An Exploratory Content Analysis of Two Local Television Stations' Tornado Warning Broadcasts

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(Manuscript received 3 February 2023, in final form 22 December 2023, accepted 12 January 2024)

ABSTRACT: In-depth analysis of the content of broadcast tornado warning coverage is limited. Such analysis is important due to local television's role as a key source for tornado warning information. This study attempts to fill gaps in our knowledge regarding broadcast coverage of tornado warnings by demonstrating how local television news stations' coverage of tornadic events can be systematically analyzed to better understand this element of warning communication. We reviewed both visual and verbal content for information such as the prominence of specific radar products, the geographic scale of warning communication, and common themes in verbal communication. A combination of deductive and inductive coding approaches was used to summarize the verbal content of the broadcasts. We found that the stations heavily used radar products with reflectivity and velocity surpassing correlation coefficient. The geographic scale of mapped products (street, city/county, and state level) appeared to be related to the rural or urban nature of the area warned, which may have implications for how readily rural residents would be able to personalize tornado threats. Verbal content was very similar between the two stations. The theme of monitoring and updating conditions, which included processes such as zooming in and out, making adjustments, reinforcing conditions, and providing damage reports was the most frequent communication type, likely because weathercasters use these processes to both communicate the warning and also to help themselves understand the situation. The results can inform future studies examining the influence of specific elements of broadcast warning coverage on risk perception and protective actions.

SIGNIFICANCE STATEMENT: Television is a key source for receiving or confirming tornado warnings, but few studies have examined the content of broadcast warnings in depth. This study examined the visual and verbal content of broadcast tornado warnings on two local television stations. Radar products were used heavily, and street-level coverage was more common when a tornado affected a metropolitan area. Coverage was most common at the city/county level. Verbal content included many elements of effective warning communication but at times included jargon that may not be understood by viewers. The results can serve as a springboard for future research on the impacts of these elements on risk perception and response. It can also serve future research by distinguishing what viewers of severe weather broadcasts are exposed to that nonviewers are not.

KEYWORDS: Social science; Tornadoes; Broadcasting; Communications/decision-making

1. Introduction

Effective warning communication is essential in reducing fatalities and helping people make safe decisions during extreme weather events such as tornadoes, but it is not common for an individual to respond immediately to a warning; the confirmation process is often necessary to help individuals understand, believe, and personalize warnings (Mileti and Sorenson 1990). An important piece in the study of warning communication and response is the existing content of warnings through channels likely to be used by those at risk from the hazard. This includes television (TV) broadcasts. Even though smart-telephone (hereinafter smartphone) alerts are becoming the primary way individuals first receive a tornado warning (Yoder-Bontrager et al. 2017), local television is still an important source to help individuals understand their personal risk from tornadoes (Miran et al. 2018; Walters et al. 2019, 2020). After receiving warnings from one or more primary sources, most individuals still intended to collect more information, such as turning on the television after hearing the warning (Walters et al. 2020).

A large body of literature focuses on factors that help explain how an individual might respond to a tornado warning, such as prior experience (Johnson et al. 2021), factors that influence motivation to take protective action (e.g., Lindell and Perry 2012; Floyd et al. 2000), proximity to the tornado (Miran et al. 2018; Nagele and Trainor 2012) or the number of weather information sources used (Sherman-Morris et al. 2022; Miran et al. 2018). Many studies have examined tornado warning messages and the influence of hypothetical text warnings on risk perception or intended behavior (e.g., Casteel 2018; Gutter et al. 2018). There have also been several studies that have looked at social media messages during severe weather (Ripberger et al. 2014; Silver and Andrey 2019) from different perspectives. While a few studies have examined broadcast coverage of hurricane warnings (Daniels and Loggins 2007; Prestley et al. 2020), the authors found only one detailed analysis of broadcast coverage of tornadoes (Cario 2016). Because there

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DOI: 10.1175/WCAS-D-23-0011.1

has been so little systematic documentation and analysis, our study attempts to establish a baseline regarding the content of television broadcast coverage devoted to tornado warning communication by closely examining two local television news stations' coverage of tornado-warned events.

2. Literature

a. *Importance of local television for tornado warning communication*

Local television has historically been and continues to be an important source of information during tornado warnings (Miran et al. 2018; Walters et al. 2019, 2020). For example, in the 1999 Moore, Oklahoma, tornado, television was used by 92.8% of respondents (Comstock and Mallonee 2005). Throughout the early 2000s, television remained an important source to gather information on tornado warnings. Among mobile home residents in multiple states who had been aware of a tornado warning for their area, television was by far the most commonly used source, reported by 85% of respondents, as compared with the next most frequently used source (sirens) with 53% (Schmidlin et al. 2009). While only three participants interviewed following the 2011 Smithville, Mississippi, tornado cited local television as their primary source of the warning, 15 of 28 participants who had received a warning reported watching television to help determine if they would be personally at risk (Sherman-Morris and Brown 2013). During the same outbreak, in Tuscaloosa, Alabama, television was also the most common information source among the respondents, many of whom were college students (Stokes and Senkbeil 2017). More recently, 61%–73% of respondents to a survey following three Oklahoma tornado events used television news "to gather information" (Miran et al. 2018). Television has been especially important when individuals are at home when the tornado is warned (Comstock and Mallonee 2005) and during the day more so than at night (Mason et al. 2018).

In recent years, smartphones have risen in importance as the first source of weather alerts (Yoder-Bontrager et al. 2017) and appear to be used consistently day or night (Mason et al. 2018). In interviews conducted in Ontario, Canada, participants reported text messages, cellular telephone (hereinafter cell phone) pop-ups, and telephone calls were the best way to provide them with Environment Canada weather warnings (Silver 2015). In a survey of 2754 individuals from Mississippi and Alabama, the most frequently used sources for severe weather information were the local weathercaster on TV, a mobile-telephone application (hereinafter app), and the local weathercaster online—all used on average "very often" (Dickey 2020). Smartphones were the preferred warning source for Mississippi and Alabama individuals who were legally blind, although television was used by nearly all participants interviewed (Sherman-Morris et al. 2020). While smartphones are valued for the level of detail they provide, synthesizing multiple pieces of risk information for oneself can be overwhelming (Walter et al. 2020; Yoder-Bontrager et al. 2017). These studies affirm television's importance as a source to help one make sense of their situation. Because weathercasters can be the curator of information on television, or other live weather coverage, they can provide more explanation or context than many smartphone weather products.

Despite the importance of weathercasters in tornado warning communication, there is a relative dearth of studies on television broadcast coverage of tornado warnings. Studies of continuous extreme weather coverage have found that weathercasters play a significant role in the coverage of hurricanes (Daniels and Loggins 2007; Prestley et al. 2020) and tornadoes (Cario 2016). The primacy of the role that weathercasters play is likely related to the stage of the event as weathercasters' communication of potential weather impacts early in an event may be supplemented by reports from the field once there are impacts to report (Daniels and Loggins 2007; Cario 2016). While studies of this nature are rare, they highlight key elements that weathercasters use during extreme weather, summarized below.

b. *Elements of tornado warning messages and broadcast coverage*

1) Visual elements

Warning information communicated visually is often presented using maps. In an analysis of continuous coverage of multiple hurricanes, radar imagery, watches and warnings and other weather maps were the most commonly used elements in the weather-related portion of the broadcast (Daniels and Loggins 2007). Maps provide a tool for identifying the location of a tornado and its path with respect to the recipient's location. Proximity to a hazard, which is often associated with higher perceived risk (Lindell 2020; Klockow-McClain et al. 2020), is frequently communicated via map, although effective communication relies on recipients understanding their location as well as their location relative to the hazard. During televised coverage, the weathercaster can assist in conveying this information through linking the danger with certain streets and landmarks. Interview participants from Mississippi and Alabama appreciated when their local weathercaster was familiar with fine-scale local places and landmarks that could help them personalize the threat (Klockow 2013; Sherman-Morris et al. 2020). Broader scales such as regional or state-level were important for providing awareness to Mississippi or Alabama interview participants (Klockow 2013).

