When Uncertainty is Certain: A Nuanced Trust between Emergency Managers and Forecast Information in the Southeastern United States

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ABSTRACT: Weather forecasting is not an exact science, and, in regions near the southern end of the Appalachian Mountains, the vastly different types of topography and frequency of rapidly forming storms can result in high uncertainty in severe weather forecasts. NOAA created its VORTEX-Southeast (SE) research program to tackle these unique challenges and integrate them with social science research to increase the survivability of southeastern U.S. weather. As part of VORTEX-SE, this study focused on the severe weather preparation and decision-making of emergency managers and, in particular, how uncertainty in severe weather forecasts impacted the relationship between emergency managers (EMs) and weather providers. We conducted in-depth, critical incident background interviews with 35 emergency management personnel across 14 counties. An inductive, data-driven analysis approach revealed several factors contributing to an added layer of practical uncertainty beyond the meteorological forecast uncertainty that impacted and helped to explain the nature of trust in the EM–National Weather Service (NWS) relationship. No- or short-notice events, null events, gaps in information, and differences in perspectives when compared with weather forecasters have led emergency managers to modify their procedures in ways that position them to adapt quickly to unexpected changes in the forecast. The need to do so creates a complex, nuanced trust between these groups. This paper explains how EMs developed a nuanced trust of forecast information, how that trust is a recognition of the inherent uncertainty in severe weather forecasts, and how to strengthen the NWS-EM relationship.

SIGNIFICANCE STATEMENT: This paper explores emergency manager (EM) relationships with the National Weather Service in the context of severe and hazardous weather that county EMs in the southeastern United States experienced. The goal was to understand how uncertainty in the forecast affects EM decision-making. We found that EMs actively sought out alternative scenarios to the official forecast and made changes to their baseline severe weather procedures because they had experienced severe weather they were not expecting. The NWS could improve decision support to EMs by providing more-frequent forecast updates and sharing signals by which EMs could anticipate changes to a forecast.

KEYWORDS: Social Science; Forecasting; Communications/decision making; Decision support; Emergency preparedness; Societal impacts

1. Introduction

For weather forecast information to be useful, it must have some degree of accuracy. This situation is especially true in the southeastern United States due to its unique profile of social vulnerabilities. Ashley (2007) identified the particular juxtaposition of factors: higher numbers of people scattered throughout rural areas with a relatively high percentage of them living in mobile and manufactured homes (see also U.S. Census Bureau 2019). Combine these factors with a higher frequency of nighttime tornadoes than in other parts of the country, and the resulting situation is that more people are at home in less wind-resistant structures when tornadoes strike (Ashley 2007). Ashley and Strader (2016) confirmed that mortality in the southeastern United States is rising in this area due to the built environment. The Southeast is also where the difficult-to-forecast high-shear, low-CAPE meteorological environments are common (Sherburn and Parker 2014). Forecasts often retain a high degree of uncertainty that may influence the decisions made by users of that forecast. NOAA’s Verification of the Origins of Rotation in Tornadoes Experiment–Southeast (VORTEX-SE) program provides an ideal mechanism for supporting further exploration of this construct. NOAA (2019) recognizes that increasing the survivability of storms requires advancements in both the social and physical sciences.

Emergency managers (EMs) are responsible for planning and coordinating preparation, response, recovery, and mitigation of hazards, the majority of which are either caused by or impacted by weather (Weaver et al. 2014). The National Weather Service (2018) has designated EMs as one of their core partners because they are one of the primary users of weather information (Doswell et al. 1999; Lussenden 2014). The EMs of most interest in this study are those who serve the critically important role of relaying meteorological information from the National Weather Service (NWS) to local officials and the public on a city or county scale. City and county EMs are acutely aware of weather impacts, and their career longevity is closely tied to their preparation and response decisions (Donner 2008).

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Several studies have examined EMs' understanding of or interest in uncertainty in weather forecasts for several types of weather in several regions of the United States and Europe. For example, EMs were less prepared when they were unaware of forecast uncertainty and the potential impacts of tornadoes than if they had received such uncertainty information before an event [Ernst et al. (2018) for southern plains and midwestern state EMs; and Donner (2008) for Oklahoma EMs]. Similarly, EMs, many of whom served in the role part-time, were not generally given forecast uncertainty in forecasts useful for preparing and responding to potential river flooding, which limited the usefulness of those forecasts (Hoss and Fischbeck 2016; Oklahoma, Arkansas, and Pennsylvania EMs). EMs often sought information (e.g., examining radar or using personal networks to get reports of weather conditions) to make up for the lack of detail (Hoss and Fischbeck 2016).

