In the Dark

Public Perceptions of and National Weather Service Forecaster Considerations for Nocturnal Tornadoes in Tennessee

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Tornado fatalities have disproportionately occurred in the southeastern United States due to social and meteorological factors (Ashley 2007), and this is expected to continue because of elevated development rates in the region (Ashley and Strader 2016). This disparity, and the deadly April 2011 outbreak across the Southeast (NOAA 2011), led to a Congressional mandate in early 2015 that spawned NOAA's VORTEX-Southeast program. VORTEX-Southeast (SE) encourages collaborative efforts from physical and social sciences and operational meteorology to address many facets of the Southeast tornado problem, emphasizing research that can directly integrate into operations and improve the tornado warning process. As part of this program, authors L. M. and K. E. assessed tornado challenges in Tennessee from a multidisciplinary perspective, including social work and physical geography. We focused on nocturnal tornadoes because they compose nearly half of Tennessee tornadoes and are 2.5 more times likely to be fatal than those during the day (Ashley et al. 2008).

Using a mixed-methods approach of climatological analysis, a phone survey ($n = 1,804$) and interviews ($n = 45$) with Tennessee residents, and interviews with NWS forecasters ($n = 11$), we examined the challenges brought by nocturnal tornadoes—from detection and the decision to warn by forecasters through warning receipt and response by the public. We focused on the three NWS County Warning Areas (CWAs) in Tennessee: Memphis (MEG), Nashville (OHX), and Morristown (MRX). Survey participants were randomly selected from four counties in each CWA (Fig. 1) from a list of landline and cellphone numbers. The participants were older (averaging in their mid-50s) and more educated (averaging at least some college education) than the average study area resident, and were more likely to be female (over 60%). The

Fig. 1. The three NWS offices in Tennessee, and their County Warning Areas (CWAs). The shaded counties are those surveyed.

specific survey questions referred to in this article are shown in Table 1. We completed phone interviews with 45 of the survey participants willing to do follow-up interviews.

Here we integrate our published results from the public interviews and surveys with new results from forecaster interviews, summarizing what we have learned and demonstrating the power of multidisciplinary collaboration. Early results were used to guide discussions between the NWS offices and their partners, including the media and emergency managers (EMs), at interactive workshops including a Spring Partners Meeting (MEG), Media Day (OHX), and an Integrated Warning Team meeting (MRX). Each workshop operates with the goal of building relationships between NWS offices and their partners to improve communication during severe weather. As a result of these discussions, we have partnered with author

Table 1. Select survey questions and their question number from the full 51-question survey. Response options are given, though participants could also respond “I do not know,” not answer, or give a nonlisted response.

No.	Question	Responses
1	Has a tornado ever hit your home?	Yes, no
2	Has a tornado ever hit a building while you were inside?	Yes, no
4	How often would you say tornadoes hit <your county>?	Never, once every 50 years or longer, once every 25 years, once every 10 years, once every few years, once a year, more than once a year
5	If ten tornadoes hit <your county> in the upcoming years, how many would you expect to occur at night when it is dark?	Number 0–10
11	To what extent do you think hills protect nearby places from tornadoes, if at all?	Not at all, somewhat, very much, completely
15	Surviving a tornado is mostly a matter of luck.	Strongly disagree, disagree, agree, strongly agree
19	If there was a tornado warning during the [daytime/nighttime when most people are asleep], what are the chances you would find out about the warning?	No chance, very low, low, high, very high
20	Thinking about tornado warnings that you get during the [daytime/nighttime when most people are asleep], how do you usually receive these? Do you usually receive these by Television Local radio station Cell phone alert Searching the internet Social media, for example, Facebook or Twitter NOAA weather radio Call, text, or visit from a friend or family member Tornado siren Some other way (specify)	Yes or no answer to each option, or specify another way
24	You are home on a Saturday [afternoon/night] and learn that the National Weather Service has issued a tornado warning for the area where you live. A tornado warning means that weather radar shows a tornado may be occurring or a tornado has been spotted in the area. Which if any of the following would you do upon learning about the warning? Do nothing, go back to sleep Turn on the television or radio to find more information Search the internet to find more information Use an app on a smartphone or tablet to find more information Look or go outside to check the weather yourself Contact friends or family Seek shelter in your home [If yes, where in your home would you go for shelter?] Leave your home [If yes, where would you go?] Pray for safety Something else (specify)	Yes or no answer to each option, or specify something else

