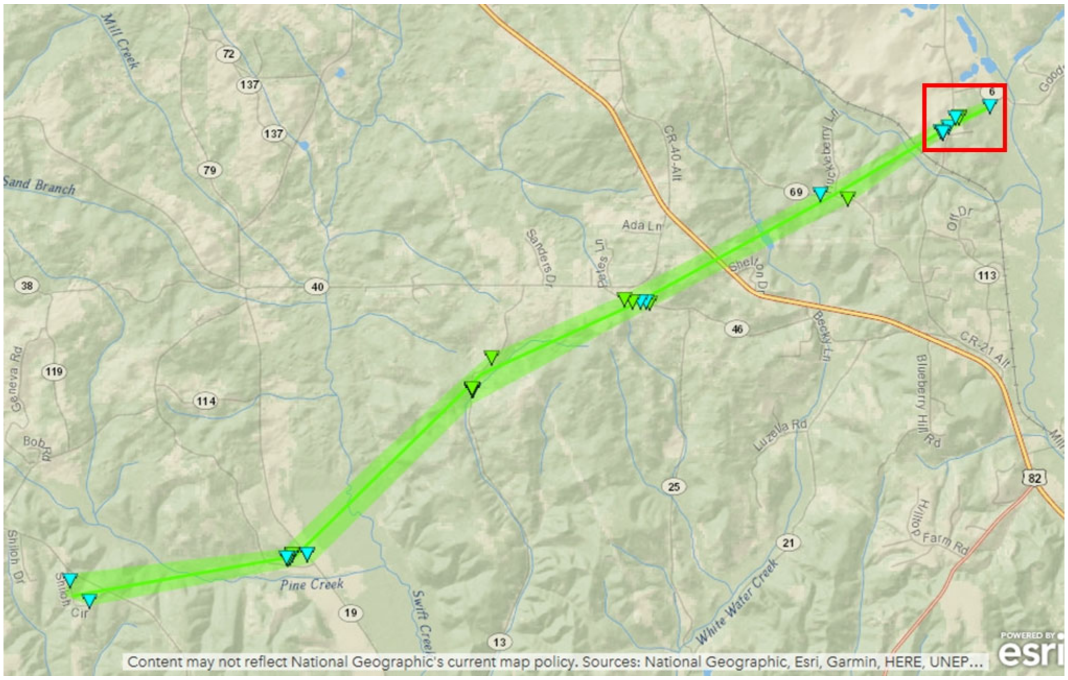


Figure 20. Path of the Booth, AL tornado. The red box indicates the location of the FAT on-site investigation. (Source: https://www.weather.gov/bmx/event_01192019booth)

1 Single-wide – no visible damage

2 Single-wide – minor roof cladding uplift

3 Single-wide – site of rolled mobile home

4 Single-wide – complete roof uplift

5 Double-wide – <10% roof cover loss; destruction of porch on north end of home.

6 Single-wide – no visible damage

Figure 21. Orthomosaic of the tornado path through a mobile home community just north of Booth, AL. The tornado path appears to have been only a few yards wide at this point.

In total, at least 7 homes experienced minor to moderate roof and siding damage, several outbuildings were destroyed, and 2 additional mobile homes were destroyed. One of the mobile homes was rolled over, as seen in Figure 22 below, and the two residents inside were injured. The other mobile home, less than 100 yds away from the home that rolled and also in the direct path of the tornado, had its roof ripped off and part of the leeward wall collapsed outwardly with the roof (Figure 23). The mobile home that rolled was already bulldozed into a pile of debris by the time of the FAT-1 assessment, but the NWS assessment team (personal communication) observed no straps or anchors present in this mobile home. The other mobile home that only lost the roof did have anchor straps consisting of helical anchors (unknown depth, spaced 8-9 ft on center) with 12 inch stabilizer plates attached to galvanized steel straps (2-inch width). At least one strap was detached from the ground anchor due to corrosion. Both mobile homes were built in the mid-1970s according to the property manager. FAT-1 also assessed a single-family residence near the tornado's path, southwest of the mobile homes mentioned above, that sustained only minor roof damage. The roof lost approximately 15-20% of its shingles, but sustained no other damage. According to the owner, the roof was installed in 2006. Another mobile home approximately 150 yds northeast of the single-family residence appeared to be undamaged. No ground anchors were visible in a limited inspection of this mobile home, which was located in a small dell relative to the single-family site-built home to the southwest and the rolled mobile home to the northeast.