Kox et al. (2018), interested in promoting the use of severe and hydrologic forecast information, found that German EMs and civil protection authorities already compared and contrasted severe weather forecast information from different sources to gauge uncertainty and be prepared to act. Uncertainty information could likely be better tailored to the needs of decision-makers to promote its use, as could facilitating communication between EMs so they can help each other interpret and use complex forecast information (Hoss and Fischbeck 2016). However, first responders such as EMs will respond to forecast information despite complications such as high false alarm rates and forecast uncertainty due to the significant penalty for being unprepared for high false alarm, high-impact events like tornadoes (Barnes et al. 2007; Donner 2008; Kox et al. 2018).

It is not clear that EMs are generally comfortable with uncertainty in weather forecasts, although some EMs strongly disagree that forecast uncertainty hinders them in their work (Lussenden 2014; Hoss and Fischbeck 2018). Hoss and Fischbeck (2018) conclude in their study that this attitude may reflect the fact that, with experience, EMs have come to expect uncertainty in weather forecasts and have become accustomed to working with information that is not deterministic. It may also reflect a strong partnership with and heavy reliance upon information from their local NWS forecast office (Demuth et al. 2012). Many EMs actively nurture and value the relationships they build with their local NWS office (Ernst et al. 2018).

Past research with EMs was often driven by or took advantage of the strong relationships EMs have with the weather enterprise. Relationships were critically important in studies related to field projects, instrumentation testing, or forecast product development. Baumgart et al. (2008) found that most Oklahoma EMs did not make decisions about the weather based upon radar information until after contacting their local NWS office. This is consistent with the finding of Demuth et al. (2012) that southern Florida EMs relied heavily on NWS input before initiating hurricane-related actions. Morss and Ralph (2007) found that California EMs tended to act sooner when they had confidence and a strong relationship with the NWS as both an organization and with NWS forecasters as individuals. Kox et al. (2018) studied how to motivate EMs to take protective actions earlier in Germany. Many EMs in the United States have strong, trusting relationships with their local NWS office (Demuth et al. 2012; Ernst et al. 2018; Morss and Ralph 2007), and those relationships lead to effective preparation and response (e.g., Goldsmith et al. 2012; Hoss and Fischbeck 2016; Lussenden 2014).

The nature of those trusting relationships between EMs and weather forecasters, generally taken as a given, is being explored by applying concepts from management and other domains. For example, trust between two different organizations, termed interorganizational trust, is posed as “the intentional and behavioral suspension of vulnerability by a trustee on the basis of positive expectations of a trustor” (Oomsels and Bouchkaert 2014, p. 582). It is not clear, however, that weather forecasters are comfortable showing vulnerability to EMs by sharing early signals that a forecast might be changing. Friedman and LaDue (2020) observed that forecasters were reluctant to share forecast updates until they were fairly certain what the new message should be. Ernst et al. (2018) found that EMs actively sought needed information and worked hard to build relationships because they were motivated to fill information gaps. From the EM side of this relationship, Ernst et al. (2018) found that EMs worked to build a relation-based trust (Rousseau et al. 1998) with the NWS, meaning a trust that resulted from interactions over time that cause one party (EMs) to have positive expectations of the intentions of the other (NWS forecasters).

Exactly how the confluence of forecast uncertainty and the nature of trust in this interorganizational relationship embodies itself in EMs’ use of severe weather forecasts has not explicitly been studied. These findings provide insight into how EMs balance their trust in forecasters with their knowledge of what is often an uncommunicated uncertainty in severe weather forecasts. Because EMs are sometimes not receiving alternate scenarios or uncertainty information, they experience greater wariness toward forecasts. This work highlights how to achieve greater trust through advancements in the science of severe weather forecasting and communication of risk.

