

Advancing Forensic Engineering Analyses of Tornadoes with Survivor's First-Hand Accounts



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NOAA VORTEX-SE Program
NA16OAR4320115 and
NA19OAR4590212



The Background We Build Upon

Ted Fujita interviewed survivors to understand tornado appearance, location, and behavior

NIST studied protective action decisions and used survivor interviews to identify tornado centerline and understand locations / mechanism of injury

BURLESON	Jun. in	101	Bedroom	sleep	Radio	NO	✓	✓	BSMT	F2
	I leave	104	"	"	"	NO	✓	✓	BSMT	F2
ATKINSON	Edgar	105	BSMT	writing	Radio	+	✓	✓	remain BSMT	F3
KINK	Lisa	106	Bedroom	in bed	NO	+	✓	+	run to Living Rm	F3
ESTES	Jammy	109	Bedroom	in bed	NO	+	✓	✓	Bedroom	F4
TIDWELL	W.D.	108	Living Rm	Something	NO	+	✓	✓	BSMT	F2
	Tony	109	"	"	NO	+	✓	✓	BSMT	F2
FRANKS	Lowell	110	Yard	watching	Radio	NO	✓	+	RUSH TO BSMT	F3
	Faye	111	Living Rm	Something	"	"	✓	✓	"	"
	Jim	112	Living Rm	Something	"	"	✓	✓	"	"
GILAS	Robert	113	DEN	sitting	Radio	+	✓	✓	rushed BSMT	F3
	Fannie	114	DEN	"	"	+	✓	✓	"	F3
DOSS	Blaines	115	CELLAR	watching	TV	+	✓	✓	rushed CELLAR	F4
	Vandy	116	"	"	"	+	✓	✓	"	FR
BERRYHILL	Mv.	117	Mobile Home	something	Radio	+	✓	✓	rushed CELLAR	F3
	Mrs.	118	Mobile Home	"	Radio	+	✓	✓	rushed CELLAR	F3

Screen capture from the PBS, The American Experience episode on Mr. Tornado



Conceptual Frameworks

Wind & Structural Engineering

Prior research focused on:

- quantify common damage mechanisms
- infer correlations
- identify common weaknesses

Less effort on:

- examination of building interiors
- incorporate resident-provided insight of structural details, damage initiation, damage progression
- verifying whether common sheltering guidance remains valid and useful

Survivor Experiences

Prior research focused on:

- protective action decision making
- receipt and comprehension of warning messages

Less effort on:

- nuances of the shelter decision
- how caregiving responsibility impacts protective actions and mitigation efforts
- willingness to adopt mitigation techniques for tornadoes
- how mitigation efforts affect long-term coping and resilience

Overall Study Objectives



Create an integrated, interdisciplinary post-tornado assessment strategy and interview **protocol**

Survivor Story Analysis Check Sheet

Date: _____ Time: _____
Present at time of tornado: _____
Interviewer(s): _____

Story

- ☐ When first hear about it? ...how usually hear?
- ☐ How threat felt compared to other days?
- ☐ Alerts or warnings that day? ...different about them? ...talk w/anyone?
- ☐ Monitoring the weather?
- ☐ What do before? Why?
- ☐ Saw, hear, feel?
- ☐ Who with you?
- ☐ Say to each other?
- ☐ Do to feel better/safe?
- ☐ Order of notifications (first, next, last)
- ☐ What all went into your decision?
- ☐ Order of damage (first, next, last)
- ☐ Shelter affected?
- ☐ Been in tornado before? ...saw/experience them? ...thought about what you'd do?
- ☐ Age of home?
- ☐ Anything about condition?
- ☐ Photos of immediate aftermath, security camera, video doorbell, etc?
- ☐ Children 10-17: what do you remember ...before? ...during? ...after? Who was here w/you?
- ☐ Did you take shelter? ...say or do while sheltering? ...try to feel better, less scared?
- ☐ Is it okay if reach out to follow up with any more Qs?

Name: _____
Phone or Email (their preference): _____

Analyze findings to characterize:

risk factors related to the tornado & surroundings

efficacy of **best available** sheltering

influences on decision-making regarding **sheltering**

benefits of the interdisciplinary protocol



Methods

Develop an inter-science protocol:

Interview: Based on Kuligowski/NIST's Joplin study

- **Main Prompt**

Story from first heard until tornado

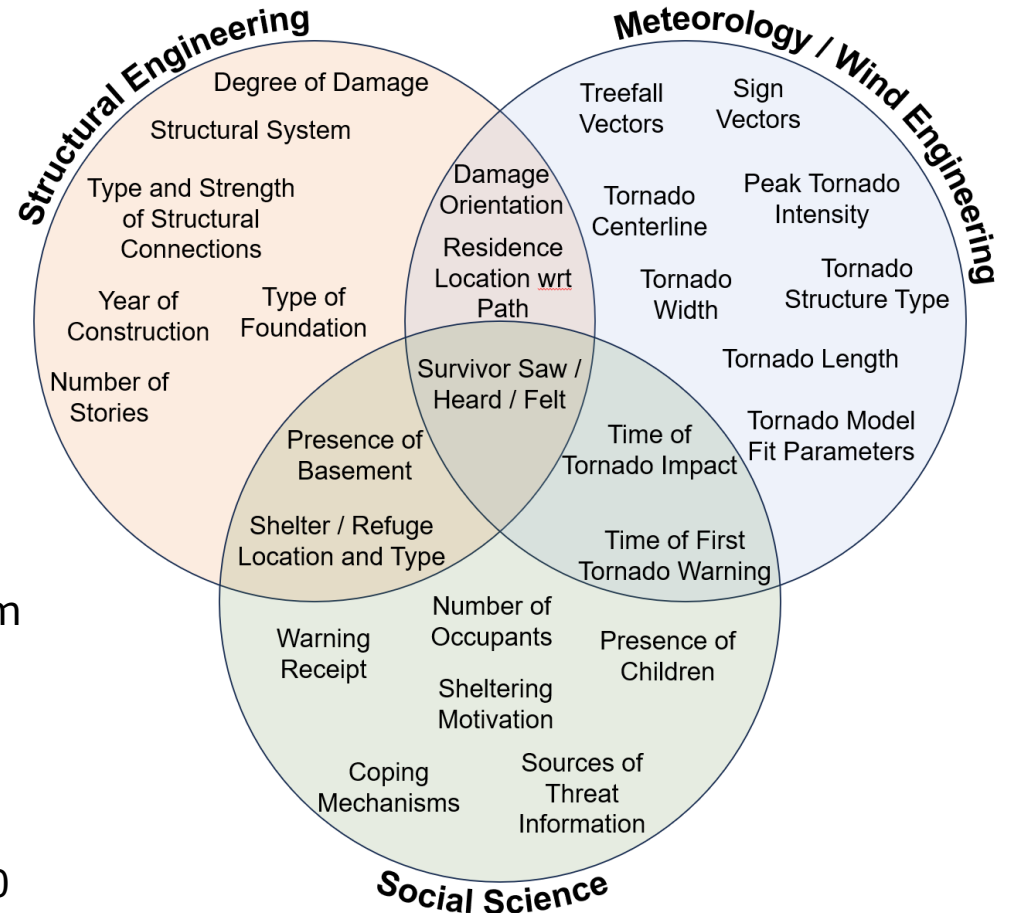
- **Follow-Up Prompts**

Address all points of interest

Follow-up Interviews: ~1 yr later

Engineering Assessment:

- Wind intensity and direction inferred from treefall patterns and debris fields
- Primary elements and strengths of the structural load path; exterior & interior
- Data include on-site photos, street-level panoramas, UAV imagery, and interior 360 photos/video.



Are Survivor Stories Accurate?



- Autobiographical memories of traumatic, highly stressful, or emotional events = flashbulb memory
 - Often cannot be forgotten
 - Consensus: ~80% of the details accurate 4-5 months post event
 - Signals exist, e.g., switching to 3rd person suggest altered aspects of story
- Other research on trauma suggests similarly that memory of key images and sounds are retained



Yuille and Cutshall 1986, Brown and Kulik 1977, Luminet and Curci 2018, Talarico and Rubin 2009, van der Kolk and Risler 1995

Development & Analysis of Our Interdisciplinary Protocol



Photo courtesy Tim Marshall

Our research was conducted under the purview of OU's Institutional Review Board, with IRB Authorization Agreements from AU and IU.

Similar research in the EU would use an equivalent approval process to protect participants' rights and welfare.

Creating a Useful Tool



Begin with an open-ended question:

- Can you walk me through your experience starting from when you first heard about the forecast of a tornado to the tornado hitting your home?

Questions for detail will be asked to build or fill in the timeline.

About preparing and information seeking prior to the storm:

- How did you first hear about the possibility of severe weather?
 - Was that how you usually hear about severe weather?
 - Was there anything different about the alerts this time? More of them, more often, what the messages said...?

Survivor Story Question Prompts
February 7, 2020

The primary goal is to have the tornado survivor describe the experience of preparing for the storm before it occurred, and the experience of sheltering during the storm. The participant will be allowed to first present their own unstructured narrative, and then some follow-up questions will be asked. Follow-up questions (below) are meant to help in copying mechanisms before and during the storm, including things like information gathering, personalization of the risk, sheltering actions, and how their personal networks affected what their thinking and actions. We are also interested in anything they can recall about what they saw, heard, or felt during the tornado to inform forensic engineering analyses of damage.

Begin with an open-ended question:

- Can you walk me through your experience starting from when you first heard about the forecast of a tornado to the tornado hitting your home?

Questions for detail will be asked to build or fill in the timeline.

About preparing and information seeking prior to the storm:

- How did you first hear about the possibility of severe weather?
 - Was that how you usually hear about severe weather?
 - Was there anything different about the alerts this time? More of them, more often, what the messages said...?
- When did you first know there was a storm?
- Did you or other family members do anything to prepare?
- For example, did you clean out your weather radio to turn on notifi...
- Was there any discussion about the possibility of severe weather anywhere else you were, in the days before?

About your experience during the storm, for those cues, and how those cues may have caused you to act:

- What did you do just before the storm?
- At some point did you feel like you were in danger?
- Did you hear or see the tornado approaching?
- Who was with you?
- Are they usually here with you?
- Was there anything that was special about this time?
- Did you talk about the approaching storm?

About the structure:

- What happened first... next... last?
- We are wanting to identify the sequence of damage, as well as identify items for further clarification: Cue → Interpretation → Action
- If manufactured or mobile home: Do you know how your home is anchored?
- Did you have any choice in how it was anchored?
- Have you heard about the pain anchors? Do you know what they do?
- Clarification questions about order and actions:
 - E.g.:
 - Was the window bowing inward the first thing that you noticed as the storm started to hit?
 - What happened after you saw the window bow inward? Did it break?
 - Was the door latched or locked before it swung open from the wind?
- What did you see / hear / feel during the storm?
- Could you tell when the tornado started to hit?
- Was your shelter affected by the storm?
- Did you have any trouble getting out of your shelter?

1.5 pages vs. 1

Sentences vs. phrases

Survivor Story Analysis Check Sheet

Date: _____ Time: _____
Present at time of tornado: _____
Interviewer(s): _____

Story

S Q When first hear about it? ...how usually hear?

S Q How threat felt compared to other days?

S Q Alerts or warnings that day? ...different about them? ...talk w/anyone?

Survivor Story Analysis Check Sheet

Date: _____ Time: _____
Present at time of tornado: _____
Interviewer(s): _____

Story

☐ When first hear about it? ...how usually hear?

☐ How threat felt compared to other days?

☐ Alerts or warnings that day? ...different about them? ...talk w/anyone?

☐ Monitoring the weather?

☐ What do before? Why?

☐ See, hear, feel?

☐ Who with you?

☐ Say to each other?

☐ Do to feel better/safe?

