# MOTIVATORS AND IMPORTANT FACTORS INFLUENCING TORNADO DECISIONS IN OKLAHOMA DURING MAY 2013

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ABSTRACT

There were three deadly tornado events in central Oklahoma in a two week time span in May 2013. A mass exodus of drivers occurred during the third event, clogging multiple interstates upwards of 60 miles away from the main storms. Scientists needed to understand what motivated people to act the way they did so they could better anticipate people's actions and better communicate to the public in the future. To gain a reliable understanding of this, surveys about what people did during the events were created, distributed, and collected. Factors correlated to driving were those with incomes of less than $30,000 and incomes between $70,000 and $100,000; younger age (20-39 years old), and some higher education (a complete or incomplete Bachelor's degree). Past direct experience with tornadoes was correlated to people staying at home, yet 33% of respondents did not feel safe at home. Of the 77 surveys collected, 27 (35%) respondents had never heard of mitigation before—the strengthening of their homes. Fear was commonly expressed (44%) with an undercurrent of self and home feeling vulnerable. Through these findings, scientists will be better able to anticipate Oklahomans' responses to tornadic events and the reasons behind them.

## 1. INTRODUCTION

In May of 2013, three tornado events occurred in central Oklahoma within a two week time span. The first event on 19 May—known as the "Shawnee and Carney" tornado event—was significant for a few small towns in Oklahoma, but it was quickly overshadowed by what became known as the Moore tornado event the next day (Hampton 2014).The "Moore" tornado touched down east of Newcastle, Oklahoma and strengthened to EF-5 intensity within the city of Moore. It destroyed two elementary schools and took 24 lives before it dissipated. 11 days later on 31 May, a third significant tornado occurred just south of El Reno—a rural area adjacent to the highly populated Oklahoma City metro area. This tornado was officially rated EF-3 (NWS 2013), but radar measurements suggested this tornado, that was 2.6 mi wide at its maximum, was much stronger.

David Payne of News Channel 9 displays the public's mindset for this event: "We were a city in freak-out mode—just on the edge of oh-my-gosh what else can happen?" (Razzel 2014b). Motorists had already taken to the roads before media suggested that the tornado may be 'unsurvivable above ground' (Garfield 2014). Traffic was at a standstill on multiple north-south roads and interstates (Fig. 1). News

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helicopter pilot Jim Gardner said this of the traffic: “This is not a good situation. I can’t believe these roads… I-35 is just a parking lot …” (Razzell 2014a). Congestion was found upwards of 60-70 miles away from the storm hours after it had dissipated (Garfield 2014).

All three events were predicted days in advance (NWS 2014), which triggered preparations by emergency response organizations (Brooks 2013, personal communication). All three major TV networks closely followed the events as they unfolded.

**Figure 1. Section of a divided highway on 31 May 2013 showing the traffic jam and contraflow. In many cases contraflow was the result of spontaneous actions of panicked motorists. *Photo ©Hugh Scott.***

Scientists at the National Weather Center had never seen a mass evacuation like the one on 31 May 2013. A group of meteorologists and social scientists (including LaDue and Correia) met in the Fall of 2013 to figure out a way to understand and study people’s decision making in May 2013.

By this time we had collectively seen or heard several unusual things, including: an estimated 7,000–8,000 people had taken refuge in buildings on the University of Oklahoma’s campus; many Oklahoma emergency managers discussed evacuation issues at their fall meeting; and colleagues in mobile radar trucks had witnessed traffic accidents every few miles on congested rural roads nearby the metro area; they also had an unusually high number of people trying to stop them to ask for information about the storms.

These three events led people to act in unforeseen ways—putting themselves and others in danger. We want to understand why people acted the way they did and whether their actions changed from one event to the next. If we can better anticipate future actions we can improve communication with the public the next time a tornado event occurs.

**2. LITERATURE REVIEW**

There is no single sheltering option that works for everyone. Actions taken depend on each person’s situation. Driving away works for some residents in certain situations, but not in all situations (Senkebeil et al 2012). It is acceptable to leave hours before storms are projected to hit an area (National Weather Service Weather Forecast Office Norman 2014); this is a planned action and not a panicked one. Once someone can see the storm, hear the sirens, or view the tornado warning, it is probably too late for them to safely leave.

There are mixed reports about driving away during a tornado. A study of the 3 May 1999 tornadoes by Daley et al. (2005) found that “in general, people driving away early found safety” and “the risk of directly related death and injury was higher among people remaining in homes.” Ever since the 1979 Wichita Falls tornado where 25 out of 42 people died in vehicles (Burgess 2014), driving away has been avoided and not recommended.

Hammer and Schmidlin (2000) found that there has been a decline in vehicle-occupant deaths; this finding “[does] not suggest that vehicles are to be considered unquestionably safe shelters during tornadoes” (Hammer and Schmidlin

2000). Marshall et al (2008) agree. In their damage survey of the Greensburg, KS tornado they found that "Surprisingly…45% [of cars] had not moved even when homes sustained EF-4 damage. However, the vast majority of vehicles had been breached by flying debris and would not have been safe shelters."

Hammer and Schmidlin (2002) concluded after the 3 May 1999 tornado that it is not true to assume that injury or death will occur if one is in a vehicle during a tornado warning. If a vehicle is caught in a tornado, however, this is different. This lesson was learned the hard way by the meteorological community during the El Reno tornado when veteran storm chasers Tim Samaras and Carl Young, and Samaras' son, Paul Samaras, died; their chase vehicle was intercepted and thrown by the tornado (Wurman et al 2013).

Cars do not make safe shelters if caught in a tornado. Garfield (2014) conservatively calculated that if the El Reno tornado had crossed into the more populated western side of Oklahoma City over some of the gridlocked interstates, around 225 drivers would have died. After surveying the Moore tornado damage it was also found that many cars at the Moore Medical center were pushed and lofted—with one car ending up on the roof (Burgess et al 2014). During the 8 and 9 May 2003 tornado events in Oklahoma City, 34% of injuries happened to people in vehicles (Bellala and Brown 2005). Bellala and Brown suggested that this was because of the time of day that the tornadoes occurred—around rush hour. This is compared to only 6% of injuries for people in vehicles four years earlier during the 3 May 1999 tornado events in Kansas and Oklahoma (Brown et al. 2000) possibly because these tornadoes happened in the evening after rush hour had already passed.

