P 11.3 (152) THE 3 APRIL 2012 TORNADO OUTBREAK: AN ANALYSIS OF THE NORTH TEXAS INTEGRATED WARNING TEAM

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ABSTRACT

The 3 April 2012 tornado outbreak across north and northeast Texas, including the Dallas-Fort Worth Metroplex, was one of the largest outbreaks in the region's history, producing 17 tornadoes within the National Weather Service Fort Worth's County Warning Area in North Texas. Despite impacting over 650 homes and causing an estimated $800 million in total damage, no fatalities and few serious injuries were reported. In an effort to explain why no fatalities occurred in an event of this magnitude, the actions of the North Texas Integrated Warning Team were analyzed. The primary members of the Team are staff from the NWS Fort Worth/Dallas Weather Forecast Office, local emergency managers, representatives of the print and broadcast media, and volunteer weather spotters. Post-event surveys were conducted to evaluate public response during the event. The surveys were designed to: identify the means by which warning information was received; ascertain the most common protective actions taken; and understand the motivation for taking those actions. This study provides evidence that the coordinated actions of the Integrated Warning Team played an important role in achieving a favorable public response. That response, combined with other circumstances, explains why no fatalities and few serious injuries occurred during the 3 April 2012 outbreak. Future analyses will be discussed with the goal of further improving the performance of the North Texas Integrated Warning Team.

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1. Introduction

On 3 April 2012, the North Texas region (including the Dallas/Fort Worth Metropolitan area, hereafter DFW Metroplex) experienced one of the largest tornado outbreaks in its history. By the end of the day, 17 tornadoes had moved across the region and caused almost $800 million in damage, ranging from EF-0 to EF-3 on the Enhanced Fujita scale (NCDC, 2012). This outbreak is notable for a few reasons. This was the first time (SPC Severe Plot 3.0, records dating back to 1950) that two significant tornadoes were active at the same time in Dallas and Tarrant counties, where the majority of the DFW Metroplex is located. It was also the first time that there were two significant tornadoes that occurred on the same day in Dallas and Tarrant counties since 28 March 2000 (SPC Severe Plot 3.0). The four significant tornadoes that occurred on 3 April 2012, developed during the late morning through early afternoon hours (1741 UTC to 2004 UTC), which is earlier than the climatological peak for North Texas (Storm Prediction Center). These storms also garnered significant attention from local and national broadcast media outlets, likely because of the unprecedented occurrence of two tornadoes active in the DFW Metroplex at the same time, and because of the broadcast of dramatic live video of tornadoes and tornado damage.

The National Weather Service forecast office in Fort Worth issued 18 tornado warnings during this event. Four of these warnings were designated as tornado emergencies during some portion of their valid times, including two simultaneous tornado emergencies for Tarrant and Dallas Counties. During this event, over 5 million people were under a tornado warning (Fig. 1). A small fraction of these people were located within the primary damage path

of significant tornadoes during this event. Based on 2010 census data, it was found that 2599 people lived within the swaths of tornado damage rated EF-2 or greater in the communities of Lancaster, Arlington, and Forney. (Figs 2-4). Ashley (2007) indicates that significant tornadoes (defined here as EF-2 or greater), while less common than EF-0 and EF-1 tornadoes, disproportionally cause more serious injuries and fatalities. One of the most interesting aspects of this outbreak is despite up to 2599 people living in the path of significant damage; no fatalities were attributed to the tornadoes.

One of the important questions that the authors wanted to investigate in this study was why were there non fatalities? In an attempt to answer this question, this study analyzes the effectiveness of the North Texas Integrated Warning Team (IWT) members and examines the unique aspects of the event itself. An integrated warning team describes the actors within an integrated warning system; according to Leik et al. (1981), this system is the process of predicting, identifying, and communicating threat information to the public. Proposed by Mileti and Sorensen (1990), an integrated warning team consists of local emergency management officials, media representatives, National Weather Service meteorologists, and amateur radio operators working together towards a common goal. In this instance, that goal is to deliver a consistent warning message to multiple publics during hazardous weather to elicit a response that leads to protective action. North Texas IWT members came together for the first IWT workshop held February 29, 2012, just over a month before the April 3 tornado outbreak. The focus of the workshop was improving communication between the partnership groups with the goal of delivering consistent warning messages.