☐ Order of notifications (first, next, last)

☐ What all went into your decision?

☐ Order of damage (first, next, last)

☐ Shelter affected?

☐ Been in tornado before? ...see/experience then? ...thought about what you'd do?

☐ Age of home?

☐ Anything about condition?

☐ Photos of immediate aftermath, security camera, video doorbell, etc?

☐ Children 10-17: what do you remember ...before? ...during? ...after? Who was here w/you?

☐ Did you take shelter? ...say or do while sheltering? ...try to feel better, less scared?

☐ Is it okay if reach out to follow up with any more Qs?

Name: _____
Phone or Email (their preference): _____



Long Initial Story, Unanticipated Info

Story

Story includes WHO was there, WHAT they were doing

Unanticipated information!

Sheltering actions

Sequence of damage

So, myself and my wife and we have two dogs. So, we were home watching T.V. and our [pause], you know, our weather radio was going off more frequently because of the storms coming in. So, we decided to switch to the local news, the local news channel. So, we switched to the local news, and we were watching them and as we started hearing the roads as they were calling them off so they were saying if you were in the vicinity of road 334, you need to take shelter now. If you're in the vicinity of 51 you need to take shelter now. So, we don't really know a lot of the names of some of the landmarks. We've only been here about three years. So, we don't know the names of a lot of the landmarks like the churches and that that they were referring to. My wife worked at Tuskegee University at the time or had worked at Tuskegee University. So, she knew some of the roads out that way a little better than I did. So, when it hit one of the roads that she recognized, she said, yeah, we need to head to the center bathroom in the house. [voice speeds up] So, we scooped up the dogs and took the iPad and our cellphones and went into the center bathroom. She got in the bathtub with the two dogs and I just kind of sat there next to her and we were listening and waiting. First thing that happened was the power went out. So, when the power went out, we kind of knew it was getting closer. Then, I had been a tornado before growing up in Wisconsin. So, I knew the sound of a like [contemplating] a freight train or a jet engine. That sound. So, we started to hear that and then once we heard that, we believed the first thing that went, we had a front awning on the front of the house over the garage here. We believe that was the first thing that went. (Pos. 3)

Challenge of Keeping Track



Photo courtesy Tim Marshall

S = information
included in Story

Q = question was
asked during
follow-up

Survivor Story Analysis Check Sheet

Date: Time:
Present at time of tornado:
Interviewer(s):

Story

- S Q When first hear about it? ...how usually hear?
- S Q How threat felt compared to other days?
- S Q Alerts or warnings that day? ...different about them? ...talk w/anyone?
- S Q Monitoring the weather?
- S Q What do before? Why?
- S Q See, hear, feel?
- S Q Who with you?
- S Q Say to each other?

Importance of Follow-up Questions



SQ Order of damage (first, next, last)

- **Q Then you lost electricity?** The power started coming on and off. And then all of a sudden about 20 minutes. ... it was before the storm. (Pos. 280-284)
- **Q how long before?** D: I'd reckon about five minutes, maybe. N: Five, 10 minutes. (Pos. 304-308)

Information
added later in
response to the
Question

Initial
Story

- **S** As soon as we walked in the hallway, glass started breaking, doors started slamming. (Pos. 20)
- **S** As soon as we closed the bathroom door, I was holding it closed, and just the pressure and the shaking, the house bouncing and just everything flying. (Pos. 24)
- **Q So your house was already shaking when you went in the bathroom?** D: Like I said, as soon as we got into the hallway N: there was just everything just crashing. D: The glass started breaking and our bedroom door slammed. And as soon as I closed the bathroom door, that's when it started doing that. And that's when I put my foot against the door and we just holding onto each other. (Pos. 168-178)
- **Q Where did you hear or sense the roof and walls falling and stuff?** That's when I tell you, when you feel that weird, that squeezing pressure? That's when I knew the roof went off. That's when I knew the roof was coming off. (Pos. 340-344)