In order to decide what to do in a real situation, a person has to understand what constitutes a safe option for them; this depends on perception of risk; basically—"Am I in danger?" And, "how close is this danger?" It also depends on how prepared someone is, the amount of danger they feel, and if they have any previous experience with tornadoes (Burton et al. 1993; Hammer and Schmidlin 2000). Indeed, previous experience seems to be a key factor: "direct experience with hazards has a greater effect on risk perception and/or protective behaviors among respondents" (Blanchard-Boehm and Cook 2004 as quoted by Silver and Andrey 2013). Silver and Andrey (2013) add that both direct and indirect experiences amplify risk perception. Burns and Slovic (2012) also state that "People nearer to the disaster have heightened emotion and… exhibit more avoidance behavior."

How bad or severe the event is predicted to be can also influence a person's perception of risk and their subsequent actions. Ripberger, Silva, Jenkins-Smith, and James [unpublished, obtained via personal correspondence] surveyed people and found when a higher impact warning is issued residents are more likely to choose the "leave residence" option on the survey than the "shelter-in-place" option; the opposite was found to be true for lower impact warnings. When a weather situation gets serious, people are more inclined to leave their homes.

Furthermore, where someone lives and the place-based biases for that location appear to influence resident's decisions during a tornadic event (Klockow et al. 2014). For example, residents in Alabama and Mississippi tend to

feel safe in their homes and most end up sheltering in place (Klockow et al. 2014). These results agree with Hammer and Schmidlin's (2000) work on the Mortality Index for drivers. They found that "the lowest Mortality Index occurred in the Deep South despite the fact that the number of significant tornadoes in this region was nearly the same as that of the Great Plains region. Explanations for this phenomenon are unclear but may be related to … the number of vehicles occupied during a tornadic event." Because more residents feel safe in their homes, fewer people drive away; this is one possible explanation that leads to a low mortality index for the Deep South.

Similarly, when residents of Austin, TX were surveyed about a hypothetical tornado-at-home situation, 82% indicated that they would stay at home (Schultz et al 2010). This suggests that there may not be regional or state differences in how people respond to tornadoes.

This study is similar to one by Silver and Andrey (2013) where they studied the effect of two tornado warned events that occurred within days of each other; one storm produced a tornado and the other did not. We are studying the effect of three tornado warned events which all produced large tornadoes. Silver and Andrey (2013) studied people's responses to these events to see if the first event influenced responses to the second. We also looked for a similar pattern.

In summary, people make their tornado safety decisions based on a variety of reasons: where they live, how at-risk they feel, how close the danger is, if they have a plan in place, and if they have any previous experience with tornadoes.

This study will examine motivators and important demographic factors of Oklahomans that influence decision-making between those who drove away and those who did not. Also, it will further assess regional and state similarities and differences in tornado responses between Oklahoma, Texas, Alabama, and Mississippi.

**3. METHODS**

A survey was created that asked a set of questions about people's actions during the three May tornado events in central Oklahoma. The same set of questions was asked for each event. Each event was introduced with a short paragraph stating the date, day of the week, general time frame, times the tornado watch and first tornado warning were each issued, and the cities or areas affected. After a few overview questions, participants were asked about preparation and sheltering before and during the event. Multiple options could be check-marked for these questions. If a respondent could not remember, they were prompted to skip that set of questions. Respondents were also asked about their knowledge and attitudes about tornado mitigation and if they had any past direct or indirect experiences with tornadoes. Demographic information included race/ethnicity, income, education, home ownership, children at home, and meteorological training. Finally, respondents were provided with a section where they could share their stories if they so desired. Example questions are included in Table 1. This paper focuses on questions 6–9, though not to exclusion of other questions. There were 48 questions total and the surveys took 20-45 minutes to complete. The University of Oklahoma's Institutional Review Board approved all phases of this study.

| Table 1: Example Survey Questions | | |
|---|---|---|
| **Question Number** | **Question (and question type)** | **Question type** |
| 2 | Where were you when the storms occurred? | Open answer |
| 5 | In the hours (or days) BEFORE the storms occurred, did you do anything different than you normally would…because severe weather was possible? | Fixed responses and 'other' [open answer] option |
| 6a | As the storms approached your area, what did you do | Fixed responses and 'other' [open answer] option |
| 6b | If you took shelter, what type of shelter was it? | Fixed responses and 'other' [open answer] option |
| 7,8 | If you drove away, when and why did you decide to do so? | Fixed responses and 'other' [open answer] option |
| 9 | If you drove away, what happened? | Open answer |
| 28 | If you have a story to tell about how these or other events have influenced the way that you think about and respond to tornadoes, please do so here… | Open answer |

Validity of the survey questions was established by conducting cognitive interviews (Willis 2005) with LaDue's Fall 2013 general education class; Approximately 70 students attended the class the day of the interviews. The estimated demographic makeup of the students attending class was 6–10% returning adult students, some of whom were veterans or active duty military, and more than 10% were members of underrepresented racial or ethnic groups; the remainder of the class was composed of typical college age and Caucasian students. A variety of humanities (theater, photography), social science, (education, English, journalism, sociology) and natural science majors (psychology, aviation) were represented. Students were divided into groups and asked to tell one of our researchers how they and others might interpret the questions and response options. The students suggested additional response options to a few questions. Three students chose to submit completed surveys.

Minor changes to some questions were applied once the cognitive interviews were completed. Two sampling events took place: one in November 2013 at the National Weather Festival where 34 surveys were collected and the other in March 2014 where a snowball sampling method was used with those who attended a panel presentation about the May tornadoes at the National Weather Center. In the second sample 40 surveys were collected from employees, their neighbors and friends who had experienced the tornado events of May 2013 or had a story related to those events.

Once all the surveys were collected, the data was digitized. Summary statistics were generated to understand characteristics of the data. Contingency questions drove conditional statistics to compare respondents who drove away to those who stayed. Text responses were inductively coded to identify common themes in the surveys. The main theme was sub-categorized.

Following are results of these analyses to explore correlations and explanations of what motivated people to take the actions they did during the May 2013 tornadic events.