Maps also provide a base for displaying other elements such as radar, warning polygons, or other elements. Despite what Klockow-McClain et al. (2020) estimate have been "millions of appearances" in media, maps are understudied with respect to their influence during tornado warnings. A larger proportion of the research on visual tornado warning elements has focused on warning polygons and how the characteristics of a polygon's shape (Lindell 2020) or whether it is presented in conjunction with radar are associated with perceptions of risk (Jon et al. 2018, 2019). However, warning polygons are only a small part of broadcast warning coverage.

Radar is arguably the most important component of severe weather coverage (Obermeier et al. 2022), and most survey respondents in the Tampa, Florida, area found a radar tool very useful (Saunders et al. 2023). Weathercasters may use radar as a backdrop for verbally describing the location of a tornado. However, research suggests that people may not understand radar products or may not be able to use them sufficiently to make the best protective decisions (e.g. Saunders et al. 2023; Senkbeil et al. 2022; Nunley 2019). Thus, it is important that weathercasters have the ability to verbally add context and explanation to the radar imagery.

2) VERBAL ELEMENTS

Very little has been documented about the language used during tornado warning broadcasts. In the only previous study of tornado warning broadcast coverage we found, information common during weathercasters' or broadcasters' discussion of the tornado risk was characterized as hazard agents, severity, lead time, direction, and protective action (Cario 2016). Many of these themes relate to components of effective warning communication. For example, the character of the hazard, time until impact, location(s) of the risk, and guidance about what people should do to maximize their safety were among the five topics Mileti and Sorensen (1990) identified as important to include in a well-constructed emergency message (the source of the warning was the fifth). Including a specific protective action recommendation in disaster messages is especially important for eliciting a safe response (Lindell and Perry 2012). Recent research on tornado warnings suggests that even when a warning message includes sufficient information about the hazard event, a lack of guidance on protective action may inhibit a safe response (Sutton et al. 2021). Cell-phone warnings were described as not providing as much information on recommended actions as television (Walters et al. 2020). Thus, it is especially important to examine broadcast warnings for protective action recommendations as well as the other elements of effective messaging.

In contrast with cell-phone warnings, the format of the on-air broadcast allows the weathercaster flexibility to explain the situation or to use their manner of speaking to communicate their message (Demuth et al. 2009). Thus, when a weathercaster is present, verbal communication can help overcome limits in the audience's understanding of the threat. Weathercasters sometimes use figurative language to help communicate complex scientific explanations about extreme weather (Prestley et al. 2020). For example, a hurricane was described as both a monster and a machine to talk about where it got its energy, why it stalled, and how bad it was (Prestley et al. 2020). A participant in another study explained that the weathercaster reading the street names off the radar also helped them to understand if they were under the threat (Sherman-Morris et al. 2020).

A study of hurricane coverage found that weathercasters used intense language like "catastrophic" or "life-threatening" to help describe risk from Hurricane Harvey (Prestley et al. 2020). The use of specific language can be important for risk perception and protective action. For example, video clips in which the threat was referred to as a tornado specifically rather than with vague language such as "this thing" were associated with higher risk perception among viewers (Sherman-Morris and Lea 2016). Signal words such as "warning" or "tornado emergency" were also found to call attention to a threat and communicate its urgency (Sutton and Fischer 2021). Similarly, in an experiment comparing impact-based warning scenarios, any hypothetical warning with a stronger impact statement led to greater protective decision-making than a warning without the stronger impact statement (Casteel 2018). Language used in the warning should also be clear and understandable (Mileti and Sorensen 1990) and avoid the use of too much technical meteorological terminology or jargon (Lindell and Perry 2012) that could interfere with understanding.

c. Rural versus urban differences

There are multiple ways that rural and urban areas may experience tornado warnings differently. Given that geographic information can help at-risk people personalize a tornado's threat (Sherman-Morris et al. 2020; Klockow 2013; Aguirre et al. 1991), differences in the density of population and geographic features between urban and rural areas alter weathercasters' ability to call out specific locations in the path of a tornado or personalize the threat for viewers (Aguirre et al. 1991). Access to warning communication resources may also vary among urban and rural areas. Urban areas may be more likely to have camera footage for weathercasters to show during warnings (Klockow 2013). Individuals interviewed from rural areas in Mississippi and Alabama believed their area was covered less and that they had less access to tornado images (Klockow 2013). Fewer storm spotters in rural areas also may inhibit real-time warning communication (Brotzge and Erickson 2010). Impacts stated in warning messages have also been perceived as less relevant to rural communities than urban areas (Harrison et al. 2014). Last, if a tornado forms farther from a radar site, it is less likely to be warned, and gaps in radar coverage coincide with less populated areas (Brotzge and Erickson 2010). These results demonstrate both real and perceived differences in tornado warning coverage and communication between urban and rural areas and demonstrate the need to take these differences into account when studying warning coverage and when communicating a warning message.

3. Research questions

Given the importance of broadcast coverage in tornado warning communication and how our knowledge that visual and verbal risk communication elements across different geographies affect risk perception during tornado warnings, it is important to understand how visual and verbal elements are present in tornado warning coverage. This study focuses specifically on the type of imagery used to communicate the tornado warnings, the spatial scale at which coverage occurs, and the verbal description of the threat. Research questions driving the study included the following:

- To what extent are radar products used to communicate the tornado threat, and, in particular, which type of radar product is most commonly used during tornado warning coverage?
- To what extent do local TV stations use various geographic scales in their tornado warning coverage?

- Where differences exist in the use of radar products and geographic scale, can differences be explained by the characteristic of the market as more urban or rural?
- What common verbal themes exist in tornado warning broadcasts?

4. Data and methods

a. The sample

We used purposive sampling beginning with a query of available tornado warning coverage on YouTube and conducted a qualitative content analysis using data from two local news stations' coverage of two separate events (see the data availability statement for the YouTube links). The first event occurred on 2–3 March 2020 and was broadcast by ABC affiliate WKRN. WKRN is available in middle Tennessee in the Nashville designated market area (DMA) and includes the Tennessee cities of Nashville, Lebanon, Murfreesboro, Cookeville, and Clarksville. Nashville DMA is the 29th largest market (of 210 markets). The second event occurred on 19 April 2020 and was broadcast by dual CBS/CW+ affiliate WHLT. WHLT is available in southeastern Mississippi's Pine Belt region and includes the Mississippi cities of Hattiesburg and Laurel. Its DMA is ranked 168. WHLT is owned and operated by WJTV in Jackson, Mississippi, which means the two stations share personnel and resources.[1] Most local news originates with WJTV, but they may deliver storm coverage along with or independent from WJTV. For this event, WHLT was only broadcasting for the Pine Belt area.