The National Weather Service (NWS) Weather Forecast Office plays the primary role in the detection of hazardous weather threats before they occur. The goal of this detection is to notify all affected individuals of the impending hazard. Meteorologists at the NWS primarily utilize remote sensing technologies (e.g. weather radar and satellite) to detect instances of hazardous weather to compose warnings, and then transmit the warnings via all available dissemination means. However, the NWS is just one branch of the IWT; investigating the entire North Texas IWT, and its consistency of message, is important because most people (outside the IWT) do not get their warning information directly from the NWS, but instead through alternate sources (Lazo et al. 2008).

The main source of visual information during a crisis comes from television (Hamblen 2009); the broadcast media is therefore a critical information source for the public during a tornado outbreak. Zillman et al. (1999) reinforce this idea by showing that images caused observers to retain more information regarding an event or issue compared to when information was received from text alone. Local emergency management officials also play a key role in getting the public to take proper protective action, whether through preparedness activities and public education before a hazardous weather event, or through the activation of outdoor warning sirens (OWS). Doswell et al. (1999) explain that amateur radio operators and storm spotters form the final component of an integrated warning team as they allow meteorologists to overcome remote sensing limitations in resolving small-scale features, like tornadoes.

Warning response itself is a complex process for people. According to Drabek (1999), the varying life experiences people have generate different responses to hazard information. Before people will respond to a warning message, they must receive, understand, believe, confirm, and personalize the warning information (Mileti and Sorensen 1990). An integrated warning team not only notifies people of a hazardous situation, but provides information through all phases of warning response. Lindell and Perry (2012) further the concept of warning response by describing facilitators as well as impediments to taking protective action; people must be able to determine if a threat exists and if protection is needed from that threat. Message consistency, a goal for the IWT, is paramount because “the style and content of a message can have a dramatic effect on public response” (Sorensen 2000). If people receive conflicting information from the media, emergency management, or the NWS, that information directly affects their ability to make an informed decision. A consistent warning message helps the public process warning information faster to make a decision on whether or not to take protective action. When it comes to getting weather information to the public, the message that the entire IWT communicates is just as important as the official weather warning from the NWS.

When a tornado outbreak occurs in a densely populated area and there are no fatalities, it seems worthwhile to investigate the causes of this outcome to increase the chances of repeating the outcome in a future tornado outbreak. Recent research in protective action decision making highlights the importance of the message delivered by the entire IWT in eliciting a protective action response from the public. The actions of the entire IWT are investigated in this study in an effort to determine how each of the members of the IWT played a role in delivering a warning message to the public on 3 April 2012.

2. Data and Methodology

To analyze the actions of the North Texas IWT on 3 April 2012, two aspects of IWT operations were investigated. The first was documenting each member’s actions and efforts to provide a warning message during this event. The second aspect investigated was the communication between members of the IWT. By studying these aspects of IWT operations, the consistency of warning message and factors that affected the consistency can be better understood. The primary goals are to identify any communication gaps and to identify a list of best practices for effective communications.

To evaluate actions taken by individual members of the IWT during the tornado outbreak, the authors

conducted interviews with broadcast meteorologists, local area emergency managers, and NWS meteorologists who were working during this event. The major topics of the interviews included (1) the level of awareness of the threat of tornadoes before they occurred; (2) the actions taken to disseminate a warning message; (3) what information was used in the decision to disseminate a warning message and (4) thoughts about why there were no fatalities as a result of severe weather on 3 April 2012. In all, 5 broadcast meteorologists, 10 emergency management officials and 5 NWS meteorologists were interviewed. To ensure confidentiality, any quotes collected from interviews with emergency management officials or broadcast media members will not be attributed to specific persons or agencies. In an effort to avoid significant National Weather Service bias, summaries of these interview responses were prepared by individual members of the IWT. That is, an emergency manager summarized the emergency management perspective, a broadcast meteorologist summarized the broadcast meteorologist perspective, and a disaster research specialist helped summarize the NWS responses with an NWS meteorologist. These responses are summarized in Section 3 of this paper.

Communications within the IWT were analyzed through the construction of an event timeline that recorded communications (verbal, text, and visual) of each IWT member minute by minute throughout the event. A common communication protocol, NWSChat, was used as the basis of this timeline as this software is already used extensively to communicate via instant messaging chat by all members of the IWT. Participation in NWSchat is restricted to IWT members in an effort to keep the information relevant to members of the IWT. An archived chat log was used, and all communications were classified with their IWT group. Once the NWSChat log was classified, timelines of media, emergency management, amateur radio, and NWS communications (sans NWSChat messages) were merged into the timeline.