**4. RESULTS**

Respondents were told to skip sections if they did not recall or experience an event. Table 2 shows the number of complete, partial and no responses to each event. Some respondents gave partial or no demographic information.

| Table 2--Event Responses | | | | |
|---|---|---|---|---|
| Event | Complete | Partial | No response | Total |
| May 19 | n = 43 | n =15 | n = 19 | n = 77 |
| May 20 | n = 66 | n = 7 | n = 4 | n = 77 |
| May 31 | n = 61 | n = 7 | n = 9 | n = 77 |

**4.1 DEMOGRAPHICS**

| Table 3—Demographics | | |
|---|---|---|
| Statistic | Oklahoma | Surveys |
| White alone* | 67.9% | 81.0% |
| Hispanic* | 9.3% | 0.0% |
| 2+ Races | 5.8% | 3.8% |
| Black | 7.6% | 3.8% |
| American Indian* | 9.0% | 2.6% |
| Asian/Pacific Islander | 1.9% | 2.6% |
| No Answer | n/a | 6.4% |
| Female | 50.5% | 57.1% |
| 65+ years | 14.0% | 10.4% |
| Own Home | 67.5% | 62.7% |
| Bachelor's degree or higher, percent of persons age 25+* | 23.2% | 70.1% |
| Median Household Income | $44,891.00 | ~<$50,000 |

**Table 3: Comparison of demographic information from survey respondents to Oklahoma Census information (United States Census Bureau 2014). An asterisk * indicates a** large difference between survey statistics and Census data.

Demographic information for the 77 surveys is shown in Table 3. Percentages were compared to see if the survey respondents' demographics represented those of Oklahomans. The survey respondents appeared to generally represent Oklahomans with two significant differences: Hispanics and Native Americans were underrepresented (Fig. 2) and those with higher education levels were over-represented (Fig. 3). More females responded to our survey than males, which is common and was also found by Sax et al. (2003), Underwood et al. (2000), and Ling et al. (2014). Of the 77 respondents, 23 had meteorology training—either a degree or military weather training.

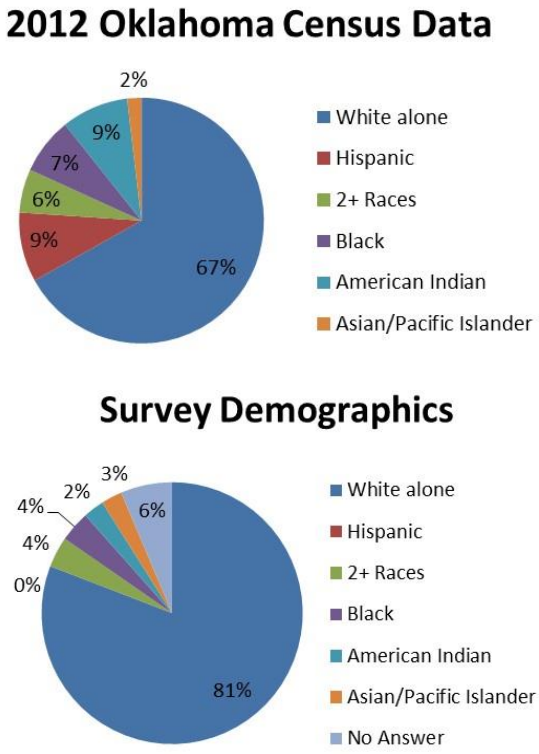


**Figure 2. The underrepresentation of minorities, especially Hispanics and American Indians.**

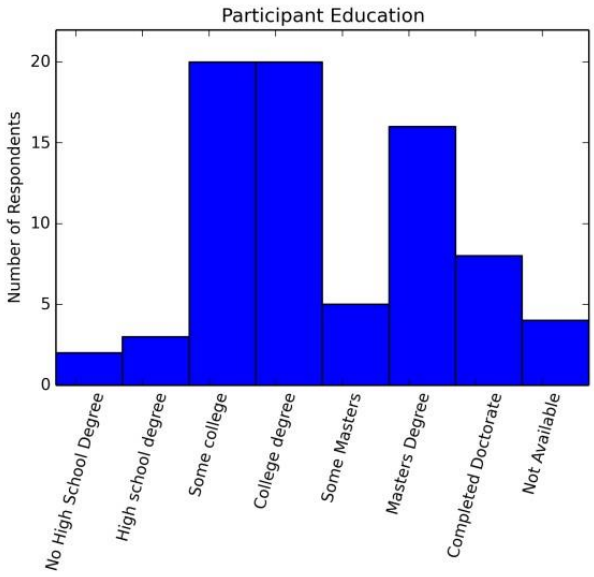


**Figure 3. The overrepresentation of those with higher education (25+ years of age with a Bachelor's degree or higher).**

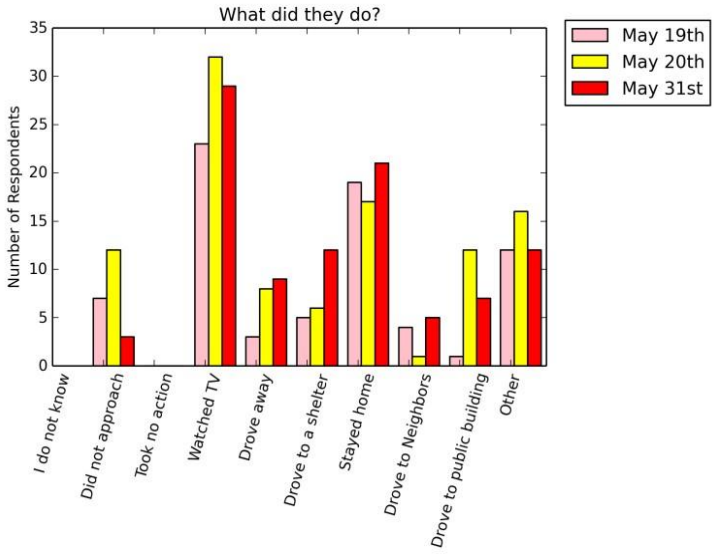


**Figure 4 (based on Question 6a in Table 1). What respondents did when the storms approached the area.**

### 4.2 QUANTITATIVE RESULTS

As the storms approached, the majority either watched TV or stayed at home during all three events (Fig. 4). No respondents selected "I did not take action." These answers were further categorized to see who stayed, drove out of the area, or drove to a specific destination (Fig. 5). Approximately 15% (9/61) of survey respondents who completed the section for 31 May drove out of the area. This number is similar to the 13% found in a previous survey conducted by high school teachers about the publics' response to natural disasters during May 2013 (Ling et al. 2014). Of those who indicated they drove to a specific destination, they either drove to a nearby shelter, took shelter at a neighbor's or family member's house, or sheltered in a public place. There is an increasing trend through the progression of events of people driving to specific places to shelter and driving out of the area.