We selected those two events and local TV stations for three reasons: 1) their urban/suburban/rural differences, 2) data availability, and 3) similar tornado intensity based on the enhanced Fujita (EF) scale. Nashville is the capital city with the largest metropolitan area in the state of Tennessee and consists of 13 counties. On the other hand, most of the Pine Belt's population of southeast Mississippi is rural. Thus, the broadcast coverage in our study ranges from urban to rural. In addition to the geographical nature of the regions, both TV stations' coverage with transcripts were publicly available on YouTube. According to Storm Prediction Center reports, both tornado events were deadly, included the occurrence of an EF4 tornado (https://www.spc.noaa.gov/exper/archive), and included multiple warnings (Iowa State University 2022).

The length of WKRN coverage (divided into two parts) was 3 h 2 min 33 s, and that for WHLT was 2 h 33 min 18 s. The first part of WKRN coverage for the 2–3 March event began at 2310 local time (LT) local time with tornado warnings for Benton and Humphreys Counties near the western edge of the viewing area. There were also flash flood warnings at the time for counties in the Kentucky portion of the viewing area. During this portion of the coverage, there was an EF2 tornado that tracked nearly 19 mi (1 mi = 1.161 km) through Benton and Humphreys Counties (Fig. 1). A second EF0 tornado with approximately 5-mi-long track later touched down in Humphreys County. Following this tornado, there was a period of 20 min in which there were no active warnings in the viewing area. For most of this time, WKRN was not live on the air. At 0035 LT, a tornado warning was issued for Davidson, Sumner, and Wilson Counties, and WKRN returned to live coverage for approximately 2 h. During this portion of the coverage, there was an EF3 tornado with a 60-mi track that passed through the Nashville metropolitan area, an EF4 tornado that tracked approximately 8 mi through Putnam County toward the city of Cookeville, and three EF0 tornadoes east of the Nashville area. The times of the tornadoes did not overlap. Coverage continued after the tornadoes had exited the viewing area in a third recording that was not included in the analysis.

WHLT coverage for the 19 April event began at 1818 LT and ended at 2041 LT when the weathercaster announced that WHLT would return to regular programming. The first warning was issued at 1801 LT, and the last warning expired at 2115 LT. Coverage began and ended when the threat entered and left the station's viewing area. During this coverage, there was one EF4 tornado that tracked nearly 54 mi across Walthall, Marion, Lamar, Forrest, and Perry Counties in Mississippi (Fig. 2).

There were three weathercasters who were seen on air during most of these events, two on WHLT and one on WKRN. Other weathercasters spent less time on air or supported the coverage off camera. Other news personnel also participated in WKRN's coverage. After conducting the content analysis, we reached out to the three primary weathercasters with questions to provide context to the results. This research was reviewed by the Human Research Protection Program/Institutional Review Board (HRPP/IRB) at Mississippi State University and was granted an exemption determination (IRB-23-178). Two current or former meteorologists at WKRN and WHLT agreed to speak with one of the authors. A semistructured interview was conducted with each by telephone consisting of the following questions.

- Could you describe what sorts of things you think about when a tornado warning is issued, and you are preparing to start continuous warning coverage?
- Are there any station/station group policies that influence your severe weather coverage?
- Is there anything that guides your decision when deciding which radar product to display (reflectivity, velocity, or correlation coefficient)?
- In spring 2020, which graphics system were you using and is there anything about it that influences your severe weather coverage? (This could be something you like about it or any way you feel it limits you).
- Does the station typically send reporters to cover damage during severe weather coverage? What factors influence whether reporters are sent into the field?
- Our analysis of broadcast warning coverage indicated that more time was spent at a street-level scale when a tornado was affecting a more urban area. Can you comment on that from your own experiences?

[1] Sharing services among local stations is not uncommon. Shared-service agreements in which stations share resources such as facilities, personnel, content, and newsroom assets, were found in nearly one-half of markets (Yanich 2014), with them being most common in small-to-midsize markets (Stelter 2012; Hull and Coffey 2015).

(Source: NOAA/Storm Prediction Center)

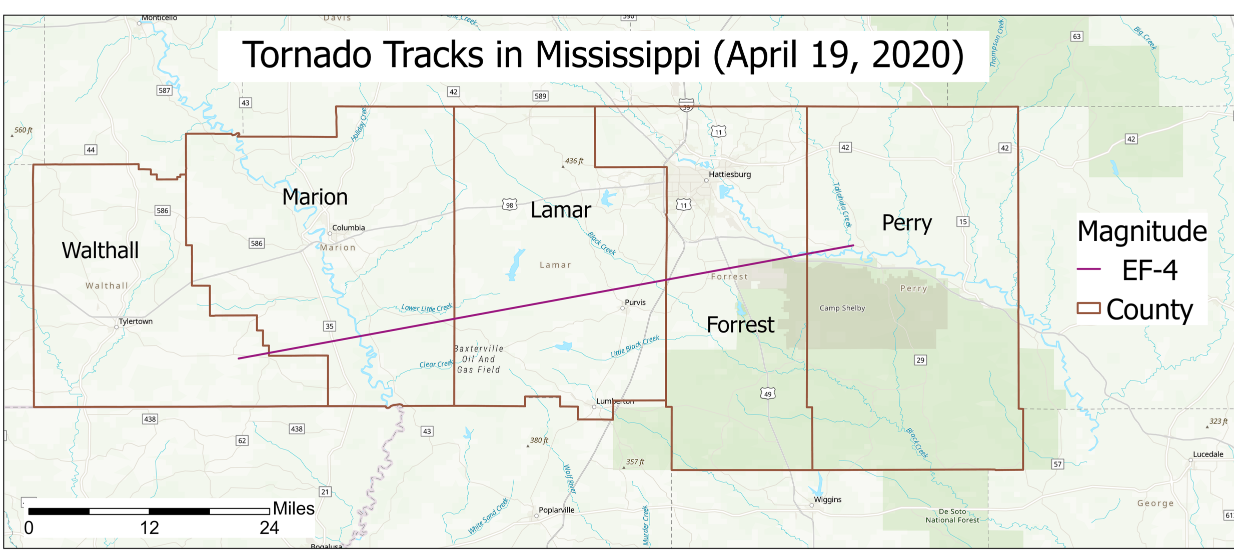
FIG. 1. Tornadoes in the WKRN viewing area.

Discussion was not restricted to these questions. Responses were handwritten during the interviews, but the conversations were not recorded. Each interview lasted approximately 20 min.

b. Visual elements

Our first research question sought to determine to what extent certain radar products are used to communicate the tornado threat. Although there are several specific types of radar imagery used in tornado warning dissemination, in this project, we focused on three major types: reflectivity, velocity, and correlation coefficient (see Fig. 3 below). Reflectivity shows the strength of the energy returned to the radar after it bounces back from the precipitation sources. Warmer colors mean more returned energy and a higher amount of precipitation. Velocity shows the magnitude and direction of the objects, that is, whether targets are moving away from or moving toward the radar. Typically, red means the targets (e.g., precipitation) are moving away from the radar, and green means they are moving toward the radar. The intensity of the colors determines the speed, and the juxtaposition of red and green can be used to infer rotation within the storm. Correlation coefficient measures the consistency of the size and shape of the objects within a radar beam and may be used by meteorologists to detect tornado debris.

To determine the frequency of radar coverage, we first classified each visual element of the coverage as radar or something



(Source: NOAA/Storm Prediction Center)

FIG. 2. The tornado in the WHLT viewing area.