To capture a timeline of media communications during the event, the authors watched video of coverage provided by four DFW Metroplex area television networks and documented what was being communicated verbally and visually each minute from 1730 UTC to 2200 UTC. Timelines were provided from Emergency Operation Center event logs from 4 of the DFW Metroplex area emergency managers. Event logs from the NWS Fort Worth meteorologists and volunteer amateur radio liaisons were recorded and merged with the rest of the timeline to complete the documentation of IWT communications.

The completed timeline resulted in over 800 documented instances of communication within the IWT during a 4.5 hour period on 3 April 2012. Every single instance of communication was not captured with this methodology, but the authors feel that the collected instances effectively capture the nature of communications between the members of the IWT during this event. The analysis for this study focuses on the communications that occurred during the period of most active hazardous weather on 3 April 2012, which occurred between 1800 UTC and 2145 UTC. To maintain the study's focus on delivery of a consistent warning message, only those communication instances that influenced the warning message to the public were analyzed. Also, during the event, IWT members communicated with one another via NWSChat more frequently than with any other form of communication. As a result, the timeline analysis for presentation at the Severe Local Storms Conference will focus on NWSChat communications from the perspective of how NWS-led communications led to changes in message dissemination by IWT partners.

3. Results and Analysis

a. Broadcast Media Interview Summary

During the 3 April 2012 tornado outbreak, all four major television outlets instituted live, uninterrupted severe weather coverage for several hours. After conducting interviews with broadcast meteorologists from those stations, some conclusions and insight can be derived about how the media coordinates with other members of the Integrated Warning Team and what drives television coverage.

How did the broadcast media maintain situational awareness during this event?

One of the primary findings from interviews of North Texas broadcast media was that NWSChat serves as one of the most valuable situational awareness tools for the media. One of the practices that the interviewees found most helpful was when the NWS sends a message via chat to give advance notice that a new warning is being issued. This allows the media precious lead time to request a decision to cut into regular programming and coordinate with on-station production personnel for the possible live report. NWSChat messages from NWS meteorologists and emergency management personnel are taken as very reliable information. As a result, information on the chat is likely to be mentioned or discussed during live coverage. There are several other sources of information that media draws upon during events like the April 3 outbreak. All stations were following the tornadoes with live helicopter footage, storm spotters, and news crews out in the field (Fig. 5). These resources aid in providing up-to-the-minute information to the viewers and may assist with public response by providing visual confirmation of the threat.

What decisions go into broadcasting during a severe weather event?

There are many variables involved in coordinating coverage of a severe weather event. The constant theme found throughout the media outlets is the need to get valuable, lifesaving information to the viewing public. Broadcasters must consider the severity of a hazardous weather event to decide if the threat is great enough to break into programming to deliver a live report. Each break in programming has the potential to cost the television outlet money. Providing live coverage during commercials results in lost income for the station in the form of advertising dollars. Breaking into regular programming can result in angry customer feedback, typically from those viewers that are not being directly affected by hazardous weather. That said, every broadcast meteorologist interviewed indicated that if a hazardous weather event posed a threat to the lives of anyone in their Designated Market Area (DMA), they had full latitude to break into programming to provide warning information and safety instructions at any time. All major television outlets were on live, continuous coverage during the entire tornado outbreak because the threat of tornadoes was thought to be significant after the first two isolated supercells developed.

During continuous live coverage of a hazardous weather event, one of the struggles media outlets face is gathering and providing new information on storms. While on the air, information relevant to the hazardous weather event must be presented continuously. The increased use of social media has led to a public that is not only demanding of new information, but also somewhat intolerant of repeated information during live television broadcasts. Frequent updates on NWSChat regarding spotter reports, the latest thinking from NWS warning forecasters, or updates on the expected evolution of the event, become valuable talking points for broadcasters. From a broadcast meteorologist perspective, when a warning is issued by the NWS there are details given on storm location, storm movement, and cities impacted. After the initial warning on a given storm is issued, there is a perception of less-frequent updates from the NWS. The broadcast media crews can fill the perceived temporal information gap for the public by providing continuous information during the event. Live pictures, phone interviews, and social media feeds all provide information to help advance the coverage of a storm and may help advance the public's response to the warning message.

How did media outlets disseminate a warning message during this outbreak of tornadoes?