Information
added later in
response to the
Question

Findings



Photo courtesy Tim Marshall

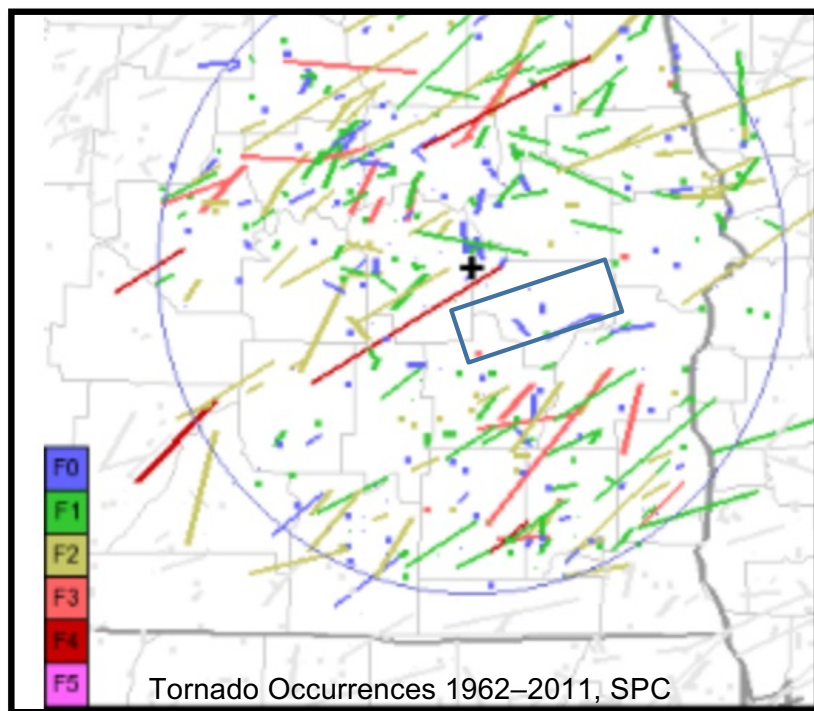
Five Clusters of Data



Lee County, AL

Sunday 2pm, ~8 min LT

Rural residential, MMH and relocated
wood frame homes

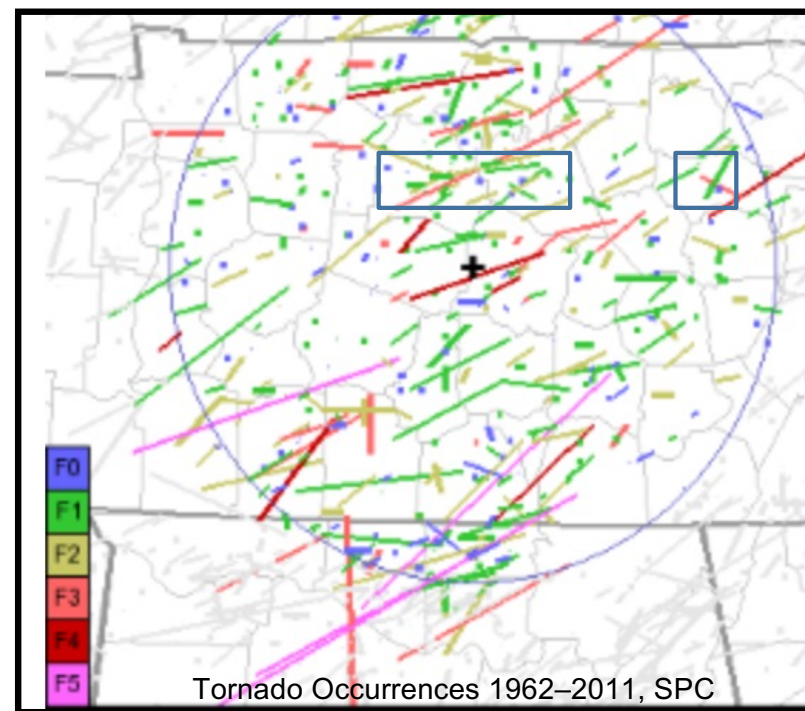


Nashville & Cookeville, TN

Wednesday 12:30am, ~8 min LT /

1:50am, 3 min LT

Urban, gentrifying, site-built homes /
Newer neighborhood, site-built homes

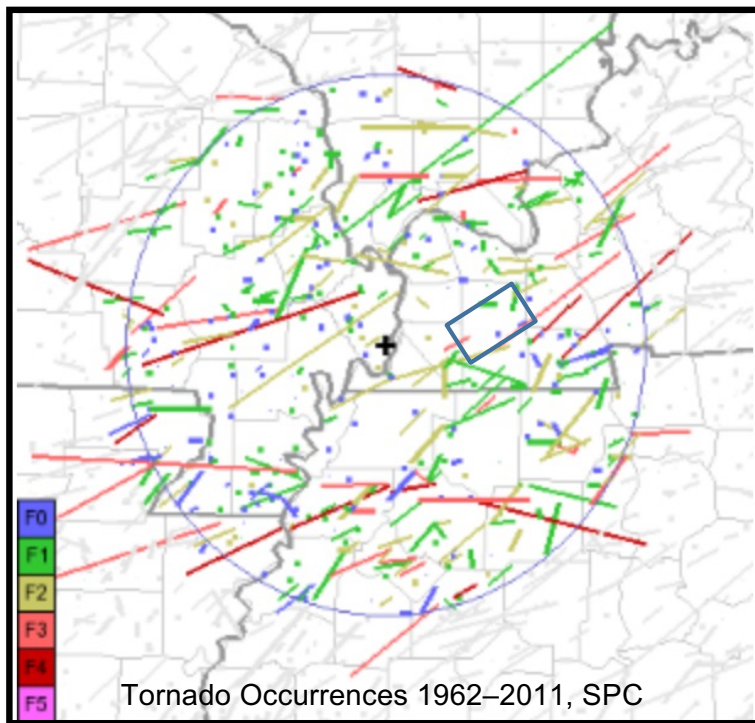


Five Clusters of Data



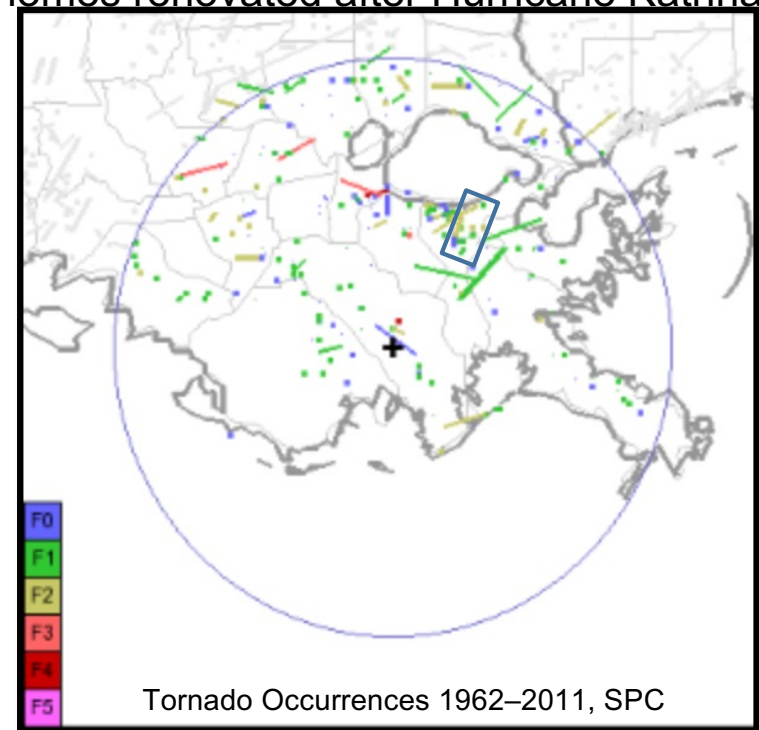
Mayfield, KY

Friday 9pm, ~23 min LT
Urban, older site-built homes



Arabi, LA

Tuesday 7:30pm, ~12 min LT
Urban, mix of new, site-built and older
homes renovated after Hurricane Katrina