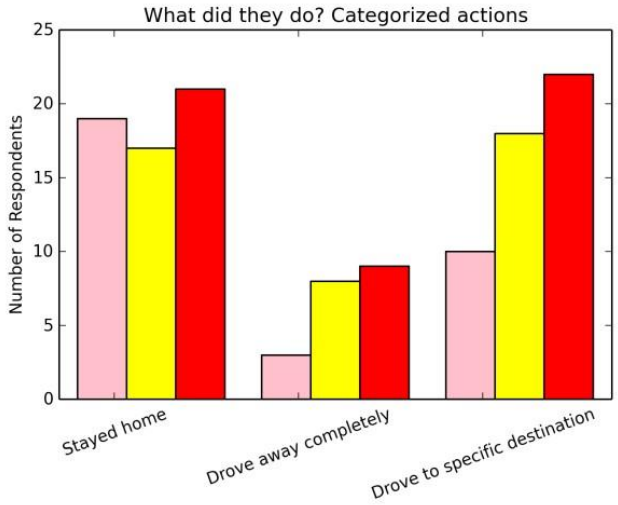


**Figure 5 (based on Question 6b in Table 1): The number of people who stayed, drove out of the area, or drove to a specific destination. Dates are colored as in Figure 4.**

People put themselves and others in danger by driving away. From these answers, we can begin to understand why people were motivated to drive away from their homes. Figure 6 shows number of responses for each category. On 19 May, the most popular reason for driving away

was because the media suggested it. On 20 May, three options were equally selected: the storm seemed more dangerous, I was afraid the building I was in was unsafe, and other. On 31 May the most popular reason for driving away was because people felt unsafe in their homes. No respondents checked "I saw others driving away" as a reason for driving away for any event.

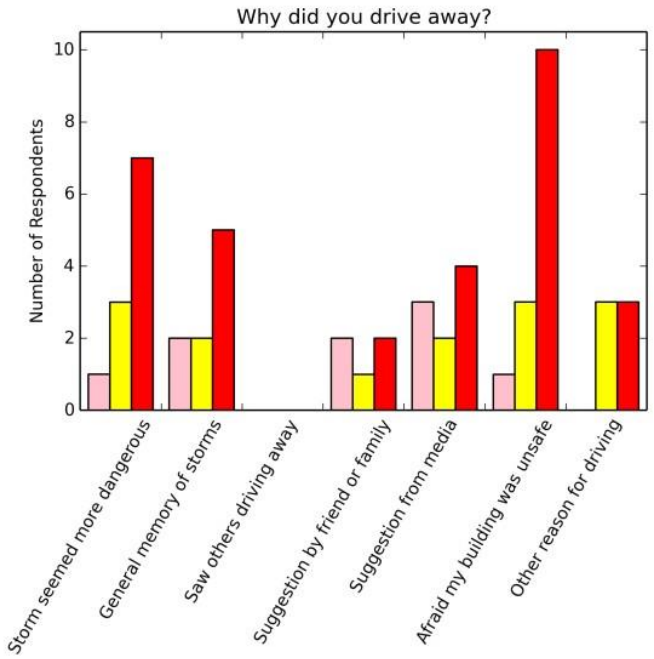


**Figure 6 (based on Question 8). Reasons why respondents drove. Dates colored as in Figure 4.**

Those who sought shelter went to several types of places to shelter (Fig. 7). Slightly more people sheltered in an interior room or closet on 19 May and 20 May than in a storm shelter, but taking refuge in a storm shelter was the most common response for the 31 May event.

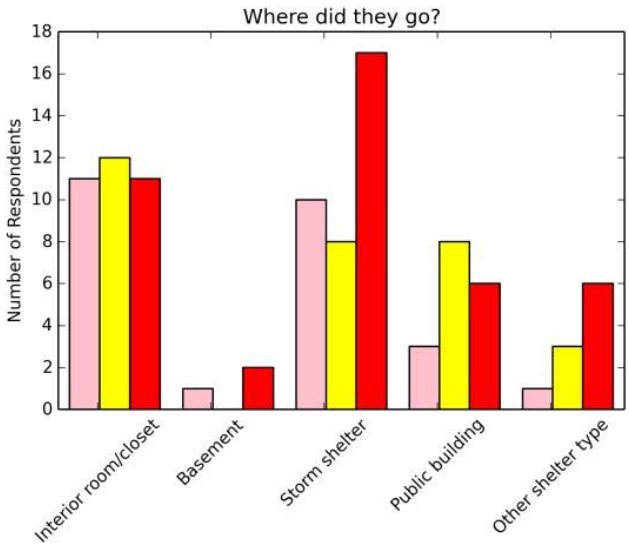


**Figure 7 (based on Question 6b). Sheltering options of survey respondents. Dates colored as in Figure 4.**

Four factors correlated with decisions to either drive or stay. People with incomes under $30,000 and those with incomes between $70,000 and $100,000 were more likely to drive away (Fig. 8). Younger respondents (20–39 year olds) (Fig. 9) and respondents with some higher education (a complete or an incomplete Bachelor's degree) (Fig. 10) were more likely to drive away. Only five respondents had less than a high school education. People with direct (personal) past experience with tornadoes were more likely to stay at home than drive away (Fig. 11); of those who had past, direct experience with tornadoes, 80% sheltered in place. Of those who stayed home, 75% of people had no prior experience and 62% of people had indirect experience where a tornado has impacted friends, family, or neighbors. Those with indirect experience were most likely to drive away. Other studies have also found that past experience—both direct and indirect—is positively correlated with sheltering decisions (Blanchard-Boehm and Cook 2004; Silver and Andrey 2013).

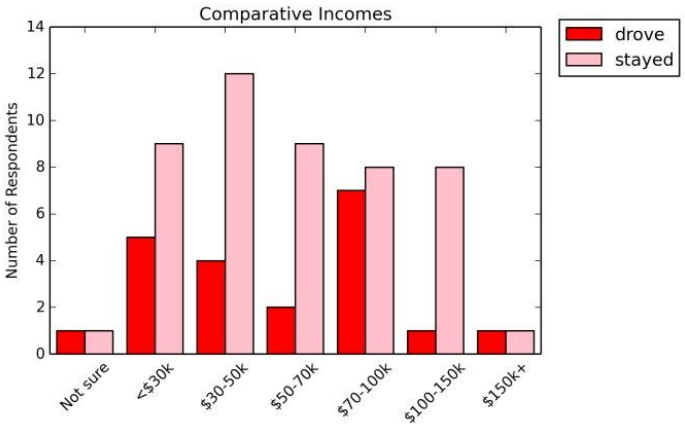


**Figure 8. People with a lesser income are more inclined to drive away. There is a spike in people who drove away for the $70,000 to $100,000 income category as well.**