2. Data and methods

Background interviews were conducted with emergency management directors, deputies, and officers from 14 counties in the Southeast before and during the 2016 and 2017 VORTEX-SE intensive field operations periods. The counties were located away from the Gulf of Mexico, within the southeastern U.S. maximum for violent tornadoes (Storm Prediction Center 2020). These semistructured, background interviews were conducted to first elicit information about the EM’s work experience and the characteristics of their jurisdiction that they thought made it unique. The main body of the interview followed the critical incident method (Dunn and Hamilton 1986) to gather context- and event-specific elaborations on how severe weather forecast information—including its uncertainty, perceived or communicated—affected how the EM handled their decision-making processes. Participants were asked to choose and describe particular severe weather events they had experienced (critical incidents) involving weather where everything went very well: they had relevant, actionable weather information when they needed it. They were likewise asked to choose and describe particular severe weather events (critical incidents) where they
did not have critical forecast or warning information they needed at the correct time. Both types of incidents helped to reveal aspects of the relationship between EMs and the NWS from the EMs’ perspectives. Nearly all of the original EMs were interviewed a second time in 2018 for a subsequent VORTEX-SE study that focused on vulnerability. All but two interviews were conducted with one person; in 2018, one interview was conducted with two EM directors who work closely together, and another was with the full EM Staff of a county. Those data are incorporated here. In total, 35 interviews with EM directors, deputies, officers, and GIS specialists, with from 1 to over 30 years of experience, are included in this study. Most had worked in county government, if not emergency management directly, before their current position. This study was conducted with the approval of the University of Oklahoma’s Institutional Review Board.

Data were coded thematically using an inductive, data-driven approach (Boyatzis 1998) similar to open coding (Corbin and Strauss 2008). Memos were extensively used during coding, as were diagrams, to more fully develop and abstract the themes and discern how they might be related to each other (Corbin and Strauss 2008). The analysis resulted in 18 codes and 67 subcodes. This paper discusses the six most saturated and elemental codes and their associated subcodes. Participants repeatedly emphasized these. These build to a central theme that we identified and defined, which provides our answer to the fundamental question that researchers ask in this kind of analysis: “What is going on here?” (Corbin and Strauss 2008).

The results were shared with all EM directors in late 2018, providing analytical triangulation (Patton 2002): our participants were able to review our results and discuss the accuracy, completeness, fairness, and perceived validity. Participants agreed and frequently commented that the data were reflective of their experiences until we introduced the central theme—which we initially called an amiable distrust of forecast information. Specifically, EMs did not like the harshness of the word “distrust” but liked that we highlighted the information and not the forecaster as the focus of this distrust. The differences between what we saw in the data and EMs’ responses shed light on how highly EMs value trust, something we discuss in detail in the discussion section of this paper.

The use of the critical incident method provides both strengths and weaknesses. A clear strength is that it yields detailed descriptions of real events; this technique was invented for, and excels at, revealing how competent someone is (Dunn and Hamilton 1986; Flanagan 1954). It can be applied in novel ways, such as to see how well weather radar serves the needs of NWS forecasters and broadcast meteorologists (LaDue et al. 2010). This technique reveals, grounded in real experience, the competency of severe weather forecasts and warnings to provide needed information for emergency managers and other decision-makers. Use of the critical incident method also limits these results because the resulting percentages are a minimum value. Each participant chose personally meaningful incidents. Other EMs may have experienced the same issues but chose to discuss a different incident that highlighted other issues. Last, participants were located within a region of the Southeast, and therefore results may not be generalizable to or beyond the southeastern United States.

3. Results

The following sections cover the main themes repeatedly emphasized by participants. These themes lead up to the central theme that we believe describes the relationship between EMs and the uncertainty in severe weather forecast information.

a. No-notice events

One of the most prevalent themes in incidents described by EMs was the occurrence of what they referred to as no-notice events. Meteorologists would term these as “missed events.” These ranged from EMs receiving no forecast, watch, and/or warning to receiving a warning only after the event had occurred. EMs in 10 of the 14 counties described this kind of incident (Fig. 1). Only three counties specified that, while they occasionally experience no-notice events, such events are rare. These events were most problematic in situations in which forecasters expected storms to remain subsevere. As one EM (county 2) noted, expressing sympathy with the NWS meteorologists: “I can understand the skipped tornado watch. If it goes from bad to worse, sometimes it can happen quickly.” These break down as follows.

At least half of the counties have experienced a type of severe weather without a corresponding severe weather watch in place. Severe storms “popped up unexpectedly” (county 4), with, in some cases, “not even a thunderstorm watch . . . and we go from nothing to full-blown tornado warning” (county 11). In other cases, there was a watch or warning in place before a tornado occurred, but it was a severe thunderstorm watch or warning. One EM (county 1) was out shopping with his wife when his attention was drawn to damaging winds occurring outside the store he was in, after which he scrambled to get to work. These events happened often enough that EMs emphasized needing to “just be prepared because [snapped fingers], [things can change] within a split second” (county 3).