Example of Data from Deployment



- Surface-Level Panoramas
- Wind Indicator (Location and Direction)
- Forensic Engineering Assessment (# = EF Rating)
- Forensic Engineering Assessment (# = EF Rating) and Survivor Interview
- Forensic Engineering Assessment (# = EF Rating) and Survivor Interview with Interior Inspection

In this area:

7 interview sites, 2
with forensic
assessment

7 home sites where
no one was present
to be interviewed

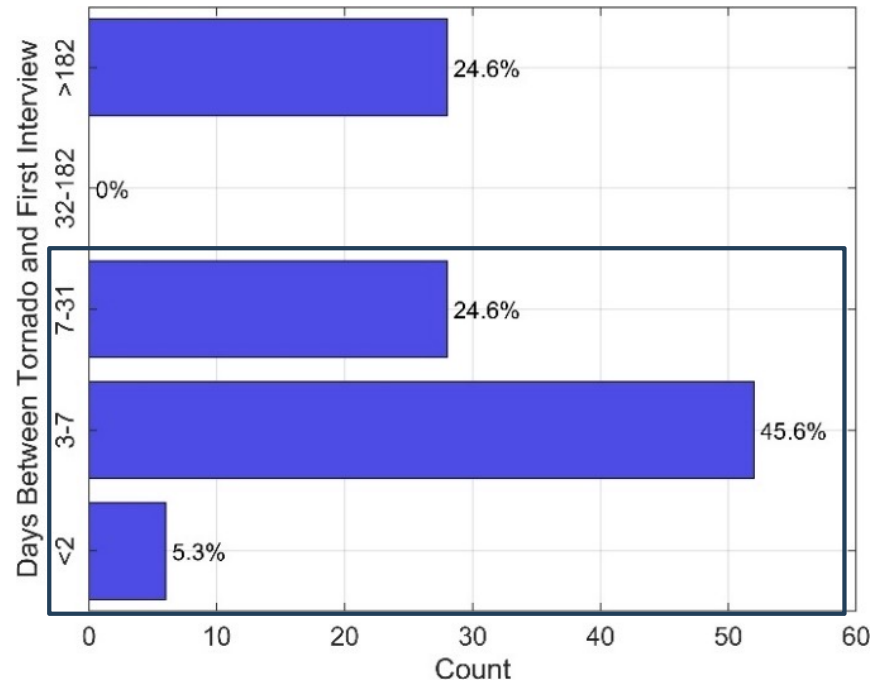
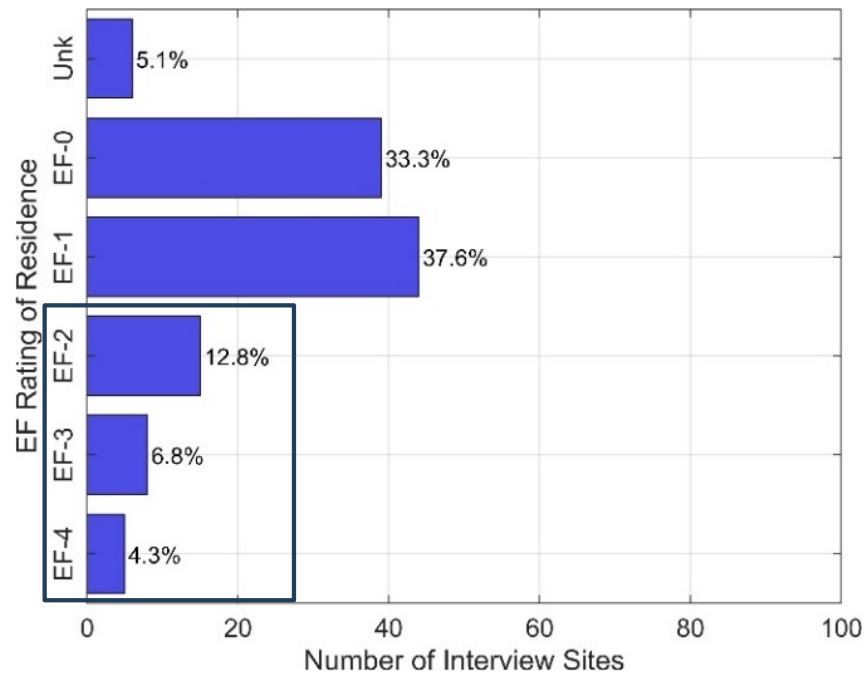


EF-Level and Tornado-to-Interview



25% of participants' homes
were rated EF-2 or higher


75% of interviews took place
within 31 days of the tornado



Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	* 	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Environmental cues were crucial given a general disbelief about threat

Phone calls from family/friends were crucial for a few

Key

* = crucial role

◇ = important

° = played a role

(blank) = absent/not mentioned

! = impact not as intended

⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*		Y
NT007	*	*	°		Y
NT002	*	*			Y
NT005	*		*		Y
NT006	*		*	*	Y
NT009	*				Y
NT004	◇	*	!	◇	Y
NT008		*			Y
NT001	!	*		!	N

Alerts were crucial given the hour and lower, later-emerging threat

Environmental cues were surprisingly important, given the hour

Key

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Cookeville, TN

Wednesday ~ 1:50am, 3 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV COVERAGE	Impact of PHONE CALL	Sheltered or attempted to?
CT001	*				Y
CT004	*				Y
CT005	*	*			Y
CT012	*	*			Y
CT009	*	*	*		Y
CT010	*	*	*		Y
CT003	*		*		Y
CT007	*	⊖; *	✧		Y
CT002	*	°		*	Y
CT006	⚠	*		*	Y
CT001				*	Y
CT008		⚠			N

Alerts were crucial

Environmental cues were also crucial, despite the late hour

Key

* = crucial role

✧ = important

° = played a role

(blank) = absent/not mentioned

⚠ = impact not as intended

⊖ = negative impact

Mayfield, KY

Friday evening ~9pm, 23 min LT



Interview ID	Impact of ENV CUES	Impact of PHONE CALL	Impact of ALERTS	Impact of FORECAST	Impact of TV	Impact of RADAR	Sheltered or attempted to?
MAY001	*		!	°	°		Y
MAY002	!, *		!, °	°		!	Y
MAY003	*						Y
MAY004	*		!	◇	◇		Y
MAY007		*		!	!		Y
MAY007a		*	!				Y
MAY009		*					Y
MAY005		*		!	!		Y
MAY006	◇		*		*		Y
MAY008			*	*		*	Y
MAY010			*	!			Y

No single factor stands out

Several factors did not have the intended impact !