K. H., a Warning Coordination Meteorologist at OHX, to provide best-practice recommendations for the NWS, its partners, and the public during nocturnal tornado events, and to discuss our results in the context of the Middle Tennessee nocturnal tornado event in March 2020.

Public perceptions of nocturnal tornadoes

Participants were asked what proportion of tornadoes they expect to occur at night (question 5 in Table 1). Overall, the largest proportion of participants (28%) correctly selected 5 of 10, though we wondered whether some may have guessed “about half” of the tornadoes would be at night, since responses to other questions suggested that many participants were unaware of when tornadoes happened in their area (Ellis et al. 2019). Approximately 10% of participants believed only 0 or 1 would occur at night, and another 10% believed 9 or 10 would occur at night, highlighting confusion on the frequency of nocturnal events.

Public perception of nocturnal tornado frequency varied geographically. When comparing regions, statistically significantly more western Tennessee participants perceived most tornadoes (8–10 out of 10) occurred at night (22% of participants), while statistically significantly more eastern Tennessee participants perceived few (0–2 out of 10) happened at night (26% of participants). Whether participants believed hills protect them from tornadoes (question 11 in Table 1) was also significantly related to their perception of nocturnal tornado frequency, but no other demographic variables (e.g., gender, education, prior experience with tornadoes) explained their perceptions. Phone interviews reinforced the importance of such local geographic features, with interviewees saying things like when “storms hit the river, they seem to die down” or “they always go to the south” of me, which forecasters and their partners at the workshops reported hearing regularly from the public.

Warning receipt and response

We asked survey participants if they believed they would get a warning should one be issued (question 19 in Table 1), with some participants being asked about a daytime warning and others being asked about one issued at night when people are asleep. Those asked about daytime warnings felt significantly more likely that they would receive the warning, with less than half of the nighttime group thinking they would receive it (Mason et al. 2018). No demographic variables were associated, in a statistically significant way, with the likelihood of warning receipt at night; instead, cognitive variables played an important role. Belief in high tornado frequency (question 4 in Table 1) and having prior experience with tornadoes (questions 1 and 2 in Table 1) increased likelihood of nocturnal warning receipt, while belief that surviving a tornado is attributed to luck (question 11 in Table 1) decreased the likelihood.

How people receive their warnings (question 20 in Table 1) changed from day to night, with significantly fewer people using each possible warning source listed in Table 1 at night, except for the NOAA weather radio, which did not significantly change. This is an interesting finding because Wireless Emergency Alerts (WEAs) should be a constant similar to the weather radio. Some commonly reported sources are concerning for nocturnal warnings; for example, sirens are not meant to alert people inside, yet nearly half of participants listed them as a nocturnal tornado warning source. Additionally, many sources, such as television or social media, are not going to wake people when warnings are issued, yet participants noted that they rely on them. In follow-up interviews, participants expressed worry about not receiving warnings at night because they are heavy sleepers (Walters et al. 2020). Interviewees reinforced that they expect to receive nocturnal warnings via sirens, and those without sirens desired them. Many recognized WEAs as a good source, but rural respondents were concerned with cell phone coverage. Indeed, these locations may lack cell phone coverage, but they may also receive warnings not relevant to their location depending on where the nearest cell tower is located. This can create confusion and a false alarm effect.