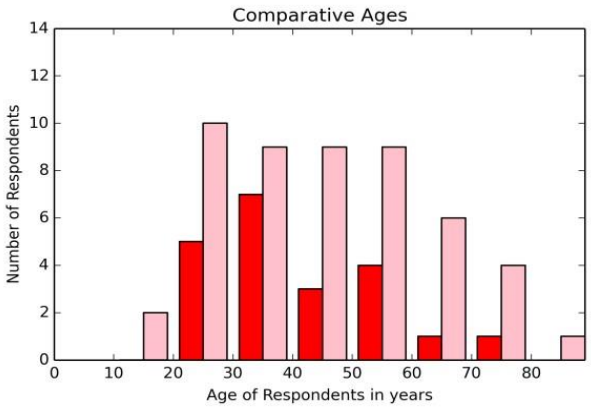


**Figure 9. People who are younger (20-39 year olds)**

**are more inclined to drive away. Dates colored as in Figure 8.**

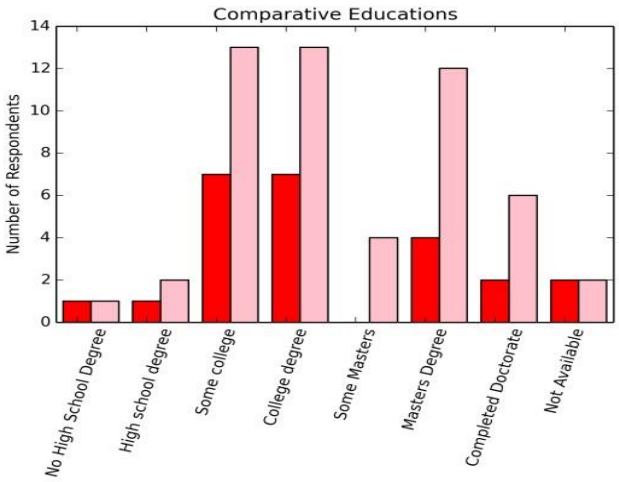


Figure 10. **People who have some higher education are more inclined to drive away. Dates colored as in Figure 8.**

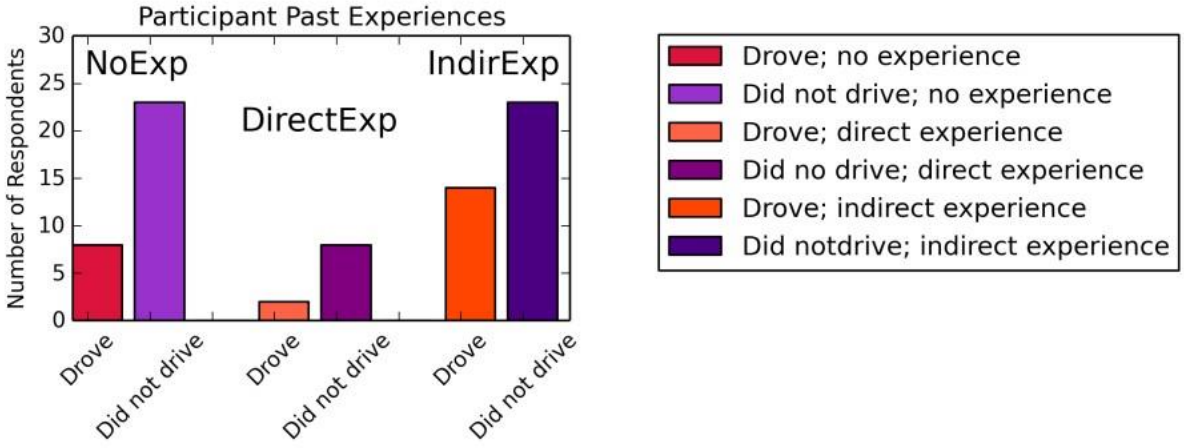


**Figure 11. People with past, direct experience are more likely to stay home.**

**4.3 QUALITATIVE RESULTS**

Quantitative analysis explains only what actions people took. Inductive analysis of text responses yielded the following themes that help understand why actions described above were taken: fear, not feeling safe at home, did not know they could mitigate, and wanting a storm shelter. Individual respondents are referred to by survey number, for instance R282.

Fear was the strongest theme in our analysis, with 44% of respondents describing fear explicitly — "The thought of severe weather season scares me" (R 283) and "[my neighbor] was clearly on-edge and scared" (R282)— or implicitly — R326 sheltered in an interior room/closet in her home for 19 and 20 May, but on 31 May, she went into her storm shelter. R187 also expressed implicit fear: "The May 20th/31st tornado … opened our eyes to the fact that sheltering in place was the safest option. We have driven away from a tornado (May 2011) and ended up in more danger than we would have been had we stayed home."

Of those who expressed fear, 50% (17/34) drove to a neighbor's or a family member's house to shelter and left either home or work to do so. Some left work early to go home. Of that 50%, over half went specifically to that location because it had either a basement or a storm shelter.

Fear was manifested in two distinct subcategories: my home feels vulnerable and I feel vulnerable. As above, these were a mix of explicit and implicit statements. Further, Figure 12 illustrates how fear was sometimes expressed as panic. First, vulnerability of one's home was expressed in both response options and text: their property had been hit or damaged in a previous event, they drove away from their home, or they drove to a neighbor's or family member's home with a storm shelter. Twenty four respondents (out of 77) —almost 33%—evacuated their homes at least once during these events. Of those 24 who drove, 25% (6/24) drove away two or more times. This indicated that respondents did not feel safe in their homes.

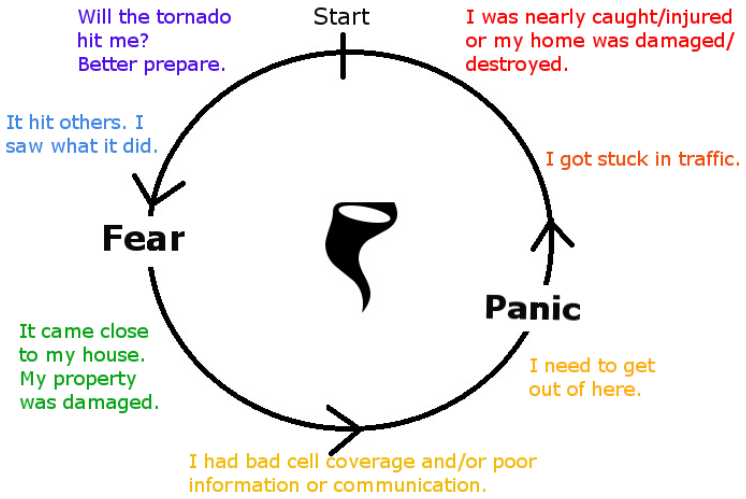


**Figure 12. The progression from fear to panic found in some surveys.**

Second, vulnerability of one's self was expressed in response options and text: I had bad cell coverage or information, I got caught in traffic, I saw panicked or dangerous drivers, I nearly got caught by the tornado, I will reduce storm chasing activities, I will not storm chase in urban areas again, and I – or others – are scared of severe weather now.