The inconsistent anchorage observed in this small, rural community of mobile homes is concerning, and work is ongoing to identify whether this is a trend in existing manufactured homes in rural settings. Rural mobile home residents typically have few if any safe options for shelter in advance of a tornado given the abbreviated warning lead times, and obvious structural deficiencies such as a complete lack of anchorage or missing anchorage elements enhance the vulnerability of what is already a highly vulnerable shelter option. Inspection of the mobile homes in the path of the Booth, AL tornado indicates that contributing factors to the heightened vulnerability of mobile homes include, amongst others, the aforementioned inconsistencies in ground anchorage, the reduced weight of the structure due to use of smaller structural members, the height-to-breadth aspect ratio (higher ratios induce larger overturning moments), and the lack of debris impact-resistant cladding materials. Moreover, for those residents who have no option but to shelter in a mobile home, it is not apparent what the best available refuge area is given the lack of interior rooms in such structures. Research is ongoing in efforts to further improve our understanding of the social and physical vulnerabilities of mobile home residents to tornadoes[18]. State regulations regarding the anchorage and installation of mobile homes is detailed in Chapter 535-X-13 of the Alabama Manufactured Housing Commission Administrative Code[19].

[18] Strader, S. M., & Ashley, W. S. (2018). Finescale assessment of mobile home tornado vulnerability in the central and southeast United States. *Weather, climate, and society*, *10*(4), 797-812.
[19] http://www.amhc.alabama.gov/PDF/Rules/13MFCH.pdf

Figure 22. Single-wide mobile home rolled over due to tornado, injuring 2 people. (Source: https://www.weather.gov/bmx/event_01192019booth)

Figure 23. Single-wide mobile home that lost the majority of its roof.

Other Events

The Tyler Tornado, rated an EF-1, touched down northwest of Tyler, AL, at County Road 74. It traveled northeast for about 6 miles before lifting off the ground just past the Alabama River. It was an estimated 75 yds wide at its widest point and had estimated maximum wind speeds of 100 mph (per the National Weather Service). There were no injuries and no buildings were damaged, but many trees were snapped and farm equipment was damaged (Figure 24).

The Coosa County Road 101 Tornado, was also rated an EF-1, but was only briefly on the ground. It touched down near County Road 101 and moved northeast along the road for 1.8 miles before lifting. According to the National Weather Service, the maximum width was 112 yds and the estimated maximum wind speeds were 100 mph. There were no injuries or buildings damaged, but as with the Tyler Tornado, several trees were knocked down (Figure 24).

Figure 24. Left: Trees uprooted by the Tyler Tornado; Right: Trees snapped and uprooted by the Coosa County Road 101 Tornado. (Source: https://www.weather.gov/bmx/event_01192019)

The Leake Tornado, rated an EF-1, touched down northeast of Redwater, MS, south of Barnes Rd. It traveled north for about 1.4 miles until lifting just north of Duncan Rd. At its widest, the tornado was estimated to be 250 yds wide with maximum wind speeds of 90 mph (National Weather Service). There were no injuries, but 4 chicken coops were turned over and several trees were knocked over (Figure 25).

Two tornadoes touched down in Rankin County, MS, very close to each other. The first, rated an EF-0, touched down just east of Florence, MS, at McCullough McLin Rd and traveled northeast for approximately 2.7 miles before lifting north of Coke Rd. The tornado was estimated to be 150 yds at its widest point with maximum wind speeds of 74 mph (National Weather Service). There were no injuries and no building damage, but branches of trees were snapped. The second tornado in Rankin County was rated an EF-1 and touched down south of Brandon, MS, near Old Lake Rd. After touching down, it traveled northeast for almost 2.5 miles before lifting just east of US Highway 18. At its peak, the tornado was 150 yds wide with estimated maximum wind speeds of 88 mph (National Weather Service). There were no injuries reported, but at least 2 homes received minor damage from fallen limbs. The tornado also downed power lines and several trees (Figure 25). The damage left almost 300 people without power in Rankin County, according to WKRG Local News.

Figure 25. Left: Trees uprooted by the Leake Tornado (Source: National Weather Service, Jackson, MS WFO); Right: Trees uprooted by the EF-1 Rankin County Tornado, causing damage to houses and power lines (Source: https://www.wkrg.com/news/local-news)

The Neshoba Tornado was a very small EF-0 tornado that touched down southwest of Philadelphia, MS, and just north of US Highway 485. It traveled north for only 0.26 miles before lifting. It was at most 50 yds wide with estimated maximum wind speeds of 75 mph (per NWS). There were no injuries or building damage, but large tree limbs were snapped.