Nearly as many EMs related situations in which there was either no tornado warning or the warning was issued late. How late was not specified but was described as being issued after an unexpected report of damage had already come into the emergency operations center (EOC) (counties 3, 1, 11, and 7) or when residents were already outside surveying the damage on their properties (county 11). EMs perceived the lack or delay in warnings as impacting not only their readiness but also their ability to notify the public. EMs cited factors that they understood to have contributed to the lack/delay of warning, including that “[the NWS] never saw it [on radar]” (county 5), or that terrain or land features may have influenced the rapid development of a low-altitude circulation (counties 1, 4, 5, 6, 9, 10, and 11). Their overall opinion was clear that “it wasn’t [the NWS’s] fault or their negligence” (county 5) but rather ex- tenuating factors of the state of the science or inadequate detection capability. Most events occurred with technology that is currently in place and were often in relatively rough terrain close to a WSR-88D site. However, in one case, a violent tornado had occurred before the installation of a WSR-88D.
At least three counties have experienced events in which a tornado watch had expired or the county was outside the watch when a tornado occurred. County 11 stayed late in the EOC despite a watch having expired because “the sun had been shining that day,” and, “next thing you know,” a tornado occurred. County 5 related an event in which both the NWS and television meteorologists said, “everything was clear” but a tornado occurred as the EM was closing up the EOC. County 6 decided to linger in the EOC after 1700 local time one day because two small echoes on radar were heading into his county, which was just south of a tornado watch. One storm ended up producing a tornado.

b. Null events

Contrary to no-notice events, null events encompass situations in which EMs described a forecast event that did not play out as initially anticipated. Meteorologists consider these to be false alarms, but no EMs used that term. EMs did not have a single way of describing these situations, so we identified “null event” as a neutral, encompassing term that is faithful to the data. Five counties chose to describe incidents of null events in their jurisdiction. Overall, EMs’ responses to such events were similar: “the cry wolf thing . . . that concerns us” (county 8), but went on to express, as county 13 similarly put it, “I’d much rather be ready than not be ready.” County 4 had a nearly identical statement. While EMs are concerned about null events, they prefer to err on the side of caution and be prepared.

EMs said they understood that forecasts had uncertainty, and, because no-notice events are problematic, they prefer to “know . . . the possible worst case” (county 5) and are “glad to be ready” for events when the potential is there (county 7). It is the EM’s job to “lessen the blow of what’s going to happen” (county 4) because there is “a certain community vulnerability” (county 9) on top of the lack of warning before what would otherwise be a no-notice event that is a concern.

Because there is a cost to opening and staffing an EOC outside regular business hours, the balance between being prepared in light of a no-notice event and staying cost efficient is delicate. EMs must plan for these costs in their annual budget requests, understanding that some forecast events either will not occur at all or will not occur in their jurisdiction. EMs are also concerned with the potential for public complacency and worry that null events will increase complacency. EMs were less concerned about cry-wolf scenarios affecting their operations than the possibility for the public to “get where they don’t listen” (county 12).

c. Gaps in information

EMs described two main types of information gaps: 1) in the timing of the information and 2) in the technical level of the information presented by forecasters versus what EMs needed for passing along to other officials and the public. The period of time between when EMs are notified of the possibility of an event (often specified as when the watch is issued) and the event’s occurrence (when storms form in or enter their county) can be long. All but two EMs spoke about how a temporal gap between the issuance of a tornado watch and a tornado warning was a concern with regard to public complacency (several mentioned similar concerns in advance of winter weather). During these gaps of information, EMs in this study were, for example, deciding when to more fully activate their

![Fig. 1. Most EMs (70%) described incidents of no-notice tornado events. In many of these situations, there was either no tornado watch or no warning, or a warning was issued after the tornado dissipated. In a few cases, the tornado watch had expired or radar coverage was inadequate for the NWS to detect the circulation.](image-url)
EOC and open (or alert others to open) community storm shelters. Thus, they frequently ask during NWS severe weather briefings when a watch might be issued and when storms might begin to impact their county. Several EMs fear that the public’s awareness will decrease during long watches and that they will stop paying attention to weather updates.