Key

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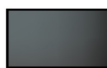
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Arabi, LA

Tuesday evening ~7:30pm, ~12 min LT



Interview ID	Impact of ENV CUES	Impact of FORECAST	Impact of ALERTS	Impact of TV COVERAGE	Impact of PHONE CALL	Sheltered or attempted to?
ARB003	*	*	◇	!		Y
ARB011	*	◇	!	!		Y
ARB007	*	◇	◇	!	◇	Y
ARB008	*	◇		*		Y
ARB004	*	°	!			Y
ARB017	*	°			*	Y
ARB012	*			*		~Y
ARB014	*		!			Y
ARB006	!, *	!	!		!	Y
ARB005	*	!	!			Y
ARB015	*	!				~Y
ARB016	*	!		*		Y
ARB002	*	⊘	!	⊘		Y
ARB001		!	*	*		Y
ARB010				*		Y
ARB013	◇		!			N
ARB009		!				N
ARB018	!	!				N

Environmental cues were crucial

Several factors did not have the intended impact ! — even more than for Mayfield

Key

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Lee County, AL

Sunday ~ 2:00pm



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TVCALL	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	*	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Weather radio went off while they were watching a movie, which got them to turn the TV on. (LC014)

Key

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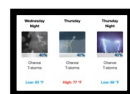
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Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	* 	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Turned TV on and heard Josh on Ch 12 call out Lee Rd 39, which was 1 mi away. (LC014)

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LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Husband looked outside and could see debris in the air. (LC014)

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LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Knew about the chance of storms by the night before but wasn't monitoring the weather. (LC001)

Key

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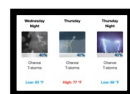
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Lee County, AL

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LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Saw a missed call; called his friend back and heard about the storms.
(LC001)

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Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	* 	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*					Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Looked outside after talking to his friend. Saw a very dark cloud.
(LC001)


Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ! = impact not as intended
- ⊘ = negative impact

Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	* 	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Heard about the chance of storms that morning at his brother's house but didn't know they were predicting a tornado or even a bad storm. After he got home, they started watching a DVD — not monitoring the weather. (LC012)

Key

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◇ = important

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(blank) = absent/not mentioned

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⊘ = negative impact

Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	*	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012		!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

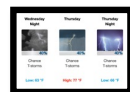
Got alert but didn't really pay attention because it looked fine outside, and they'd previously spent 2 hrs in the dark for nothing. (LC012)

Key

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- ◇ = important
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- (blank) = absent/not mentioned
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- = negative impact

Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	*	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Sister called and said there's a tornado headed toward Beauregard. Looked outside; they said, it's not even raining here. (LC012)

Key

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◇ = important

° = played a role

(blank) = absent/not mentioned


! = impact not as intended

⊘ = negative impact

Lee County, AL

Sunday ~ 2:00pm, 8 min LT



Interview ID	Impact of ENV CUES	Impact of ALERTS	Impact of TV	Impact of PHONE CALL	Impact of FORECAST	Sheltered or attempted to?
LC014	*	* 	*	◇	°	Y
LC009	*	*	*			Y
LC004	*	*	!			Y
LC006	*	◇				Y
LC008	*	*				Y
LC003	*	°				Y
LC001	*			*	!	Y
LC012	⊘	!		*	!	Y
LC013	!	*				Y
LC011			*		*	Y
LC005	◇	*				N
LC007	*		!			N
LC010						N
LC002		!		!		N

Sister turned up the volume and that's when they heard the Montgomery station say the road intersection by them with an urgent admonishment to "get in your safe place now!!" (LC012)

Key

* = crucial role

◇ = important

° = played a role

(blank) = absent/not mentioned

! = impact not as intended

⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV	Impact of FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*			Y
NT007	*	*	°			Y
NT002	*	*				Y
NT005	*		*			Y
NT006	*		*		*	Y
NT009	*					Y
NT004	◇	*	!	◇		Y
NT008		*				Y
NT001	!	*		!		N

Watching TV in bed and got an alert for the tornado on their phones. Switched to local news and it said they had 10 min.
(NT006)

Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ! = impact not as intended
- ⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV	Impact of FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*			Y
NT007	*	*	°			Y
NT002	*	*				Y
NT005	*		*			Y
NT006	*		*		*	Y
NT009	*					Y
NT004	◇	*	!	◇		Y
NT008		*				Y
NT001	!	*		!		N

Usually look at the radar to see which way it's going; this time, it was heading for them. (NT006)

Key

* = crucial role

◇ = important

° = played a role

(blank) = absent/not mentioned

! = impact not as intended

⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV	Impact of FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*			Y
NT007	*	*				Y
NT002	*	*				Y
NT005	*		*			Y
NT006	*		*		*	Y
NT009	*					Y
NT004	◇	*	!	◇		Y
NT008		*				Y
NT001	!	*		!		N

After receiving the alert, looked at the window and noticed the sky was a weird color and realized it was a tornado. (NT003)

Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ! = impact not as intended
- ⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV	Impact of FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*			Y
NT007	*	*	°			Y
NT002	*	*				Y
NT005	*		*			Y
NT006	*		*		*	Y
NT009	*					Y
NT004	◇	*	!	◇		Y
NT008		*				Y
NT001	!	*		!		N

After getting kids downstairs, they turned on the news. Realized the tornado was coming for them so they moved* to underneath the stairs in a bathroom. (NT003)