Individual vulnerability was richly described in survey responses. Eighteen percent (6/34) of respondents reported the panicked actions of others. Several of the six were storm chasers who described the fear and panic of other drivers as well as their own fear and the overcrowded roads on 31 May. R337 revealed that "…well after 9pm and many miles away from the storm, traffic was gridlocked and

people were clearly frightened". Another person who had been storm chasing concluded,

"I probably will not storm chase near a metropolitan area again. I observed some dangerous driving behavior on May 31st 2013 that I have never seen before while storm chasing. I saw drivers carrying unrestrained children and animals[,] begging storm chasers for directions. I saw a person come running from her house trying to wave down passing vehicles (presumably to hitch an evacuatory ride out of the area…). I saw expressions of panic on people's faces…" (R314).

This changed dynamic was evident when R337 said, "I had always assumed that I would be able to leave the threat area of a tornado with my family if necessary using my meteorological knowledge. That's no longer the case; the amount of congestion on [southbound US 81] made it impossible to get anywhere quickly. Now that I'm living in Oklahoma, I'm planning on seeking shelter … rather than driving away." R342 also had a new sense of vulnerability. He "...had never felt the need to invest in a storm shelter given [his] severe weather awareness, but the traffic gridlock that day ruined [his] plan to drive out of the danger zone." His family had a below-ground shelter installed the following fall.

Fear was widespread and palpable on 31 May, which R223 described as "a mess." "Droves of people [were] flowing out of OKC" and "panicked strangers [were] looking for refuge and begging to get in [his] storm shelter." R223 was one of many people in Norman who welcomed non-family into their shelters or homes. He eventually had 14 non-family members in his 8-person storm shelter. Although he was not worried about the safety of his family of five — storms were not moving toward Norman — this situation "panicked [his] family."

Finally, the senses of personal and structural vulnerability were supported by a combination of fixed response options and qualitative analysis. Of the 77 respondents, 27 (35%) did not know that they could strengthen their homes through mitigation (Fig. 13); one resident who had lived in Oklahoma for all of her 67 years had never heard of mitigation before. Respondents who had storm shelters (14%) were also willing to mitigate against tornado damage to their homes. Of the people surveyed 20% knew about mitigation but had not yet acted upon that knowledge. Roughly half (48%) of respondents overall indicated that they would be willing to spend money on mitigation, with most willing to spend at least $500–$1,000. Six percent had already spent money on mitigation (Fig. 14). Storm shelters and access to storm shelters and basements were highly desired during and after the May 2013 tornado events: 9% of respondents indicated that they wanted a storm shelter after the events and 14% indicated that they already had one.

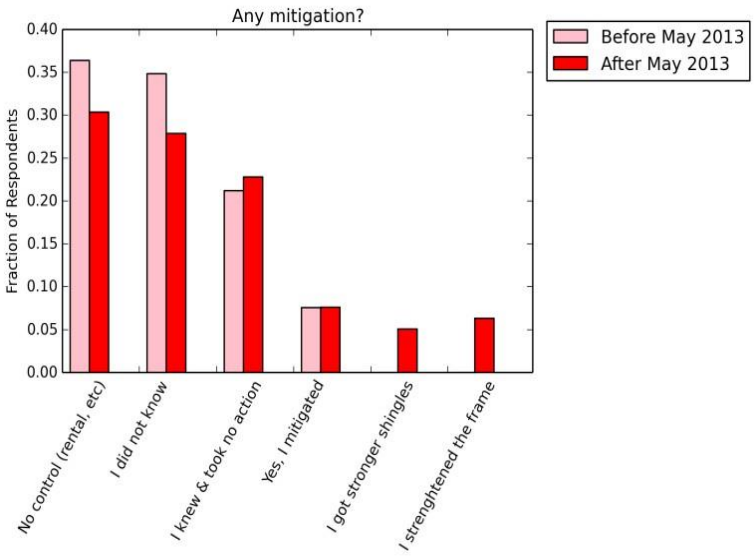


**Figure 13. What people did and did not know about mitigation. Of those that did mitigate, impact-resistant shingles and frame strengthening were the most common adjustments.**

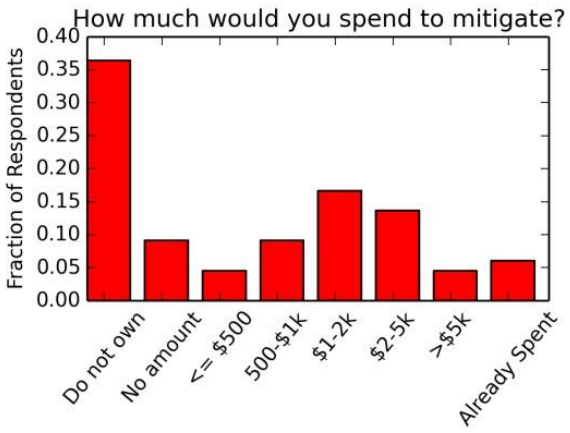


**Figure 14. Forty-eight percent of respondents that are willing to spend money on mitigation. Six percent have already spent money on mitigation.**

## 5. DISCUSSION

The high number of people who sheltered in storm shelters on 31 May may have been due to the public being told that they could not survive the storm above ground (White 2013). Although false, it was asserted by many that day, including at least one television broadcaster, and this appears to be one factor affecting behaviors on 31 May. For example, resident Teri Black was interviewed by Neil Razzell (2014) for BBC News and she describes her reaction to the media message: "I hear somebody say 'you're not going to outlive this if you're not underground' and so being shell-shocked from the 20th, I decided … I'm going to run."