EMs cited different amounts of ideal lead time for varying purposes. They desired to give the public at least a 20-min lead time to travel to community storm shelters [counties 1, 5, and 9; also supported by Strader et al. (2019)], have ~45 min for the EM staff to be in place and prepared [counties 3, 5, 6, 9, 10, and 14], and have 4 h for schools to close and buses to finish all routes [counties 4 and 6]. EMs were not making school closure decisions but helped to provide school superintendents with information from the NWS and monitored what they decided to do [similar finding to that of Hoss and Fischbeck (2016)]. EMs were nearly always aware of timing needs for the schools; no county was comfortable with less than 2 h of lead time for a school closure decision, and most required 4 h (see https://twitter.com/nwas/status/1172190943090487297). EMs also seek updated timing information during this period, such as “is it speeding up or slowing down” (county 2). A county on the east end of a county warning area (CWA) had experienced an incident in which the time between a tornado watch and warning stretched to 9 h with little to nothing happening and few updates from the NWS.

Four EMs specifically requested that the NWS fill a gap in the level of information provided so that EMs have a “reader’s digest version . . . that I can convert into layman’s language” (county 11). Specifically, EMs sought something they could pass along that had the NWS’s best guess of when, where, what, and any potential impacts with regard to the event. EMs are well aware that weather forecasts often contain substantial uncertainty, and they often seek information about that uncertainty, as the theme in the next section describes. However, although most EMs in this study have developed some measure of comfort with technical language, at least one (county 5) would prefer to only have forecast information with “all the fluff out of it”;

I love [the NWS forecasters] to death, but . . . It’s like you ask an engineer for an answer . . . you’re going to get an answer that is above your head. And when they do weather briefings sometimes, and you’ve got [the superintendent] sitting there trying to decide whether to close schools . . . [We have seen the superintendent walk out saying] “how am I supposed to make a decision off of what he said?” . . . [The NWS] throws in things like well, our confidence level is 60% . . . but that doesn’t tell me what I’ve got [to do] . . . I know [they] may not be right every time but tell me what you see coming to my county, what time you expect it to hit my county. And that’s all I really need.

d. Differences in perspective

The difference in job function between EMs and forecasters has, at times, a profound effect on how they are thinking about the weather. For example, during severe weather observations, it became clear that forecasters who were deciding, for example, on whether to change a severe thunderstorm forecast did not reveal their deliberative process to EMs until well after their decision was made (Fig. 2). Once a warning or forecast update was issued or communicated, “their [the NWS’s] time clock stopped ‘cause they got it to us, but ours starts” (county 5). EMs might then jump into a brief action phase, such as calling dispatchers from law enforcement and other agencies into the EOC. Forecasters move on to another prolonged period of evaluating new forecast information, or, if in warning mode, to storm analysis. Both of these leave EMs in another waiting phase. The length of these phases could stretch into multiple hours, leaving EMs with little information from the NWS, especially when the forecast is not changing much. EMs do occasionally seek additional information about the threat during these times.

While EMs and forecasters work together to inform the public of weather hazards and threats, the two entities have different functions. NWS forecasters aim to produce usable weather information across a multicounty domain. EMs focus their efforts on being a conduit for county-specific meteorological information. They pass this information to the public, first responders, and local officials while also using it to make their decisions.

Forecasters have a larger geographical area of responsibility compared to the county-level EMs in this study. Thus, while EMs have their county as their top priority, forecasters must analyze conditions across multiple counties—in the terminology of the NWS, this is the CWA. EMs sometimes saw that
forecasts overlooked their county when a weather event was nearby, but outside the CWA. To address this perceived gap in NWS information, counties 1, 2, 3, 8, 11, 12, and 13 explained that they all routinely monitored information from neighboring NWS offices or neighboring county EMs—and usually both. An important finding is that when they see differing forecasts from neighboring NWS offices they gain some understanding of the uncertainty of the forecast for their county, which is valuable to them. As one put it, “I do not put my faith into any one [office] anymore.”