Survey participants were asked what actions they take when receiving a tornado warning either at night or during the day (question 24 in Table 1) and then grouped according to a latent class analysis. We identified three groups of responders at night: tech users, typical actors, and nonreactors, each defined by the suite of actions they were most likely to take (Walters et al. 2019). Nonreactors were less likely to seek additional information and were significantly less likely to seek shelter. Typical actors and tech users likely seek information on the television/radio and contact friends and family. Tech users likely seek more information on the internet and apps. Those with cell phones, especially smartphones, were more likely to be tech users. Though dangerous, some tech users and typical actors feel compelled to look outside for evidence even at night, and this was supported by the interviews, where participants explained they were sometimes checking for sounds instead of visual cues (Walters et al. 2020).

Challenges for NWS forecasters

Using thematic analysis, we uncovered four themes regarding how nocturnal tornadoes affect NWS forecasters and their procedures: lack of ground truth, staffing issues, effects on communication before and during the event, and fear for public safety.

Lack of ground truth. Andra et al. (2002) listed ground truth as a principal tool for forecasters issuing warnings, only second to radar in importance. The forecasters we interviewed noted that the lack of ground truth at night causes them to rely more on their “ability as a forecaster to diagnose the environment.” There are few spotter or social media reports informing them if “the storm is actually showing the signs on the grounds that radar is indicating aloft.” One forecaster said, “The hardest part as a warning forecaster is you issue a warning, and there’s no reports that come in until the next day.” Another agreed, saying the lack of reports does not necessarily indicate a lack of severity. Several forecasters mentioned that the few spotters that are out there have difficulties interpreting what they are seeing in the dark. Feedback from other partners (e.g., EMs) is also lacking at night, but comes in more frequently than spotter reports and public feedback on social media. Several forecasters also mentioned that nocturnal events present a challenging forecast environment, noting the storm is often linear or a MCS, and is rarely a discrete supercell, thus the lack of ground truth is even more impactful.

Staffing issues. Forecasters explained that if a nocturnal event is expected, then they plan to have extra people in the office or waiting on call. They may also plan in advance to have some forecasters stay later or come in earlier. However, one forecaster told a story about a rapidly changing forecast at two in the morning. Only that forecaster and their partner were on the midnight shift, and because they were not expecting the severe weather to make it to their area, they let the evening shift go, and they were unable to get in touch with someone to come back in and help.

Effects on communication before and during the event. Forecasters mentioned the importance of highlighting the nocturnal threat to their partners as early as possible via webinars and NWS Chat, so that EMs are prepared and the media can stress to audiences that there is a risk at night. One forecaster highlighted the importance of getting the message to people during the day. Another said that during the event, it is important that they are in a constant conversation with the media to “keep a narrative going.” Because feedback from the public and spotters during an event is potentially minimal during a nocturnal event, one office mentioned that they communicate more with 911 dispatch to understand what is happening on the ground. However, this is not a perfect situation because emergency operators are sometimes too busy to give forecasters all of the information they need. During the event, one

forecaster mentioned being hopeful that WEA alerts reach most people. We hypothesize that WEAs may help equalize the fatality rates of nocturnal and daytime tornadoes; however, in the last 5 years in middle Tennessee where author K. H. works for the NWS, the only tornado fatalities (28) have been at night.

Fear for public safety. Forecasters mentioned being fearful, worried, or nervous for the public during nocturnal tornadoes because fatalities “are a given.” For one office, this fear has driven the communication efforts before an event to show “how dangerous nocturnal events are.” Some forecasters are more willing to issue warnings at night, one mentioning that it may even be a subconscious bias, because of the likelihood of fatalities. Forecasters mentioned concern for those in unsafe structures, emphasizing people should make a sheltering plan once a watch is issued, and that it is safer to seek shelter before deeming it necessary.