The Washington Parish Tornado, rated an EF-1, touched down near Franklinton, LA, west of Buford Creek Rd. It traveled northeast for 1.2 miles before lifting near T.C Brunfield Rd. The estimated maximum width of the tornado was 75 yds and the maximum wind speeds were 105 mph. No injuries were reported, but one house lost its roof and a mobile home was destroyed (Figure 26), according to the National Weather Service. The tornado also downed several trees and flipped a truck over.

Figure 26. Mobile home that was destroyed by the Washington Parish Tornado (Source: https://www.wdsu.com/)

The Tyndall Air Force Base in Florida also experienced an EF-1 tornado, just months after being hit by Hurricane Michael. The tornado touched down near Suwannee Rd. on the base and traveled northeast for approximately 0.8 miles. It was 50 yds wide with estimated maximum wind speeds of 90 mph. There were no injuries, but the winds damaged a portion of a new roof on a barracks

(Figure 27), damaged, moved a car (Figure 28), and flipped dumpsters (NWS). It is unknown at this time whether the roof had been replaced before or after Hurricane Michael. Either way the damage deserves further scrutiny, as either 1) a new roof that should have been designed to 135 mph or greater was damaged in an apparent 100 mph tornado, or 2) a roof that survived the 135+ mph wind speeds of Hurricane Michael failed in a relatively weak tornado. More details are being sought.

Figure 27. New roof of a barracks peeled back due to tornado winds on the Tyndall AFB (Source: National Weather Service, Tallahassee, FL WFO)

Figure 28. Car was moved and the windows were shattered due to the tornado on the Tyndall AFB (Source: National Weather Service, Tallahassee, FL WFO)

Recommendations for Further Study

FAT-1 primarily focused assessments on downtown Wetumpka, AL and a mobile home community north of Booth, AL. Preliminary review of assessments logged by the team in these areas, in addition to observations by the team members as they traveled throughout the impacted areas, have led to the following recommendations for future study:

1. Investigate the potentially elevated short-term and longitudinal vulnerability of urban clusters (populations 2,500 - 50,000) and rural communities to tornadoes. Urban centers (population > 50,000) are better able to absorb the impacts of tornadoes due to the relatively small area of impact in a typical tornado. In urban clusters or rural communities however, the impacts are magnified relative to the available resources, particularly if damage does not qualify for FEMA assistance. With fewer resources available to absorb tornado impacts, heightened resilience measures (e.g., choosing to build above minimum life safety construction standards) should be considered, similar to how island nations must often choose heightened resilience standards for hurricanes, in part due to their isolation[20].
2. Document vehicular movements in tornadoes whenever possible, as doing so will ultimately improve our understanding of the dynamic, multi-axis components of the near-surface flow within and near the tornado vortex.
3. Investigate the physical vulnerabilities of existing mobile homes in light of the requirements for manufactured housing provided in Alabama Manufactured Housing Commission Administrative Code.
4. Investigate best available refuge options for mobile home residents in both single-wide and double-wide mobile homes where interior rooms are generally not present. While sheltering in a mobile home is not recommended, many residents are limited in their sheltering options, particularly in rural settings when the distance to the nearest community shelter is prohibitive.
5. Investigate further the failed roof system on the Tyndall Air Force barracks building. It would appear that the roof system failed well below design, but it is unclear whether installation deficiencies may be to blame, or whether this is evidence of the enhanced wind loads that tornadoes may induce at localized scales, whether accumulated damage in previous storm events (i.e., Hurricane Michael) led to premature failure, or if this roof was only temporary replacement for a roof damaged in Hurricane Michael.

Appendix

The following graphics and tables document the downtown portion of the Wetumpka, AL tornado and observed damage or lack thereof. Data should be considered preliminary. Final data will be published through DesignSafe.