More than one-quarter of the studied counties noted having poor radar coverage. In many parts of the country, storm spotters can mitigate the impacts of inadequate low-altitude radar coverage, but in the Southeast terrain and land-cover obstructions and frequency of nighttime or rain-wrapped tornadoes make spotting relatively ineffective. EMs also stated that terrain or land features appeared to cause rapid development of low-altitude circulations (counties 1, 4, 5, 6, 9, 10, and 11). Unwarned, rapid-spinup tornadoes resulted in a tension that was palpable in how EMs described their interactions with the NWS. Sometimes EMs received reports from spotters, law enforcement, or adjacent counties of a tornado on the ground or of having trees down; however, there is no radar confirmation, or radar is late in detecting that a tornado may be occurring. EMs find it difficult when, as in one incident, “[a tornado] was on the ground for four or five miles [6.4–8 km] before [forecasters] ever saw it [on radar]” (county 5). Thus, there are sometimes situations in which an EM wishes to activate their alerting systems, but meteorological information is not able to support the need for such action.

e. Altering procedures

EMs would nominally activate their EOC upon issuance of a tornado watch. However, because watches could be in place several hours before storms affected their county, EMs frequently opted to alter their established procedure, including employing a staggered staffing practice. To do this effectively, they need up-to-date forecasts for the onset of severe weather in their county. They also monitor radar (as was also found by Hoss and Fischbeck 2016), use past experience, and use their impressions of how worried the NWS is. For example, upon issuance of a tornado watch, EMs usually wait to “throttle up” (county 6) and call in all extra personnel or dispatchers from other departments into the EOC, saving those agencies money. All EMs will instead maintain vigilance of the weather situation, with most stating they watched to see if storms held steady, intensified, or weakened when they passed a specific geographic point (counties 2, 3, 4, 5, 6, 9, 10, 11, 12, and 14).

To illustrate the difficulty of navigating the delicate balance between “crying wolf” and being unprepared to respond, most EMs do not activate their EOC for a severe thunderstorm watch. They will, however, stay vigilant if out of the office and watch local weather coverage to see if the possibility of a surprise tornado or two exists (all but two counties). In contrast, a few EMs do activate their EOC for severe thunderstorm watches. The former is a result of receiving mostly null events, while the latter is a result of having experienced multiple no-notice tornado events during severe thunderstorm watches.

The trigger point for EMs varies and is dependent on what the EM is seeing and how they feel about the situation. County 4 EMs often go into the office when storms are coming from the southwest because their strongest storms have come from that direction. County 3 activates their EOC during a tornado watch but will alter staffing levels based on additional information from the NWS. Similarly, county 1 will activate their EOC based on various criteria, some of which include forecaster confidence, the probability of widespread severe thunderstorms, and forecast information from the NWS. As is seen in the next section, EMs have developed a variety of methods for mitigating the negative impacts of receiving either no notice or late notice that a storm has or will become severe.

f. Sources of information

While the local NWS office is the primary and most trusted source for weather information, some EMs look to additional sources for confirmation of what their local NWS is telling them. A few were willing to make decisions based on information from other sources, but most stated, for example, “we don’t take any action without the weather service telling us” (county 4). The most common nonhuman information source is radar data. EMs explained that Baron Services gifted Alabama EMs a Baron Threat Net system (Baron Services 2019) after the 27 April 2011 tornado outbreak; they also used a few other radar programs. All other sources of information, mentioned by at least half of the EMs, were human sources: despite the poor spotting conditions, 71% have some form of spotter-type information despite few having formal spotter programs (reports are often from volunteer fire personnel or law enforcement); at least 57% of EMs watch local television stations; and at least half receive information from other counties and neighboring NWS offices. Recall that these data are from interviews that focused on specific critical incident examples; they are likely undercounts.

On the other hand, our choice of method elicited information on how important sources of information for their decision-making were making were the EMs’ own experiences with locations, landmarks, or weather patterns. It meant something if storms were coming from specific directions or tracking through certain areas (counties 1, 9, 10, 11, and 13). There was typically a useful amount of lead time once storms heading their way had passed a particular landmark or “cheat line” (counties 1, 2, 9, 10, 13, and 14). Also, EMs from the eastern counties observed that storms tended to change intensification once they reached the center of the state.

All monitored local television stations. County 10 pointed out that television maps are “more detailed” about landmarks that might be impacted, and a few counties perceived a particular station as covering their county better than the others. While the authors have observed heavy EM use of the NWS instant messaging program NWSChat for the Norman Weather Forecast Office (WFO), only 29% of the EMs in this study utilize NWSChat in their decision-making processes, but those that do appreciate seeing others’ questions and receiving updates that way. Those that did not use NWSChat pointed out that radio was a much faster means of communication, and many of them had prior positions (e.g., fire or law enforcement) for which radio was a primary tool.
While most sources of information served as a confirmation of preexisting NWS information, some sources had been a basis for adaptive behaviors. These adaptive behaviors included hearing information or reports from other counties, forecasts from multiple NWS offices, storms passing familiar locations and landmarks, and the EM’s intuition, the latter of which was only mentioned by two of the most experienced EMs.