A. Velocity B. Reflectivity C. Correlation Coefficient

FIG. 3. Screen captures from the WHLT Hattiesburg/Laurel broadcast showing the three radar products; (a) velocity, (b) reflectivity, and (c) correlation coefficient. The velocity image shows a broad (weaker) rotation, the reflectivity image shows areas of heavier precipitation surrounding an area of rotation, and the correlation coefficient image indicates areas with a debris signature. Images were acquired from NWS WSR-88D instruments located in New Orleans, Louisiana, and Mobile, Alabama.

else. Visual elements that were not radar included watch and warning graphics, temperatures, traffic camera footage, a hail tracker, accumulated rainfall, safety or storm impact-related graphics, storm reports, and damage footage (including video, photographs, and reports from the field). To calculate the relative frequencies of each type of radar, we categorized each portion of the coverage with radar present as reflectivity, velocity or correlation coefficient, recorded the amount of time spent with each displayed, and divided them by the total time overall or the total time spent only on radar products. WHLT had a tool that showed velocity imagery superimposed over other products. These were recorded as a separate category and were not included in the time spent in any one of the three radar types. The weathercaster did not have to be talking about the radar product specifically for it to be counted as present.

Our second research question, which explored the use of visuals, examined the use of geographical scale in the broadcast warnings (Table 1). We examined the geographic scale for all mapped products by recording the time spent in three geographic scales, which we refer to as state level, city/county level, and street level. We defined a widest screen distance less than 15 mi as street-level scale, between 15 and 65 mi as city/county-level scale, and anything larger than 65 mi as a state-level scale (e.g., Fig. 4). In many cases, it was obvious which level of geographic scale was being used. Where it was not obvious, Google Maps was used to measure the distance between points at each end of the screen. Any time that the weathercasters zoomed in or out a judgement was made as to which geographic level was being displayed.

The third research question asked whether differences could be explained by the characteristic of the market as more urban or rural. To address this research question, we explored differences in geographic scale observed within urban and rural portions of WKRN's coverage. We considered the time in which tornadoes were on the ground in Benton and Humphreys Counties to be rural coverage and the time a tornado was on the ground in the Nashville area (Davidson, Wilson, and Smith Counties) to be urban coverage. Warning times and times when tornadoes were on the ground were obtained from the Iowa Environmental Mesonet and the Nashville National Weather Service website. We tested the observed differences with a difference-of-proportions Z test.

c. *Verbal elements*

Our last research question asked what common themes exist in the spoken portion of tornado warning coverage. To answer this question, we utilized a descriptive method and conducted a qualitative content analysis (QCA) using a "directed approach." Hsieh and Shannon (2005) defined QCA as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns." QCA is suitable for inductive and deductive approaches and offers more flexibility with emerging or adjusting existing codes (Kansteiner and König 2020;

TABLE 1. The categories and subcategories used in verbal and visual analysis.

Criteria	Category	Subcategories
Visual analysis	Radar products	Reflectivity, velocity, and correlation coefficient
	Geographic scale	State level: >65 mi, city/county level: between 15 and 65 mi, and street level: <15 mi
Verbal analysis	Lead time (trajectory)	—
	Process of monitoring and updating condition	Adjustment and reinforcement, zoom in and out, and damage report
	Severity	Weather hazards, storm features, descriptors, and tornado watch/warning polygon
	Protective actions	—
	Jargon (meteorological terms)	E.g., rotation, mesocyclone, shear, hook, and echo

A. Street Level B. City/County Level C. State Level

FIG. 4. Example of (a) street-level-, (b) city/county-level-, and (c) state-level-scale maps from WKRN Nashville [in (a) and (c)] and WHLT Hattiesburg/Laurel [in (b)].

Schreier et al. 2019). In a directed approach, researchers utilize existing theories or concepts to create research questions and adopt "codes" or "categories" based on their study requirements (Hsieh and Shannon 2005; Ali and Gill 2022). Following this approach, we adopted four categories developed by Cario (2016) that best answered our research questions: lead time, monitoring and updating conditions, severity, and protective actions to guide the analysis. To this list, we added jargon. See Table 1 for a list of the categories used in the verbal analysis. Subcategories were generated both deductively based on literature on effective warning communication and inductively within the main categories through an iterative process.

One author applied these codes based on a portion of the transcript, as well as identified additional emergent codes in NVivo. After meetings with the coauthor, revision of the codebook, joint coding of the transcript to resolve any discrepancies, and reanalysis of that portion, the full list of codes was finalized, and one author completed the data-coding process. Although only one author was involved in data coding, the authors conducted a weekly meeting to resolve any issues involved in the coding process. The unit of analysis was a complete statement made by one of the weathercasters. It was at least a sentence, which could be as short as a few words. Most codes consisted of multiple sentences (2–5) because it helped to capture the full message along with necessary context of the remark. Segments of the transcript could represent more than one code. In addition, not every second of the coverage was associated with a code. We only coded segments in which meteorologists were speaking about or displaying any element related to the tornado or severe thunderstorm threat. For example, statements strictly about flash flood warnings and text from live shots were not coded since they were not related to the tornado threat.

Lead time is a crucial component of tornado warning information (Montz 2012) and indicates the interval between the issued warning and actual occurrence at a given location. The weathercasters often describe tornado lead time in terms of time with respect to a given location or distance. Thus, our definition of lead time was not restricted to time before impact. We considered any description of trajectory to be the same code as lead time.

The process of monitoring and updating a situation refers to the techniques used by weathercasters to describe the current scenario, help to confirm warning information, and provide future updates. This code is more about process than message content and was an umbrella for the specific types of processes observed. For example, weathercasters or broadcasters sometimes use the damage report to show the destruction caused by the tornado. Similarly, they use "reinforcement" to emphasize the potential risk of severe weather based on observations or evidence provided by storm spotters or emergency officials. Weathercasters also zoom in and zoom out to narrow down a location or provide an overall picture. Updating coverage also included an adjustment process where viewers are told about expired tornado warnings or where weathercasters switch from one warning to another.

In our analysis, severity referred to the intensity and the possible damage that a tornado or severe storm may cause. Different tools are used to communicate the tornado threat during a broadcast, and we developed a list of subcategories that helped to convey the severity of the situation. These included tornado watches and warning polygons, descriptions of storm features, weather hazards, and adjective descriptors. A tornado watch is used to inform the viewers that tornadoes are possible in and near the watch area and a warning polygon indicates there is an imminent danger to life or property and is issued when a tornado has been spotted or indicated by radar (https://www.weather.gov/safety/tornado-ww). Both indicate some threshold for severity or forecasted severity has been met. Literature supports the idea that a warning is perceived as more severe than a watch (Schultz et al. 2010; Silver 2015) so it made the most sense to be included as representing severity. Descriptors such as "violent" or "dangerous" help indicate the magnitude and possible impact. The subcategory storm features reflected explanations of the aspects of the storms that either caused them to be potentially severe (or not severe in the event they were used to describe a weakening storm) or helped the weathercaster to understand its severity. Weathercasters also described other weather hazards including, but not limited to rain, hail, lightning, and thunderstorms to indicate the severity of the current situation. These were used individually as well as in conjunction with the overall tornado threat.

The protective action code captured the safety measures recommended to avoid or minimize the potential threat from the tornado. For example, messages such as "move to your basement," "seek shelter," "check your mobile phone for updates," and "keep your distance from your window" can help people protect themselves during tornado outbreaks and minimize the risk of harm.