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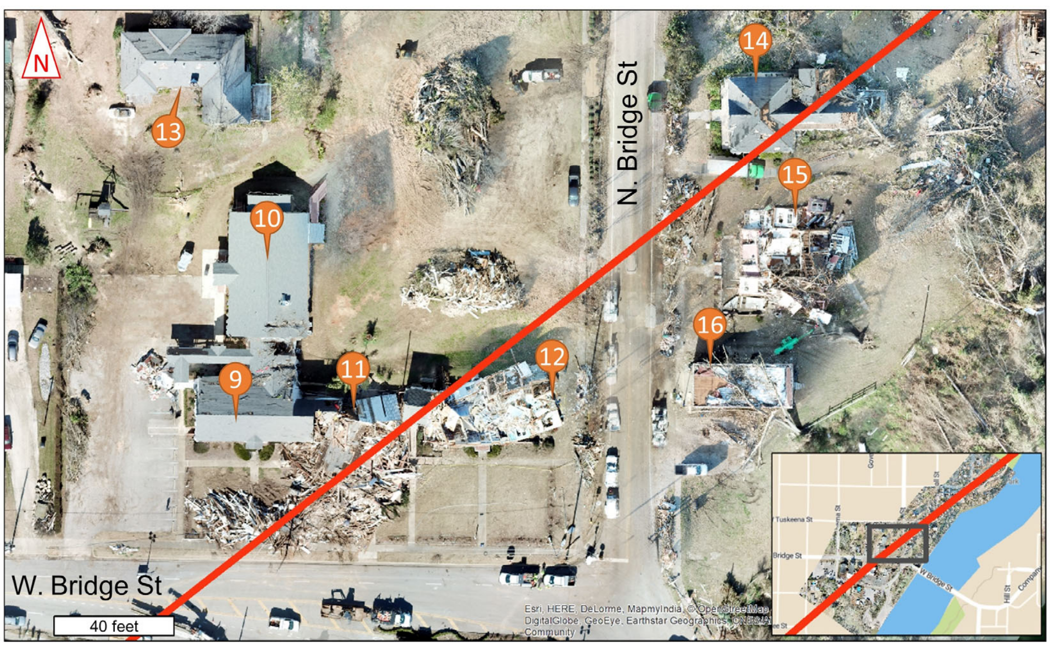
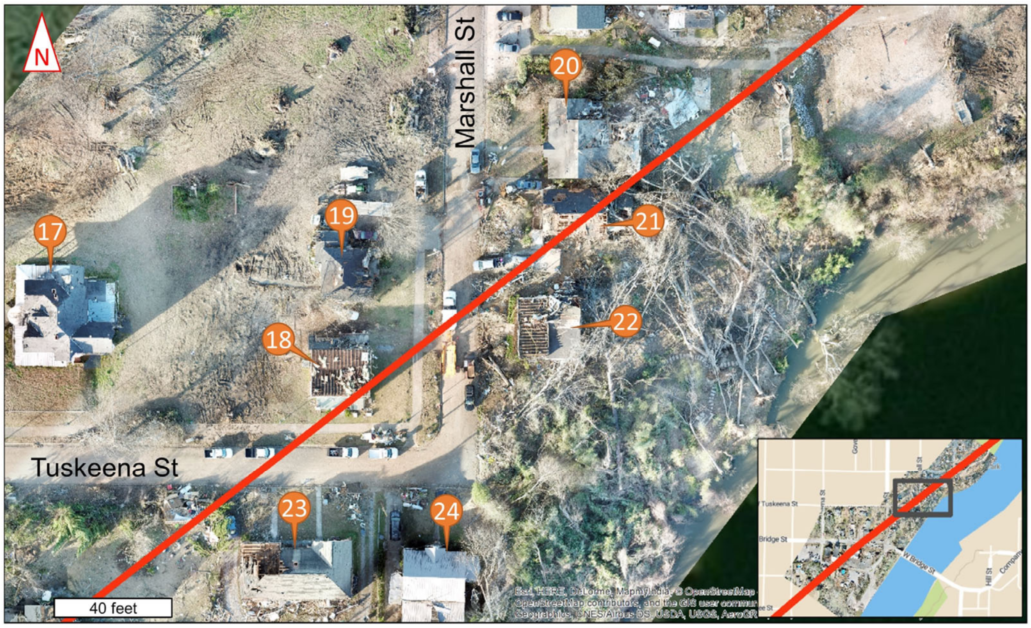
[20] Prevatt, D. O., Dupigny-Giroux, L. A., & Masters, F. J. (2010). Engineering perspectives on reducing hurricane damage to housing in CARICOM Caribbean Islands. *Natural Hazards Review*, *11*(4), 140-150.