4. Discussion

As Cova et al. (2017) stress for natural hazards, it is crucial that the weather enterprise better understands how to convey forecasts, warnings, and other action-triggering information to EMs, including uncertainty information. Donner (2008) further asserts that consideration must be given to the ecological context of the EM, as situated in a local political system. This paper uses a perspective akin to Donner’s. It also takes a next step toward understanding how EMs think about severe weather forecasts and the resulting implications on their needs for information. We found that EMs both do—and do not—want uncertainty information.

The county EMs in our study have competing needs that drive them toward seeking either deterministic forecasts or an understanding of what else could happen. Most of them accepted hearing technical language about the challenges of the forecast and possibilities of what might happen, similar to what Hoss and Fischbeck (2016) found. Ultimately EMs needed clear, actionable information to both act upon and pass to others in their jurisdiction. If the forecast is ambiguous, local officials might question their preparations (or lack thereof), and their jobs could be at risk (also found by Donner 2008). Thus, EMs need a deterministic forecast from what they called “an authoritative source,” which they clarified as a source with no competing interests other than to provide the most accurate forecast possible: the NWS. At the same time, EMs must be prepared [e.g., these findings and Donner (2008)] and desire to, for example, provide school superintendents with information on high-risk forecast contingencies. These responsibilities caused many EMs in our study to occasionally find deterministic forecasts to be inadequate.

EMs used a variety of strategies to overcome those inadequacies, including comparing forecasts with those from neighboring NWS offices. While there may at times be issues with inconsistencies between neighboring NWS offices or the weather enterprise generally (Uccellini and Ten Hove 2019), EMs in our study relayed incidents in which those office-to-office inconsistencies provided crucial information to them that was not otherwise communicated. Understanding a potential alternate forecast helped to minimize the impacts of an event. In essence, those inconsistencies between NWS offices conveyed reasonable, alternate scenarios, even if not intended in that way. Thus, our first recommendation is that the NWS consider when and how to provide useful, alternate forecast scenarios for potential severe weather events.

EMs in this study used several additional strategies to gain some idea of how a forecast might be wrong. EMs were generally seeking anywhere between 20 min and 4 h of lead time, although the authors are aware that other local officials require longer lead times (e.g., https://twitter.com/nwas/status/1172190943090487297). Our EMs did not count on receiving such notice, employing several adaptations. Some EMs turned to familiar landmarks that they knew, through experience, would provide them with the time they needed to prepare. They also relied on their intuition and reports of damage from other county EMs, partly for this reason (the latter being similar to Hoss and Fischbeck 2016). Similar to Barnes et al. (2007), the events EMs experienced ranged from what we referred to as a null event to various types of no-notice events. These events impact EMs differently depending on their type and frequency and the location of
no-notice events were particularly difficult for our EMs. This study reveals some of how EMs walk this fine line: by staggering their staffing and altering their procedures, and, in rare instances, taking action early. While these changes to procedures are a response to the “stay ahead of the storm” and “better to be safe than sorry” mentality, several counties went a step further. They displayed what we initially referred to as an “amiable distrust” of forecast information.

The initial phrase for our central theme, “amiable distrust,” was inspired by the descriptions of four distributions of trust and distrust between two corporations in the paper by Oomsels and Bouckaert (2014). The fourth of these distributions was a balance between high levels of trust and distrust, where businesses had both shared and competing objectives. They had both suspicion and confidence in their relationship. What we saw between our participants and their local NWS forecast office was similar, with the exception that we did not see distrust or suspicion attributable to intent. As previously described, the NWS and EMs have similar objectives in that they are both concerned with warning the public of weather threats as accurately as possible, leading to an amiable relationship. However, they have different perspectives in terms of their area of focus and the timing in providing others with forecast information versus interpreting that information and acting off of it.

What Oomsels and Bouckaert (2014) termed “suspicion” might be thought of as the uncertainty in forecast information. Their “confidence in the relationship” might signify the strong trust EMs have with their local forecast office and their understanding that “[forecasters] have a tough job” (county 2). These considerations inspired us to initially create the term “amiable distrust”—acknowledging a measure of “distrust” due to the inadequacy of forecasts while still realizing the positive and important, “amiable” relationship EMs have with their local NWS office.