Also, weathercasters used what we considered to be jargon. Jargon is an occupation-specific technical language commonly used to communicate in a given profession (Eachus and Keim 2020; Patoko and Yazdanifard 2014). Examples in the coverage included different meteorological terms such as "rotation," "hook," and "mesocyclone." Jargon may not be useful to all viewers (Eachus and Keim 2020) because understanding is an important part of the warning process (Lindell and Perry 2012). Following the coding of the transcripts, exploratory tools in NVivo such as word frequency and cluster analysis were used to visualize and help interpret the data.

5. Analysis and findings

a. Visual elements

1) Radar product use

Weathercasters spent the vast majority of time during the tornado warning coverage using some radar product. Radar imagery accounted for 95% of the coverage by WHLT Hattiesburg/Laurel and 71% of the WKRN Nashville coverage. The primary difference was the result of a considerable amount of time spent by WKRN on damage footage (video, photographs, live reports, etc.). This was absent in the WHLT coverage but accounted for about 15% of the broadcast for WKRN. The damage footage was largely associated with the Nashville tornado. The first, brief instance of damage footage was about 30 min into the coverage and was associated with earlier damage from "the same cell" that led to an active warning for Dickson County. It was described by the weathercaster. Later in the WKRN broadcast, damage from the Nashville area became more prevalent. This part of the coverage was more frequently delivered by a reporter in the field. It began while a tornado was still affecting the Nashville area and continued after the tornado threat had moved east of the metropolitan area.

Reflectivity, velocity, and correlation coefficient were the three dominant radar products used by the two local TV stations in their broadcast of tornado warnings (see Fig. 5). Both stations spent a higher percentage of time using velocity products. The percentage of time showing velocity ranged from 54% to 61% with reflectivity accounting for 22%–35% (see Fig. 5 for the total time spent). The percentages do not include times when multiple radar products were used. Those accounted for about 5% of WHLT's time displaying a radar product (7 min, 43 s).

Because we only reviewed coverage for one event each, no generalizations can be made about radar product use. However, there are characteristics of radar that may help determine which is more useful. Because velocity is used to locate areas of intense rotation, it is often used to find and communicate where a tornado might be occurring. Radar units have an area overhead, sometimes called a cone of silence, where they are limited in their ability to detect targets. Closer to the radar site, they also are more likely to detect objects that are not

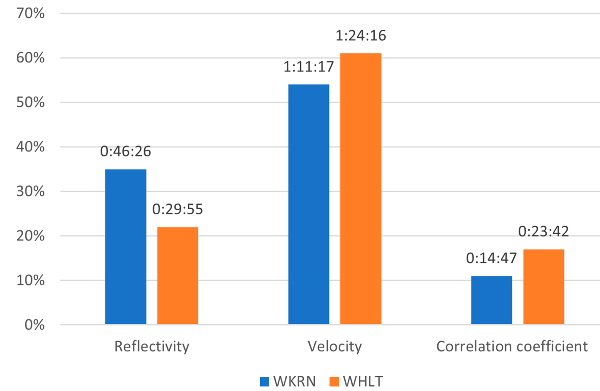


FIG. 5. Percentage of time that reflectivity, velocity, and correlation coefficient radar products were used by WKRN Nashville (blue) and WHLT Hattiesburg/Laurel (orange). Labels indicate time in hours, minutes, and seconds.

associated with precipitation, commonly called ground clutter. Discussion with the weathercaster from WKRN noted that during the time the tornado was close to the Nashville radar site, reflectivity was more helpful because the tornado was harder to see near the radar site on the other products. Similarly, as distance increases from a radar unit, the radar sees higher up in the atmosphere. This limits its ability to see features of the storm close to the ground. The WHLT weathercaster noted that Hattiesburg is farther from a radar unit, which can limit what they are able to show on air. They also explained that they often let the structure of the storm determine which radar product they use. For example, if a storm has a pronounced hook, they may favor reflectivity to help them tell the story. Similarly, the WKRN weathercaster noted that if they detect what they called "tightening up" they will turn to the correlation coefficient for confirmation of the tornado.

2) Geographic scale

In examining the geographic scale used by the two stations, we found that both stations spent the greatest amount of time on city/county-level coverage overall (see Table 2 for percentage and total time spent). WHLT spent approximately 65% of the time at the city/county level (as a percentage of the total time using a mapped product). WKRN spent less time proportionately (48% of mapped product time) on the middle-scale range overall, but it was still the scale most used. The second most frequent category of map time was state-level coverage, and the least amount of time occurred at the street level.

The urban nature of parts of the WKRN coverage area prompted us to examine whether differences could potentially be explained by urban versus rural characteristics. During the approximately 57 min when a tornado was on the ground in the Nashville area (Davidson, Wilson, and Smith Counties), weathercasters used a much greater percentage of street-level maps than during the portion of the coverage when tornadoes were on the ground in Benton and Humphreys Counties. In the just under 30 min that the tornado was on the ground in

TABLE 2. Differences in the amount of mapped time spent in the three geographic scales between WKRN Nashville and WHLT Hattiesburg/Laurel. Times are given in hours, minutes, and seconds.

Coverage	WHLT (percentage)	WHLT time	WKRN (percentage)	WKRN time
State level	29.40%	0:44:44	29.20%	0:42:44
City/county level	65.20%	1:39:11	47.80%	1:09:55
Street level	5.40%	0:08:13	22.90%	0:33:28

Benton and Humphreys Counties, WKRN spent 5% of the time at the street level, whereas they spent almost 50% of the time at the street level during the Nashville tornado (Table 3). A difference of proportions test indicated that the proportion of street-level coverage was significantly different between WKRN's coverage of the Benton and Humphreys tornado and the Nashville tornado ($Z = 30.1$, $p < 0.001$). While the observed differences between the two stations may be a function of other factors, the statistically significant differences within WKRN's broadcast suggest that street level was used to a greater extent in more urban areas in that broadcast. The interviews with the weathercasters also suggest that the density of landmarks in urban areas can be a benefit for coverage, while the lack of landmarks in rural areas can be a challenge. For example, the WHLT weathercaster explained that more people are familiar with the addresses and other features in urban areas and the WKRN weathercaster commented using street level is more difficult in very rural areas. Because we only reviewed coverage for one event, attempts should not be made to generalize these results. However, the patterns observed call for further research with a broader sample within and among local markets.

b. *Verbal elements*

As shown in Fig. 6, the most popular verbal theme based on the number of times the code was assigned was monitoring and updating conditions, followed by severity, lead time, protective actions, and jargon. Results are provided separately for each station, but most categories were very similar. A word-frequency query of the top 500 most frequently used words indicated that "now" was the most often stated word (1812 times) followed by "right" (1642 times), which was often used as its modifier (as in "right now"). This helps to show the urgency with which weathercasters communicated the warning message. "Tornado(es)" and "county/counties" were next with approximately 1200 mentions. The fifth most-spoken word was "see(ing)" (1024 times).

1) LEAD TIME

In the coverage, the weathercaster referred to lead time before the arrival of weather hazards in three different ways: 1) in terms of time, 2) in terms of distance and speed, and 3) in terms of location. Local weathercasters sometimes combined all three elements; for example, they gave the lead time in minutes with storm speed and direction. The direction also includes the future movement of the storm and possible locations (i.e., as roads, highways, or counties) that interact with the storm path. The following quote is an example where the weathercasters describe the lead time using time, location, direction, and speed:

> Within a minute or two, this large, damaging, tornado, producing damage right now, is going to be crossing Highway 43 north of Spring Cottage south of Hub and eventually, this is also going to be moving close to the community of Pinebur and then crossing Highway 13 near or just to the south of Hub and Pinebur in southern Marion County. Again, this is a large damaging tornado that is on the ground moving to the east at 55 miles per hour and if you live along Highway 43, Highway 13, and anywhere south of Hub along Highway 13, this is moving in your direction (WHLT-TV 2020).