1 First Baptist Church Campus Building (MC1)
2 First Baptist Church Campus Building (MC2)
3 First Baptist Church Campus (MC3)
4 First Baptist Church iMPACt Center
5 First Baptist Church Campus - Detached garage
6 First Baptist Church Campus - Detached garage
7 Single-story, light wood-frame home
8 Single-story, light wood-frame home



9 First Presbyterian Church (West Wing)
10 First Presbyterian Church (North Wing)
11 First Presbyterian Church (Historic Sanctuary)
12 First Presbyterian Church (East Wing)
13 Single-story, light wood-frame home
14 Single-story, light wood-frame home
15 Single-story, light wood-frame home
16 Prissy Hen commercial building



17 Two-story, wood-frame home
18 Single-story, wood-frame home
19 Single-story, wood-frame home
20 Single-story, wood-frame home
21 Single-story, wood-frame home
22 Single-story, wood-frame home
23 Single-story, wood-frame home
24 Two-story, wood-frame multi-family structure

25 Wetumpka Police Station

26 Wetumpka Senior Center

Building Number	Building Description (DI)	DOD	Exp. Wind Speed (mph)	Est. Wind Speed (mph)	Year Built
1	FBC Building (20)	2	86	86	1967*
2	FBC Building (20)	2	86	86	1967
3	FBC Building (20)	5	114	120	1852
4	iMPACt Center (17)	6	143	130	2013
5	Detached Garage (21)	1	67	120	n/a
6	Detached Garage (21)	8	155	120	n/a
7	Single-Family Residence (2)	4	97	105	1875
8	Single-Family Residence (2)	6	122	120	1875
9	FPC North Wing (5)	2	99	99	n/a
10	FPC West Wing (5)	2	99	99	n/a
11	FPC Historic Sanctuary (n/a)	-	-	120	1857
12	FPC East Wing (5)	8	152	135	n/a
13	Single-Family Residence (2)	2	79	79	1960
14	Single-Family Residence (2)	4	97	105	1890
15	Single-Family Residence (2)	8	152	135	1930
16	Prissy Hen Retail Building (8)	4	98	98	1930
17	Single-Family Residence (2)	3	96	96	1960
18	Single-Family Residence (2)	4	97	110	1936
19	Single-Family Residence (2)	4	97	100	1930
20	Single-Family Residence (2)	4	97	97	1934
21	Single-Family Residence (2)	4	97	105	1940
22	Single-Family Residence (2)	4	97	110	1890
23	Single-Family Residence (2)	6	122	122	1946
24	Single-Family Residence (2)	2	79	79	1930
25	Police Station (17)	5	133	130	n/a
26	Senior Center (8)	8	144	130	n/a
Notes: FBC = First Baptist Church, FPC = First Presbyterian Church					

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StEER further thanks the National Weather Service Birmingham Weather Forecast Office, specifically meteorologists John Deblock and Chris Darden, for their efforts in coordinating the successful early warning efforts, conducting the initial damage surveys and sharing helpful information with the StEER team. Appreciation is also expressed to First Baptist Church of Wetumpka for their willingness to share the security footage and other information to help inform the report.

About StEER

The National Science Foundation (NSF) awarded a 2-year EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network. StEER's vision is to *build societal resilience by generating new knowledge on the performance of the built environment through impactful post-disaster reconnaissance disseminated to affected communities*. StEER achieves this vision by: (1) deepening structural engineers' capacity for post-event reconnaissance by promoting community-driven standards, best practices, and training; (2) leveraging its distributed network of members and partners to coordinate early, efficient and impactful responses to disasters; and (3) broadly engaging communities of research, practice and policy to accelerate the potential to learn from disasters. StEER works closely with other extreme event reconnaissance organizations and the Natural Hazards Engineering Research Infrastructure (NHERI) to foster greater potentials for truly impactful interdisciplinary reconnaissance after disasters.

StEER relies upon the engagement of the broad NHE community, including creating institutional linkages with dedicated liaisons to existing post-event communities and partnerships with other key stakeholders. While the network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Atlantic/Gulf Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER aspires to build a network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI),** University of Notre Dame, serves as StEER Director responsible with overseeing the design and operationalization of the network.
- **Khalid Mosalam (co-PI),** University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, leading StEER's Pacific Regional node and serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI),** University of Florida, serves as StEER Associate Director for Wind Hazards, leading StEER's Atlantic/Gulf Regional node and serving as primary liaison to the Wind Engineering community.
- **Ian Robertson (co-PI),** University of Hawai'i at Manoa, serves as StEER Associate Director for Assessment Technologies, guiding StEER's development of a robust approach to damage assessment across the hazards.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data.

StEER's response to these tornadoes preceded the formation of its official policies, protocols and membership, which are still in active development. All policies, procedures and protocols described in this report should be considered preliminary and will be refined with community input as part of StEER's operationalization in 2018-2019.

StEER Event Report Library

2019

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