**example of multi-staged sheltering!*

Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ! = impact not as intended
- ⊘ = negative impact

Nashville, TN

Wednesday ~ 12:30am, 8 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV	Impact of FORECAST	Impact of RADAR	Sheltered or attempted to?
NT003	*	*	*			Y
NT007	*	*	°			Y
NT002	*	*				Y
NT005	*		*			Y
NT006	*		*		*	Y
NT009	*					Y
NT004	◇	*	!	◇		Y
NT008		*				Y
NT001	!	*		!		N

Phone was on silent so did not hear any alerts. (NT001)

Knew there were tornado watches happening but continued to play games and then went to bed. (NT001)

Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ! = impact not as intended
- ⊘ = negative impact

Cookeville, TN

Wednesday ~ 1:50am, 3 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV COVERAGE	Impact of PHONE CALL	Sheltered or attempted to?
CT001	*				Y
CT004	*				Y
CT005	*	*			Y
CT012	*	*			Y
CT009	*	*	*		Y
CT010	*	*	*		Y
CT003	*		*		Y
CT007	*	⊖; *	◇		Y
CT002	*	°		*	Y
CT006	⚠	*		*	Y
CT001				*	Y
CT008		⚠			N

When he first saw the warnings/watches for his county, he looked outside and saw it was pouring rain, which he assumed meant there wasn't going to be a tornado. (CT007)

Key

- * = crucial role
- ◇ = important
- ° = played a role
- (blank) = absent/not mentioned
- ⚠ = impact not as intended
- ⊖ = negative impact

Cookeville, TN

Wednesday ~ 1:50am, 3 min LT



Interview ID	Impact of ALERTS	Impact of ENV CUES	Impact of TV COVERAGE	Impact of PHONE CALL	Sheltered or attempted to?
CT001	*				Y
CT004	*				Y
CT005	*	*			Y
CT012	*	*			Y
CT009	*	*	*		Y
CT010	*	*	*		Y
CT003	*		*		Y
CT007	*	⊖; *	✧		Y
CT002	*	°		*	Y
CT006	⚠	*		*	Y
CT001				*	Y
CT008		⚠			N

But 10-15 min later, he looked and saw the sky was empty and everything was being sucked out of the sky. Then got the phone and TV alerts, then heard fence panels rattling and ran first to get his wife, then to get his daughter, who by then was running out of her room with debris following her. (CT007)

Key

* = crucial role

✧ = important

° = played a role

(blank) = absent/not mentioned

⚠ = impact not as intended

⊖ = negative impact

Mayfield, KY

Friday evening ~9pm, 23 min LT



Interview ID	Impact of ENV CUES	Impact of PHONE CALL	Impact of ALERTS	Impact of FORECAST	Impact of TV	Impact of RADAR	Sheltered or attempted to?
MAY001	*		!	°	°		Y
MAY002	!, *		!, °	°		!	Y
MAY003	*		!				Y
MAY004	*		!	◇	◇		Y
MAY007		*		!	!		Y
MAY007a		*	!				Y
MAY009		*					Y
MAY005		*		!	!		Y
MAY006	◇		*		*		Y
MAY008			*	*		*	Y
MAY010			*	!			Y

Got alerts...The one at 8 said to go to the basement. Didn't pay attention to it; they were in bed. (MAY001)

The siren went off probably over an hour before the tornado, after dark. She didn't know what it was for because nothing was there yet, according to radar. (MAY002)

Heard the siren, but didn't think anything of it because always, when he hears the sirens, the wind kicks up but then goes away. (MAY003)

Key

* = crucial role

◇ = important

° = played a role

(blank) = absent/not mentioned

! = impact not as intended

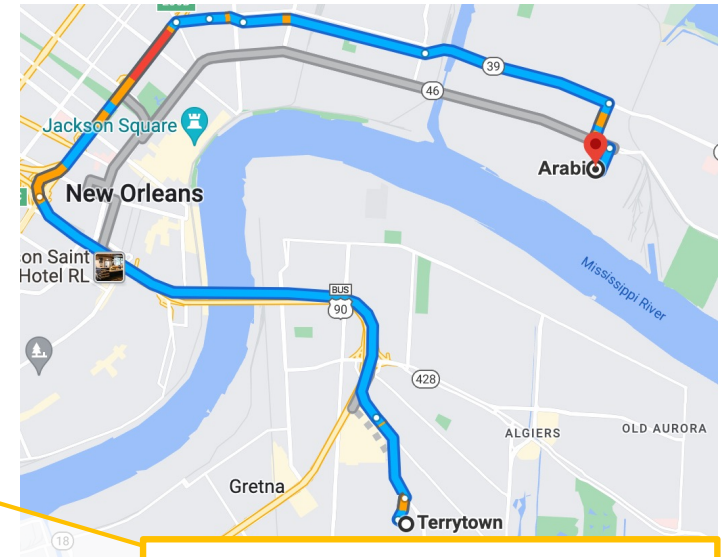
⊘ = negative impact

Arabi, LA

Tuesday evening ~7:30pm, ~12 min LT



Interview ID	Impact of ENV CUES	Impact of FORECAST	Impact of ALERTS	Impact of TV COVERAGE	Impact of PHONE CALL	Sheltered or attempted to?
ARB003	*	*	✧	!		Y
ARB011	*	✧	!	!		Y
ARB007	*	✧	✧	!	✧	Y
ARB008	*	✧		*		Y
ARB004	*	°	!			Y
ARB017	*	°			*	Y
ARB012	*			*		~Y
ARB014	*		!			Y
ARB006	!, *	!	!		!	Y
ARB005	*	!	!			Y
ARB015	*	!				~Y
ARB016	*	!		*		Y
ARB002	*	⊘	!	⊘		Y
ARB001		!	*	*		Y
ARB010				*		Y
ARB013	✧		!			N
ARB009		!				N
ARB018	!	!				N



When got TV app alert, clicked on coverage. ...didn't realize how close Terrytown was. (ARB003)

They all looked at their phones but ignored it because when do they ever get a tornado in that? (ARB006)

TV said it would be bad but we've had them before; it happens so much you tune it out. (ARB002)

Unique Insights From Survivors



- Four distinct channels of wind through the home
- Several enhancements above code

Internal Wind Flow / Non-Obvious Damage



- Computer monitor came out of upper room and was smashed on the ground below this window
- How did it come out?