A word similarity cluster analysis performed in NVivo indicated that items coded lead time often occurred in the same context as a protective action coded statement.

2) MONITORING AND UPDATING CONDITIONS

The process of monitoring and updating conditions included three specific types of updates: zooming in and out, adjustment and reinforcement, and damage reports. Zooming in and out was used in different ways to monitor conditions while the other codes reflected updates.

(i) Zoom in and zoom out

Weathercasters used the zoom-in category to offer a microlevel observation with a narrow focus area, usually at street-level coverage. Zooming in allowed weathercasters to show locations that were closer to the tornado's projected path. The WKRN weathercaster mentioned that they always zoom into street level as soon as they understand a tornado is on the ground. Below is an example from the broadcast where the zoom-in tool was used to indicate the danger at street level:

> So, as we kind of zoom in here, we just want to take you down to street level. If we have a tornado on the ground, it's likely gonna

TABLE 3. Differences in the amount of mapped time spent in the three geographic scales by WKRN for two individual tornadoes: Humphreys/Benton and Nashville. Times are given in minutes and seconds.

Coverage	Humphreys and Benton tornado (percentage)	Humphreys and Benton	Nashville tornado (percentage)	Nashville time
State level	44.60%	12:37	8.4%	04:21
City/county level	50.50%	14:16	42.0%	21:54
Street level	4.90%	01:23	49.6%	25:50

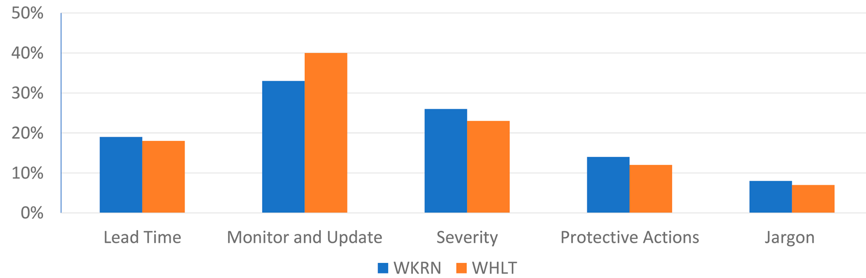


FIG. 6. Comparison of the uses of coverage themes between WKRN Nashville (blue) and WHLT Hattiesburg/Laurel (orange).

be near Huron, Mixon, Gillsburg, moving very quickly towards Terry's Creek, Magnolia and Chatawa here, so likely somewhere along Highway 568 pushing off towards the east at about 60–50 miles per hour rather and so if you live along a Hamp Lea Road, Centerville Road, Magnolia Progress Road, some of these areas you need to be seeking your safe place (WHLT-TV 2020).

Weathercasters utilized the zoom-out category to provide a macrolevel observation with a wider geographic area, usually occurring at the county, state, and regional levels. By zooming out, they could offer a bigger picture of storm activities. The following example displayed the utilization of the zoom-out technique at the county level:

I'm gonna zoom out here, Gordonsville. This is coming straight at you. Gordonsville, this is coming straight at you. You don't have much time. This is a fast-moving storm. It's quick. It flies fast, and I mean if this holds together, we've got Old Middleton. It's right in front of you right now Old Middleton if you're not downstairs in the basement you are in trouble (WKRN-TV 2020).

Zooming out was also used on WKRN to show the location of active severe weather relative to the Nashville metropolitan area. In the cluster analysis, "zoom out" was more closely related to meteorological factors such as storm features, jargon, temperature, or radar, which often helped explain what is going on. "Zoom in," on the other hand, was more closely related to locations such as roads or intersections.

(ii) Adjustment and reinforcement

Because of the uncertain and evolving nature of the severe weather, weathercasters make adjustments about what they are observing and any changes to hazardous conditions. For example, adjustments included announcement and discussion of new warnings issued by the NWS, such as any changes in the tornado's path, location, or speed. In the following example, the weathercaster talks about the cancellation of a tornado warning for Pike County and updates the viewers on the current situation:

By the way you see this original tornado warning right here in Pike County, that's really been canceled. It's gonna take a few minutes for that to come off, but that's no longer in effect. So the rotating part of the severe thunderstorm definitely is now totally within Walthall County and it continues to progress to the east at about 50 miles per hour (WHLT-TV 2020).

Weathercasters of both TV stations used reinforcement to confirm threats from other actors, such as storm spotters or the National Weather Service, and emphasize the dangers using strong wording. For example, in the following excerpt, the weathercaster repeatedly warned viewers about the possible threat by using video confirmation and requested them to take shelter and protective actions:

We've had we have video confirmation. It was on the ground in East, and it was on the ground in East Nashville. So, we know that it was on the ground from multiple spotters, so we just looked a video of it as it was moving through East Nashville. So, this is an extremely dangerous tornado that has moved multiple miles at this point from when it was spotted, and it cut a path through Nashville into East Nashville and right now it looks like it is just north. We're seeing that rotation around Northwest Rutland Drive and Belinda Parkway right along 40 (WKRN-TV 2020).

(iii) Damage report

Both stations utilized damage reports to update the audience regarding the current situation. Examples included damaged trees, power outages, debris, property damage, deaths, and flooding. In the following example, the weathercasters described the damage in Camden, Tennessee:

So, we just want to give you a heads-up on that there are damage reports back in Camden, the Benton County area. In Camden a large tree down and a home with damage. And there was another report of some large trees as well and there's also a report of some large hail an inch and a half in diameter. So those storm reports and also the other report I was talking about multiple homes damaged. So earlier we just had one tree in one house but now they've gotten new reports of multiple homes damaged back in the Camden area and that's what's in White Bluff, right now (WKRN-TV 2020).

3) SEVERITY

Items that helped to convey the severity or dangerousness of the situation included the weather hazards themselves and storm features that help to explain why the weathercaster believed the storm to be severe. Descriptors that help add emphasis and emotion were also used to communicate the severity. Tornado watches and warning polygons help convey the immediacy of the impact, which helps to emphasize its severity. The issuance of a tornado warning polygon indicates both that a hazardous situation has crossed a threshold for being severe and also illustrates those areas that are at risk of an immediate tornado threat.

(i) Weather hazards

Weathercasters use the weather hazards category to call out other weather hazard threats (i.e., hail, wind, and lighting) as well as to describe how those threats are related to the tornado threat. They also help to illustrate how bad the situation will be. In the following example, the weathercaster describes how the change in the hail core is related to the intensity of the storm:

> We've got a tornado-warned storm and very large hail. This hail core is starting to increase. I don't like the look of that when the hail core starts to increase that means the storm is actually jumping up or intensifying. The hail is now up to 1.8 in. in diameter which is bigger than ping-pong ball sized hail (WKRN-TV 2020).

WHLT anchors used quantitative information, such as the frequency of lightning (another weather hazard) to describe the severity of the threats (see the following example):

> Another dangerous part of the storm in this box here from Kentwood mostly over the southeastern part of Amite County and over a little portion of Louisiana as well. We're looking at 344 lightning strikes, so the storm is not gonna sneak up on you. You're gonna know that the storm is headed your way. You're gonna see a ton of lightning. You're gonna hear a lot of thunder but I do believe the tornado if one is being produced could be rain-wrapped (WHLT-TV 2020).