Our findings are contrary to that of Mileti and Sorensen (1990), and Klockow et al. (2014). Mileti and Sorensen said that people did not panic when warned of a low probability, high-consequence event (like a tornado), but our data show that people panicked during the 31 May event. Klockow et al. (2014) found that residents of Mississippi and Alabama preferred to stay home because they felt safe there; they did not think that they would be hit. One participant in their study described her perspective as:

"I guess it's a different type of culture. A type of tornado culture down here, where it's not that you don't worry about it. You know it's going to happen. But at the same time, you think 'Oh, it's just a tornado in Alabama. It's just tornado season.' I guess we go through tornado season every year, it's just like 'Oh, it's tornado season' as though 'Oh, it's fall' … We might think that we can get out of it. It'll blow right over us."

Oklahomans acted differently towards tornadoes, particularly on 31 May. By the third event, Oklahomans they drove away in large numbers. R193 described this fear by stating that strong tornadoes have formed close to her home four years in a row and this had "helped remove the assumption of invincibility." Perhaps there are regional and situational differences in how people react to tornadoes. Is this unique to Oklahoma or would Alabamans, for example, also feel personally vulnerable if there were repeated strong events nearby? Is the 31 May evacuation unique to Oklahoma? How common is it for people to drive out of a tornado's expected path? When people drive away, do they regret this decision, as some of our participants did, or are they pleased with it? It may have appeared to work well to ease their fears.

Oklahomans' sense of vulnerability in their homes could be due to many being unaware that it is possible to strengthen homes against tornadic winds (Fig. 13). The focus on mitigation is relatively new, as illustrated in Figure 14 for a 67-year old participant in our study. Unfortunately, most wind mitigation studies have focused on hurricanes (for example, see: http://www.fema.gov/fema-mitigation-assessment-team-reports), but in late 1999 FEMA's Building Performance Assessment Team released their analysis of damaged caused by

tornadoes in Oklahoma and Kansas on 3 May 1999 (Fig. 15). This report showed that key failure points could be strengthened to help homes better withstand tornadic winds (FEMA 1999). This has led companies like Simpson Strong Tie, for example, to create educational materials on how to use their products to prepare homes for high winds (http://www.safestronghome.com/highwind/).

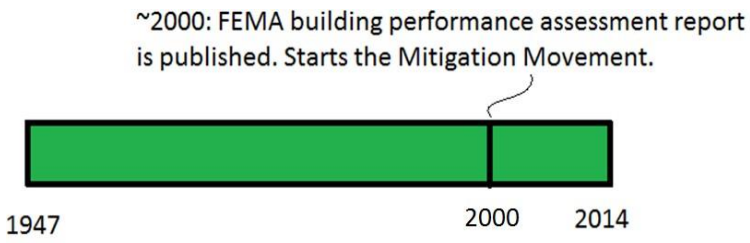


**Figure 15. An example timeline of 67 year old respondent who had never before heard of mitigation. Mitigation has only been around for roughly 1/5$^{th}$ of her lifetime.**

There were two survey respondents who doubted that mitigation would work. R192 did not think that mitigation would have helped the houses caught in the Moore tornado. R330 did not think that a strengthened home could withstand a direct hit from an EF-5 tornado. Mitigation is a preventive innovation—it takes time to see the reward of this action, so people have a hard time deciding if it is worth the investment (Rogers 2003). Is it not worth it to have a house stand even a few more seconds against a tornado? If the occupants inside could be saved from flying debris for a few seconds longer, they may be able to survive.

It was found in our survey that respondents wanted to protect both life and property. Gast et al.'s (2014) survey of summer 2013 visitors to the National Weather Center had found that a majority of respondents clearly valued personal safety over property. This was the common sentiment from media stories at the time and may have skewed answers to Gast et al.'s survey. We feel that the responses in our survey were less biased with the distance of time after the events.

Ling et al (2014) produced results similar to ours. She also found (1) that some respondents looked into buying a storm shelter in response to the events, (2) there was an increase in the number of people who went to private shelters (storm shelters) on 31 May compared to 19 and 20 May, and (3) there was an increase in the number of people who drove for each event. The findings of her surveys and ours suggest that we have gotten verifiable data: these are new trends.

How people with children reacted compared to how people without children reacted was not studied. Would these groups act similarly or differently? How children reacted to these storms was also not studied. Multiple stories in *The Norman Transcript* (May 18 2014) and one quote from a survey respondent talk about how children are now fearful or are probably fearful of weather events and storms, loud noises, etc. after the May 2013 tornado events in central Oklahoma. Was this a temporary reaction or is this an ongoing fear?

## 6. CONCLUSION

There are many lessons to be learned from the three May 2013 tornado events in Oklahoma. The fear shown during these events was strong, and drove unusual actions. Was this a unique reaction to the three storms in May 2013 or is this a true phenomenon of Oklahomans or of others around the country?

Factors correlated with people driving away are lesser income, younger age, and some college education. Past, direct experience with tornadoes is correlated with people sheltering at

home. One third of respondents did not feel safe in their homes and 35% did not know that they could mitigate and strengthen their homes. Storm shelters where highly sought after during and following the tornado events of May 2013.

Now that more is known about why and how people reacted to these tornadic events, they should be publicly addressed: advertise both storm shelters and home strengthening. Of the people surveyed 20% knew about mitigation but had not yet acted upon that knowledge. Some doubt that mitigation would be effective, but mitigation does work and what it is, how to do it, and how much it costs should be made common knowledge.

The fear that drove evacuative actions on 31 May could be lessened through advance notice for those wishing to leave the area where storms are likely to be tornadic. If given hours prior to the start of an event, those motivated to leave may have sufficient time to do so. Once storms are approaching, however, it is clear there is insufficient time for an evacuation of a large metropolitan area. Messaging must change to one of seeking shelter within the immediate vicinity. Encourage planned and practiced actions.

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**8. REFERENCES**

Bellala, R. K. and S. Brown, 2005: Injuries Treated in Hospitals Following the May 8 and 9, 2003 Tornadoes in Oklahoma City. *Injury Update*. Available online at http://www.ok.gov/health2/documents/Torn.

Blanchard-Boehm, R. D. and M. J. Cook, 2004: Risk Communication and Public Education in Edmonton, Alberta, Canada on the 10th Anniversary of the 'Black Friday' Tornado. *International Research in Geographical and Environmental Education* **13.1 (2004)**, 38-54.

Brown, S., E. Kruger, and J. Bos, 2000: Investigation of Deaths and Injuries Resulting From the May 3, 1999 Tornadoes. *Injury Update*. Available online at http://www.ok.gov/health2/documents/Torn.