Internal Wind Flow / Non-Obvious Damage



- Sweaters from the dresser in this room ended up in the attic

Complexity of Internal Wind Flow



First-hand account and walk-through revealed information on how winds flowed through the house. Many interviews contained this type of information.



Engineering Investigations were Enhanced with Survivor Interviews



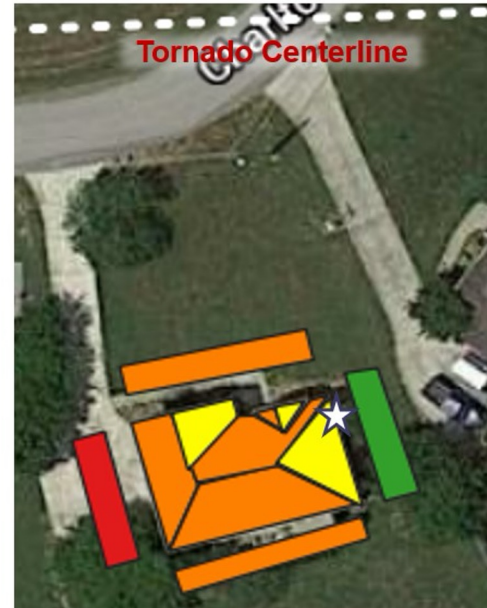
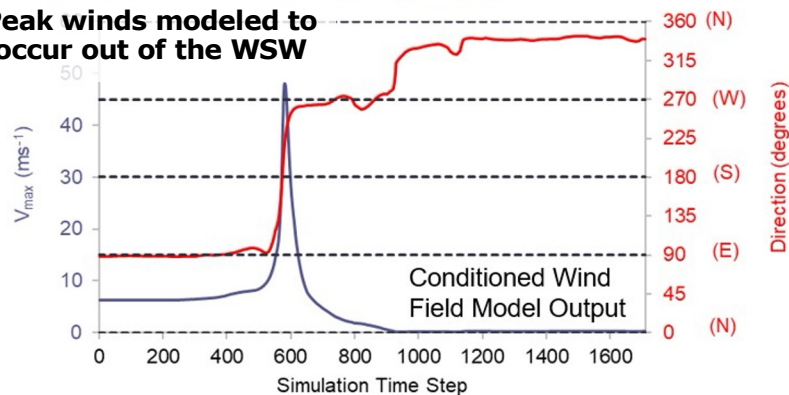
- **Survivor interviews help mitigate failure bias** — learned equally from severely damaged and better performing structures
- **Interviews uncovered enhanced construction** in better-performing homes for at least 4 home-sites; exterior damage-based wind estimates may underestimate wind speeds at these sites
- **Interior walk-throughs** allowed us to document actual and “best” shelter locations
- **Many survivors shared photos** from immediately after event before cleanup/repairs begin



Consensus Between Engineering Analysis and Survivor Experience



Peak winds modeled to occur out of the WSW



- Covering/cladding < 50%
- Covering/cladding ≥ 50 OR Sheathing < 50%
- Sheathing ≥ 50% OR Framing < 50%
- Framing ≥ 50%

Survivor Story Highlights:

- Four occupants sheltered in bedroom in SE corner of basement; first choice of sheltering location was the basement bathroom but was too small for everyone.
- Window of bedroom in SE corner blew in first with debris
- Door to bedroom shelter was sucked shut from high winds
- Debris funneled down first-floor hallway from southwest to northeast at high velocity
- North entry door and frame blown inward
- Vehicles in front of garage were pushed North.

Outcomes:

Coping & Resilience



Research as therapy

- People were very receptive; helpful for many to talk through what they experienced
- People especially appreciated inter-science interviews, enabling them to make sense of the damage

Open to learning about how to reduce damage

- Of the early interviews, four attempted to strengthen their homes
 - Two had positive experiences, resulting in a **greater sense of safety and control**
 - Two faced significant barriers, resulting in a **deep sense of unease**

Factors that helped/hurt:

- Several charities included storm shelters w/MMHs
- Some opted for a MMH to regain a sense of normalcy
- Delay in FEMA shelter rebates resulted in unease: they wanted their new storm shelter *before* storm season



Charity-provided MMH home with above-ground shelter for homeowner with mobility challenges

Outcomes:

Sheltering Availability, Practices



- **Considerable variability in sheltering behavior**
 - 1/10 of survivors did not attempt to shelter
- **Thinking/rethinking sheltering:**
 - availability of safe places in the home*
 - initial damage taking place during the storm
- **Multi-staged sheltering**
 - Some prepared a safe place and had the kids go there early
 - Some moved closer to shelter but did not shelter until threat was clear
 - ~1 in 5 participants



*Sheltering plans sometimes changed based on barriers (e.g., the closet was full of supplies)

Outcomes: Benefits to Participants



Photo courtesy Tim Marshall

- Validation of & context for their experiences
- Resources for dealing with stress, learning they can rebuild stronger
- A sense of purpose, that their experiences would advance science and the safety of future communities

...what you're doing right now is huge. I'm glad to support it because I think you're going to help in more than one way. Not just scientifically, but I think you're asking some questions that are deeper. (CT006)

Our Contributions

Wind & Structural Engineering

- examination of building interiors
- incorporate resident-provided insight of structural details, damage initiation, damage progression
- verifying whether common sheltering guidance remains valid and useful

You cannot carry their burden, but
you can walk with them for a bit



Survivor Experiences

- how experiences with tornadoes vary by time of day, region
- multi-staged sheltering
- the power of interviews — for data & for the participants



QR: Link to BAMS paper on this work

Contact: Dr. Daphne LaDue (dzaras@ou.edu)