Both stations used wind speeds to talk about wind gusts that were possible or occurring (e.g., "wind gusts still to 50 miles an hour, lots of heavy downpours and lightning"; WKRN-TV 2020) or to describe the forward track of the storm producing a tornado (e.g., "and all this is going to be shifting very quickly to the east as it rolls fast down the road at about 50 miles an hour"; WKRN-TV 2020). WHLT also described the inbound and outbound wind speeds as detected by the velocity radar product a dozen times:

> I want to query or show you these winds how fast they are rotating and we're seeing winds 30 miles per hour coming to the south, 65 miles per hour to the north that's nearly 95 miles per hour of rotation that we're seeing now along Pike Highway 93 south along 575 moving towards Gladhurst. Chatawa and Osyka should be in their safe place right now as this possible tornado is moving overhead (WHLT-TV 2020).

(ii) Storm features

Storm features refer to any convective weather referenced during tornado warning coverage, but typically they are used to describe the storm producing or the storm capable of producing a tornado. Weathercasters discussed different features of the storms, including rotation, storm morphology, and other descriptions of storm structure. Weathercasters also used the EF scale to indicate the severity of the potential tornado outbreak. There was overlap between storm features and other codes. For example, there was a tendency among the weathercasters to use intense language and adjectives (large, dangerous, and deadly) to describe storm features. A cluster analysis suggested that storm features and jargon were also often used in a similar context. Reflectivity and velocity lend themselves to discussion of different storm features as shown by the two examples below. The first used a velocity product to describe rotation while the second example used the reflectivity product to highlight what storm features were and were not present that would indicate a tornado:

> We're watching this really carefully here by the way. We're looking at velocity products here. I like to put it in the velocity mode just to make sure nothing too crazy's happening but we do still have some bright reds and some bright greens in here so I would not be surprised if it's trying to tighten back up the rotation that is here. I'm going to circle and show you exactly what I'm talking about (WKRN-TV 2020).

> We continue to have a dangerous storm on the ground. In addition to that we're seeing some large hail right now at the core of this storm and as we look here on our radar I think a few moments ago, I was seeing the potential for maybe a weak echo region but I'm not seeing that. We still have a very kind of classic notch here where we're getting the inflow winds coming in from the south. Our tornado is wrapping in from the north and this is where we're seeing the circulation (WHLT-TV 2020).

Nearly all the discussion about storm features occurred while the weathercaster was showing a radar product. Approximately three-quarters of the discussion about storm features occurred with the velocity product to highlight rotation. There were four instances in which the hail tracker graphic was shown to call attention to the location of the hail core. Hail tracker is a radar-derived product, but we did not consider it radar in this analysis.

(iii) Descriptors

On several occasions, both local TV stations employed intense descriptions by using language such as "large," "violent," "extremely dangerous," and "incredibly fast-moving." Weathercasters also tended to add storm speed to emphasize the danger:

> So again, this is a dangerous tornado. Again, if you are in Hattiesburg especially south Hattiesburg, 98 to the south down interstate 59 towards the airport, we're 49 and 98 meet this is an area now that I'm growing more concerned about where we could see this damaging and destructive tornado move towards the Northeast (WHLT-TV 2020).

(iv) Tornado watch/warning polygon

Weathercasters use tornado watches and warning polygons to indicate areas currently under severe weather threats. The tornado polygon helped meteorologists communicate the areas that need to take shelter versus those that do not. In many cases, the weathercaster pointed to the polygon overlayed on the radar imagery and told viewers that if they live in this polygon or area, they should be taking protective actions:

> So, folks if you live in this purple polygon right now. I can't stress it enough it's nighttime out, we've already had a storm or two produce a tornado. You need to get down into the lowest level of

> your area preferably a room with no windows, a basement, a closet a bathroom (WKRN-TV 2020).

The warning polygon also was used to call out communities or roads located in the warned area to describe the extent of the threat. In several cases, weathercasters noted the tornado's location within the polygon such as it being near the edge. Weathercasters often announced the color of the polygon to help draw attention to it. Other than one weathercaster calling the warning polygon a box due to its squarish shape, none mentioned any details about it such as shape, size, or orientation. The tornado watch was mentioned less frequently than tornado warning polygons, but was referenced somewhat regularly, at least during the WKRN coverage.

4) Protective actions

Weathercasters of both TV stations recommended several protective actions such as "to take shelter right now," to "get down to the lowest level a room with no windows," to "move to the closest substantial shelter," "staying away from widows," and to avoid the roads or highways that were included in the warnings. In addition to weaving these recommendations into the broadcast, the WKRN meteorologist informed the authors that they created a sequence of graphics that includes protective actions.

Because of the nighttime tornado warning, the weathercaster of WKRN emphasized to the viewers the need to "get down into the lowest level of your area preferably a room with no windows, a basement, a closet, a bathroom . . . because it's nighttime you're not going to see the tornado." WKRN used visuals containing recommended actions and suggested their viewers charge their mobile telephone, download the WKRN app and join the Facebook Live streaming if there is a power outage:

> So just a heads up any storm tonight heavy rain wind hail and tornadoes all threats with the storms and of course since they're coming overnight. By the way, if you have friends or family in Charlotte, please give them a phone call right now if you think they're sleeping because it's right over you, right now, the tornado warned storm. Have a safety plan; get into your safety spot, if you're in Charlotte right now. Phone charged in the on position, we are streaming on Facebook live, right now. So if you lose power go to our Facebook live the main accounts just WKRN News 2. You can follow us on there and then also have the WKRN weather app for all the instant alerts (WKRN-TV 2020).

The weathercasters of WHLT also advised the viewers about the possibility of a nighttime tornado as the terrain is covered with many trees and hills that could reduce visibility. They also indicated the sound of sirens should urge the viewers to take shelter and protective actions.

5) Jargon

Last, the weathercasters of both TV stations used jargon such as "hook" and "debris ball." They both frequently described the rotation on the velocity radar product. Even though the frequency of jargon used was roughly the same between the stations, we observed that WHLT used additional jargon words such as "mesocyclone," "shear," and "wall cloud." Jargon may be used in conjunction with other verbal categories. The exploratory cluster analysis indicated jargon was often associated with the discussion of rotation. At least 17 meteorological terms were coded in the transcript that could be considered jargon.

6. Discussion and conclusions

a. *Discussion*

A weathercaster often uses multiple visual communication elements to describe the status and severity of a tornado threat to viewers (Drost et al. 2016). Radar was found to be the most common weather element in a study of continuous hurricane coverage (Daniels and Loggins 2007) and that prominence held true in the current study. Velocity and reflectivity combined accounted over 80% of the time for each station. Correlation coefficient represented a lower percentage of the time. The less frequent use of correlation coefficient was not surprising because the debris signature is only present when the tornado is actively causing damage the radar can detect. Both stations spent more time using correlation coefficient during the EF3 or EF4 tornadoes when a debris signature was clearly present; however, they also used it briefly to show times that there was no debris signature. Future research should examine the effectiveness of correlation coefficient in communicating the threat. In the interviews, weathercasters offered features about the storm's structure as reasons why they chose a specific radar product. Because this explanation of radar features is not normally available with smartphone radar apps, it would be useful for future research to examine whether exposure to specific radar products used in broadcast coverage improves one's use of radar in smartphone apps.