Best-practice recommendations

One strategy that may improve public safety during a nocturnal tornado event, and which addresses the forecaster challenge of communication prior to and during an event, is to develop “One Message”—a consistent message that EMs and the media use throughout broadcasts, briefings, and social media. Examples of messages could be “Nighttime tornadoes expected. Sleep with your phone ON tonight!” or “Tornadoes will form quickly! Make plans now where you will take shelter.” or “If you live in a manufactured home, you may not have much time to seek shelter tonight.” One Message may decrease confusion for receivers, making them more likely to make safe decisions. Messages could similarly be used to dispel misconceptions about local geography in ways relevant to the specific listening area: for example, “You are not protected by nearby hills. Seek shelter immediately!”

For One Message to succeed, NWS and their partners must build relationships prior to events. This has been done with some success through Integrated Warning Team meetings, media workshops, partners workshops, and Severe Weather Awareness Day outreach events. Specific to Tennessee, NWS offices are collaborating on a multiyear project called “Building a Weather Resilient Tennessee,” bringing all four NWS offices that serve the state together to share best practices and unique decision support services, leading to cohesive weather messages and services for residents.

For the public, best practices for nocturnal tornado events are clear: have multiple ways to get tornado warnings, do not rely on outdoor sirens, sleep with your phone on and charged during severe weather, and do not stay in particularly vulnerable locations such as mobile homes or vehicles. The implementation of One Message with messages specific to the local area should help encourage dissemination and application of these practices. For public safety to be greatly improved during tornado events, many other critical challenges need to be resolved, especially the lack of safe shelters for residents of vulnerable locations (Ash et al. 2020), specifically those in rural mobile homes in the Southeast (Strader et al. 2019).

The 2–3 March 2020 nocturnal tornadoes

Overnight between 2 and 3 March, 10 nocturnal tornadoes were confirmed in Tennessee, causing 25 fatalities (NOAA 2020). The strongest tornadoes were rated EF3 in Nashville (0032 CST) and EF4 in Cookeville (0148 CST). The Storm Prediction Center had the area under “marginal” and “slight risk,” mainly highlighting the hail threat. NWS OHX forecasters became increasingly concerned about a tornado threat and at 1736 CST shared a graphic (Fig. 2) that included the possibility of a nocturnal tornado threat and associated recommendations; this graphic was then shared over 800 times and included on the 2200 CST news. Through NWS chat, the office along with their partners (e.g., broadcast meteorologists, volunteers on Twitter at @NashSevereWx) were able to produce a single, clear message, that likely saved lives.

The office was staffed with a typical midnight shift “slight risk” staff of four meteorologists. They later called in as many people as they could with two additional meteorologists arriving before the Cookeville tornado, while others were not woken by their phone.

Near-real-time feedback from the public and storm spotters was minimal. NWS OHX received zero reports from western Tennessee, nor any from Humphreys County, the first county in their CWA that was impacted. The first notion that there was a tornado in the Nashville area was the tornado debris signature on radar and the live cameras on WTVF, NewsChannel 5, showing power flashes. The fast development of the system, coupled with lack of information from the ground, provided a challenging forecast environment.

The devastation from the event was a result of intense, long-track tornadoes striking heavily populated and vulnerable areas. It demonstrates the depth of the tornado safety problem, including those associated with the expansion of the built environment (Ashley and Strader 2016), with the perception and communication challenges highlighted in our work only being one piece. Additionally, the severity of the weather during a slight risk event without a tornado watch in effect shocked NWS OHX partners and demonstrates a problem with communicating risk categorically, especially with a quickly evolving threat. We hope our work can assist improving message consistency, while exposing areas that still need more work.

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Severe storms are possible overnight tonight for all of Middle Tennessee. Be sure to keep your phones on and have a way to get warnings while you sleep. This entire event will take place overnight tonight. Damaging winds, large hail, and tornadoes are all possible.

Fig. 2. Graphic shared by NWS OHX on social media at 1736 CST 2 Mar 2020.

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