In presenting the results of this work to our participants in late 2018, we introduced the term “amiable distrust” as describing what we saw in their attitudes toward the uncertainty in climate information. There was a range of reactions, going from the description being “dead on” (county 9) to squirms, scowls, and crinkled foreheads at the “distrust” part of the term—“It’s a harsh word” (county 9); “definitely not a distrust of the forecasters” (county 8). Instead, they clarified, it is “an understanding that [the forecast is] fluid” (county 13). The extent to which EMs were comfortable with the term “amiable distrust” seemed to depend on how frequent and impactful no-notice and null events had been to their county. Those EMs who more frequently experienced a lack of sufficient lead time had greater comfort with the notion. Still, we felt compelled to change the term.

The Rousseau et al. (1998) term “relation-based trust” that Ernst et al. (2018) settled on is not quite adequate to describe our central theme. What we found is better described as a combination of Rousseau et al.’s calculus- and relation-based trust, the former term capturing the trustee’s belief in the positive intent of the trustor but with the caution “trust but verify.” These EM–NWS relations have survived missed expectations due to ongoing efforts to maintain them, a feature of relation-based trust (Rousseau et al. 1998). Thus, whatever term we settle on should not have negative connotations. Given all considerations above, the term “nuanced trust” captures the “extent to which [the EM] is confident about, and willing to act on the basis of” (McAllister 1995) severe weather forecast information.

Combining observations of EM and NWS operations during VORTEX-SE intensive operations periods with results
presented here revealed that forecasters were sometimes engaged in internal or interoffice communications about changes to the forecast that were held internally before being shared with EMs (Friedman 2019). Observations of rapid, small-scale evolution in environmental conditions that would affect whether storms were severe often drove these forecast changes. Friedman (2019) designed his brief vulnerability overview tool to nudge forecasters into sharing such information sooner, leading to our second recommendation: that forecasters be willing to alert EMs to possible changes as they deliberate and settle upon those changes. Doing so would enable EMs to increase vigilance in monitoring information streams and potentially begin to adapt to the upcoming changes in the forecast while forecasters finalize those changes. Third, we recommend that NOAA continue to give priority to county-scale, 20-min to 4-h lead time improvements in tornado prediction. These efforts might include gap-filling instrumentation recommendations that result from VORTEX-SE, Warn-on-Forecast (Stensrud et al. 2009, 2013), and Forecasting a Continuum of Environmental Threats (FACETs) probabilistic hazard information (PHI) (Rothfusz et al. 2018). Improvements to the tools and the science behind them would increase forecaster confidence and the ability to provide more specific forecast information sooner. Such advancements would enhance NWS–EM trust and lead to a more cost-effective local response.

EMs take on considerable risk, depending on the performance of the weather enterprise, and the NWS specifically (Donner 2008), and we see that EMs have learned to either suspend or retain their vulnerability in trusting forecast information, depending on circumstances. The difficulty in forecasting severe weather in the southeastern United States is an expectation “shared by all those involved,” a concept important to trust literature [Zucker (1986), as cited in Oomsels and Bouckaert (2014)], and is a driving force behind NOAA’s VORTEX-SE program (NOAA 2019).

5. Conclusions

This paper reports on our analysis of critical incident background interviews conducted with county EMs in the southeastern United States as part of a VORTEX SE-funded study aimed at better understanding how the uncertainty inherent in severe weather forecasts affects NWS forecasters and EMs. The core interview data analyzed and reported on here are EMs’ descriptions of critical incidents (severe weather events) that had either gone well or with which they had difficulty dealing. The imperfect nature of severe and hazardous weather forecast and warning information engenders an increased reliance on and motivation for EMs to strengthen their relationships with the NWS. EMs require up-to-date information so that they and others in their jurisdictions make the best, most cost-effective decisions. They understand that severe weather forecasts can change quickly and carefully monitor communications with the NWS—when they know they need to do so. Unfortunately, EMs do not always know to monitor communications for what they called “no-notice” severe weather events. When viewed this way, adaptations EMs made to what would be otherwise standard operational procedures are attempts to anticipate these changes to either save money or give themselves adequate lead time to prepare for an event. These adaptations are a recognition of the inherent uncertainty in a deterministic forecast. They also reveal the impacts of not having information at crucial points in time both in and beyond the context of warnings.

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Data availability statement. Data are from human research participants. Our participants are expecting that we will maintain their anonymity. Thus, data can be shared, upon request to the authors, after identifying information has been removed.

REFERENCES