Radar imagery, watches and warnings, hail and rainfall tracker products derived from radar, temperatures, and storm reports were all displayed during the tornado coverage on maps, which are a very common component of tornado warning communication (Klockow-McClain et al. 2020). We observed differences in the geographic scales at which they were displayed (street, city/county, or state level) that suggested scale may be related to whether the tornado was occurring in an urban or rural area. While both stations spent the most time overall on the city/county-level scale, coverage shifted to a more zoomed-in level on WKRN during the Nashville tornado. State-level coverage was more commonly used during the time tornadoes were on the ground in more rural portions of the WKRN market area. State-level maps were often used to provide the bigger picture of the event, as in the zooming-out example above. WKRN also zoomed out to state-level multiple times to show the location of severe weather relative to the Nashville metropolitan area. This echoes the reason interview participants found state-level information useful for providing awareness in a past study (Klockow 2013). Future research should examine whether coverage scale influences perception of risk or protective action.

One difference that can be observed between radar maps in the Nashville area when compared with maps in a rural county is how much more detail can be obtained by zooming in to the street level. Coverage at the street level is not as helpful when the map does not provide the details necessary for viewers to recognize the location affected (Klockow 2013; Sherman-Morris et al. 2020). In addition to there being more roads in general in an urban area, the WHLT weathercaster explained that more people are familiar with the addresses and other features. Thus, lack of geographic information on radar may present a challenge for communicating with rural areas. The WKRN weathercaster stated that they always use street level as soon as the tornado is on the ground regardless of location, but acknowledged it is more difficult in very rural areas. They explained that other weathercasters supporting the coverage help by using online maps to identify landmarks such as a fast-food restaurant. In addition to recommending that weathercasters become familiar with these landmarks in rural locations, the need for greater detail to communicate locations where geographic information is sparse is an issue that weather graphics vendors may wish to consider.

Anchors and reporters became more prominent after the tornado moved east of the Nashville metropolitan area in the current study much like in Cario (2016). Unlike in Cario's study, where detailed discussion of the tornado risk did not continue as storms left the Oklahoma City metropolitan area, WKRN weathercasters still used the majority of the time to report on tornado risk to the east of Nashville once the tornado threat had left the metropolitan area. The WKRN weathercaster explained that they believed it was essential to continue covering the active tornado. It is unclear whether reporters' prominence was a function of logistics, the level of damage that occurred, or some combination of factors. For example, the tornado in rural portions of the WKRN coverage was not as strong as the tornadoes affecting more urban areas and thus did not produce the same level of damage to report on from the field. Weathercasters may not have sole authority on what should be included in a weather broadcast, even during severe weather. News stations are sensitive to external forces such as competition with other news stations in the market, whether they are in a ratings period, the needs of their audiences, the resources and information they have available or internal factors such as station policies (Demuth et al. 2009; Obermeier et al. 2022). Thus, any differences may be the result of a number of factors both within and outside of the station's or weathercaster's control. Additional research should be conducted with other stations and events to determine to what extent generalizable patterns might exist such as differences in the geographic scale of the maps displayed for urban or rural areas or differences in the use of live footage among stations in different sized markets.

The content of verbal coverage on the two stations was very similar. "Monitoring and updating conditions" was the type of communication most frequent in each station. Actions used to monitor and update the viewers included zooming in and zooming out, making adjustments, reinforcing conditions, and providing damage reports. Processes such as these have been used in both the communication process as well as to help the warning communicators understand the risk (Cario 2016). The rapidly evolving nature of tornado warnings means that a weathercaster must assess the situation and communicate the risk simultaneously on air. Thus, weathercasters needed to zoom in and out to help both viewers and themselves understand the situation. Content classified as focusing on severity was second most common for both stations. Severity was reflected in discussion of the weather hazards (e.g., having a large hail core or ping-pong size hail), the storm features (e.g., the presence of couplets, circulation, tightening rotation, inbound and outbound wind), with warning polygons, and with descriptive language such as "violent" or "extremely dangerous." Many times, what we considered jargon was used to describe the storm features, such as rotation. An excerpt could be coded to multiple categories. For warning information to be most effective, it should avoid language that may not be understood or useful to viewers, such as jargon (Mileti and Sorensen 1990; Lindell and Perry 2012; Eachus and Keim 2020). Future research should examine the extent to which viewers understand commonly used jargon and if its use has an impact on risk perception or response to tornado warnings. Also, recommendations for protective actions were made frequently during the broadcasts. A future study should examine the influence of these recommendations on viewer and nonviewer perceptions of response efficacy. In this vein, one of the most important outcomes of this research is to provide a sense of what nonviewers of severe weather broadcasts could be missing when they rely on other sources. This is especially relevant as smartphone use for warnings becomes increasingly prevalent (Yoder-Bontrager et al. 2017).

b. *Limitations*

Our study was limited by using only one station and one event for each market. Additionally, both stations were located in the Southeast. Much of the area of the United States at risk from tornadoes is located in a rural area and weathercasters may have developed effective ways to discuss tornado risk tailored to their broadcast areas. Thus, it would be incorrect to assume any differences that we observed between urban and rural areas would exist throughout the entire area at risk in the United States or elsewhere. Many contextual factors may have also influenced the results such as the time of day in which the event occurred (prime time vs late night), the day of the week (weekend vs weeknight), the characteristics of the event itself, or the specific weathercaster working during that shift. The availability of resources because of the joint ownership of WHLT was also a factor that we could not fully account for. Another event in the same area could potentially look different due to the sharing of resources on that date. Additionally, decisions about what to include and exclude with respect to how radar is being displayed (e.g., how to count multiple products used concurrently) can lead to subtle changes in the results.

c. *Conclusions*

While our study was limited to two stations and two events, future studies can build on these results using a representative sample of coverage. Based on our sample of only two stations, we document that the predominant visual elements were radar products (specifically reflectivity and velocity with correlation coefficient used to a lesser extent) displayed over a base map. Additionally, city/county level was the most common geographic scale for all maps in the coverage; however, street-level coverage was more common when a tornado affected a metropolitan area. The less frequent use of zoomed in maps in rural areas was likely the result of a lack of landmarks to zoom into, which may affect weathercasters' ability to personalize the location of the threat for viewers. The spoken portion of the coverage included many elements of effective warning communication such as specific protective actions to take, and information about the threat's location, duration, and impact, but at times included jargon that may not be understood by viewers. If found to be consistent in other analyses of broadcast warning coverage, these findings suggest that extra efforts on the part of weathercasters or graphics vendors regarding the geography of rural areas would be beneficial in communicating the location of a tornado threat. Additionally, while further research is needed to understand the impact of jargon in this context, weathercasters may help more viewers understand if they avoid it or follow up with simpler explanations. These findings and recommendations demonstrate the value of this kind of in-depth analysis, which we believe is the first of its kind to quantitatively examine the types of radar used and the spatial scale of coverage. As such, we believe our analysis of the visual and verbal elements can serve as a springboard for future research on both the content of broadcast warnings and also on the impacts of broadcast warning elements on risk perception and response.

Acknowledgments. This work was supported by Award NA16OAR4320199 to the Northern Gulf Institute at Mississippi State University from NOAA's Office of Oceanic and Atmospheric Research, U.S. Department of Commerce. We also thank the two weathercasters who agreed to speak with us about their broadcast coverage.

Data availability statement. The video broadcasts used during this study are available online [https://www.youtube.com/watch?v=coGzBFLlmpI&t=963s (WHLT), https://www.youtube.com/watch?v=i7Xh4YBM1SA&t=3493s (WKRN Part 1), and https://www.youtube.com/watch?v=hTTZgawBskw&t=799s (WKRN Part 2)].

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