Burgess, D. (2014, February 27). National Weather Service Weather Forecast Office. Synopsis and Discussion of the 10 April 1979 Tornado Outbreak. Available online at http://www.srh.noaa.gov/oun/?n=events-19790410-burgess.

Burgess, D., K. Ortega, G. Stumpf, G. Garfield, C. Karstens, T. Meyer, B. Smith, D. Speheger, J. Ladue, R. Smith, and T. Marshall, 2014: 20 May 2013 Moore, Oklahoma Tornado: Damage Survey and Analysis. Wea. Forecasting. doi:10.1175/WAF-D-14-00039.1, in press.

Burns, W. J. and P. Slovic, 2012: Risk Perception and Behaviors: Anticipating and Responding to Crises. *Risk Analysis*, **32(4)** , 579-582.

Burton, I., R. W. Kates, and G.F. White, 1993: *The environment as hazard* , 290 pp.

Daley, W. R., S. Brown, P. Archer, E. Kruger, F. Jordan, D. Batts, and S. Mallonee, 2005: Risk of Tornado-related Death and Injury in Oklahoma, May 3, 1999. *Am. J. of Epidemiology* **161.12 (2005)**: 1144-1150.

FEMA, 1999: Midwest tornadoes of May 3, 1999: observations, recommendations, and technical guidance. FEMA Building Performance Assessment Report 342, 216 pp.

Garfield, G., 2014: Sheltering Behavior during 2 Major Tornadoes in 2013: Is More "Lead Time" Better?, *American Meteorological Society 94th Annual Meeting*, Atlanta, GA.

Gast, K., J. A. Brotzge, and D. S. LaDue, 2014: Tornado damage mitigation: what National Weather Center visitors know and why they aren't mitigating. *13th Annual AMS Student Conference*, Atlanta, GA, American Meteorological Society, S166.

Hammer, B. and T.W. Schmidlin, 2000: Vehicle-occupant deaths caused by tornadoes in the United States, 1900–1998. *Global Environmental Change Part B: Environmental Hazards*, ***2*(3),** 105-118.

Hammer, B. and T.W. Schmidlin, 2002: Response to Warnings during the 3 May 1999 Oklahoma City Tornado: Reasons and Relative Injury Rates. *Wea. Forecasting*, ***17*(3),** 577-581. Available online at http://dx.doi.org/10.1175/1520-0434(2002)017<0577:RTWDTM>2.0.CO;2

Hampton, J., 2014: Rural residents still recovering from devastating May tornadoes. *The Norman Transcript*, 18 May, 16-17, 20.

Klockow, K. E., R. A. Peppler, and R.A. McPherson, 2014: Tornado folk science in Alabama and Mississippi in the 27 April 2011 tornado outbreak. *GeoJournal*. doi:10.1007/s10708-013-9518-6.

Ling, C., M. Madison, J. Adams, K. Warren, M. Mudd, K.G. Wolfinbarger, E. Mintmire, and L.P. Rothfusz, L. P., 2014: General Public's Weather Information Seeking and Decision Making behavior during Tornado outbreaks in Oklahoma City Metroplex in May 2013. *American Meteorological Society 94th Annual Meeting*. Atlanta, GA.

Marshall, T. P., D. McCarthy, and J. LaDue, J., 2008: Damage survey of the Greensburg, KS tornado. *24th Conference on Severe Local Storms*,Savannah, Georgia. Available online at https://ams.confex.com/ams/pdfpapers/141534.p

Mileti, D. S., and J. H. Sorensen, 1990: Communication of Emergency Public Warnings: A Social Science Perspective and State-of-the-Art AssessmentORNL-6609.

NWS Weather Forecast Office Norman, cited 2014: Fast Facts for the Tornado and Flash Flood Event of May 31-June 1, 2013. Available online at http://www.srh.noaa.gov/oun/?n=events-20130531-fastfacts.

NWS Weather Forecast Office Norman, cited 2013: The Newcastle-Moore Tornado. Available online at

http://www.srh.noaa.gov/images/oun/wxevents/20130520/products_presentation.pdf

Razzell, N., 2014a: News Hour from BBC News, digital media. Available online at http://www.bbc.co.uk/programmes/p023

Razzell, N., 2014b: Tornado: Hide and Seek from BBC News, digital media. Available online at http://www.bbc.co.uk/programmes/p0230.

Rogers, E. M., 2003: *Diffusion of innovations*. 5th ed. Free Press. 551 pp.

Sax, L. J., S. K. Gilmartin, and A. N. Bryant, 2003: Assessing response rates and nonresponse bias in web and paper surveys. Res. Higher Educ., **44**, 409–432.

Senkbeil, J. C., M.S. Rockman, and J.B. Mason, 2012: Shelter Seeking Plans of Tuscaloosa Residents for a Future Tornado Event. *Wea. Climate Soc.*, ***4*(3),** 159-171.

Schultz, D. M., E.C. Gruntfest, M.H. Hayden, C.C. Benight, S. Drobot, and L.R. Barnes, L. R., 2010: Decision Making by Austin, Texas, Residents in Hypothetical Tornado Scenarios. *Wea. Climate Soc.*, ***2*(3),** 249-254.

Silver, A. and J. Andrey, 2014: The Influence of Previous Disaster Experience and Sociodemographics on Protective Behaviors during Two Successive Tornado Events. *Wea. Climate Soc.*, ***6*(1),** 91-103. doi:10.1175/WCAS-D-13-00026.1.

Underwood, D., H. Kim, and M. Matier, 2000: To mail or to Web: Comparisons of survey response rates and respondent characteristics. *40th Annual Forum of the Association for Institutional Research*, Cincinnati, OH.

United States Census Bureau, cited 2014: Oklahoma QuickFacts from the US Census Bureau. Available online at http://quickfacts.census.gov/qfd/states/4000.

White, R., 2013: The Original Weather Blog : Surviving a Tornado Above Ground vs. Driving Away From It: More El Reno Tornado Controversy from 5-31-13. Available online at http://originalweatherblog.blogspot.com/2013/06/surviving-tornado-below-ground-vs.html.

Willis, G. B., 2005: *Cognitive interviewing: a tool for improving questionnaire design*. Sage Publications, 352 pp.

Wurman, Joshua, Karen Kosiba, Paul Robinson, Tim Marshall, 2014: The Role of Multiple-Vortex Tornado Structure in Causing Storm Researcher Fatalities. *Bull. Amer. Meteor. Soc.*, **95**, 31–45. doi:http://dx.doi.org/10.1175/BAMS-D-13-00221.1.