The 3 April 2012 event in North Texas featured a total of 17 tornadoes (in the DFW DMA). At several times during the event, there were multiple tornado warnings in effect for different areas of the DMA. The stations were faced with the difficult task of deciding how much time to spend in coverage of each warning to alert as many people as possible. The interviews revealed several motivating factors that dictated decisions for live coverage of each warning. Warnings for population centers and live visuals were the driving factors in storm coverage. Storms that were affecting highly populated areas were given more time on-air. Storms where live pictures or video were available from either helicopters or storm chasers also received preferential coverage. When two "Tornado Emergencies" were in effect at the same time for the two most populous counties (Dallas and Tarrant) in the DFW DMA, the stations had to bounce back and forth in the coverage based on the latest information available at the time. While all interviewees indicated they spent time on both storms, all indicated that available live video and pictures resulted in a decision to spend more time on one storm over the other.

The use of "Tornado Emergency" by the NWS during this event had mixed reactions from the interviewees. Half of the interviewees indicated that the use of emergency wording in the products was essential because it immediately set this event apart from other tornado outbreaks that have affected the region in recent years. The other half of the interviewees indicated that they thought the use of "Tornado Emergency" in NWS tornado warnings did not alter their coverage or the public response to the tornadoes. They felt that the broadcast of the dramatic visuals of tornadoes conveyed the severity of the threat more than emergency wording in the warning. All interviewees indicated that in the absence of live pictures and video of tornadoes to broadcast, the use of emergency wording in a tornado warning may be a useful way to convey the seriousness of the threat to the public to encourage protective action.

Why were there no fatalities during this tornado outbreak?

When asked to provide their thoughts on why there were no fatalities during this event, interviewees responded with a few common themes. The first reason provided as a lack of fatalities during this event was attributed to circumstance. All interviewees stated that they thought the time of day when the tornadoes happened helped prevent fatalities. The primary areas that were damaged were residential areas, and the common thinking was that many people that would have been in those houses when the tornadoes struck were either at work or at school, limiting the number of people in the direct path of damage. However, all media provided live coverage of people who had survived tornado damage while at home, so the second reason given was that the "massive media coverage" (local and national) and easily recognizable tornadoes during the daylight hours, provided the impetus for the public to take warnings seriously, encouraging a decision to take protective action. A third reason given by all media interviewees for the lack of fatalities was timely and accurate warnings communicated from the NWS, supported by frequent updates and communications relayed via NWSChat. Other reasons provided by broadcast meteorologists interviewed included all local media outlets providing live, wall-to-wall coverage of the event, public

preparedness and training programs, the public's previous experience of severe weather events locally, and knowledge of deadly tornado outbreaks that were well publicized during the spring of 2011 (such as the Tuscaloosa and Joplin tornadoes).

b. Emergency Management Interview Summary

From an emergency management perspective, the tornado outbreak in North Texas on 3 April 2012 was an overall success. Even though 17 tornadoes struck the large DFW urban area, and just outside of the urban area in the rural/urban interface, no fatalities occurred with the storms. To determine why no fatalities occurred with such a large outbreak of severe weather, an analysis of emergency management activities was conducted by an emergency management professional in conjunction with the National Weather Service.

How did emergency managers maintain situational awareness during this event?

The events of 3 April 2012 were discussed as unique by several of the emergency management interviewees due to the scope of the event and because a significant number of DFW-area emergency managers were out of town for the State of Texas Emergency Management Conference in San Antonio, Texas. Because so many emergency managers in the affected areas were attending the training conference, some emergency managers at the conference were forced to coordinate warning dissemination and response efforts remotely.

Before most hazardous weather events, the Fort Worth NWS Office sends out what emergency managers term a "heads up" email regarding expected impacts of a forecast weather event. Typically these messages are sent out a day or so in advance of the expected onset of hazardous weather, and updated as the potential event gets closer. While the email is sent directly to emergency management and public safety staff, it is often forwarded to multiple other individuals within a jurisdiction to increase awareness of the possibility for hazardous weather events.

A briefing email sent to all area emergency managers on 2 April 2012 primarily mentioned a threat for large hail and downburst winds, however isolated tornadoes were mentioned as a threat. On 3 April 2012, a brief message was sent from the NWS Fort Worth office to the emergency management community approximately two hours before the tornado outbreak started. The overall confidence in the forecast was low, and as the bulk of emergency management officials were at the state conference and the message was released just prior to a lunch break, many individuals did not see the message or did not pay adequate attention to the message due to the uncertainty surrounding the forecast. This was echoed in comments from emergency management officials interviewed who did not attend the state conference but remained in the North Texas area.

For many individuals attending the state conference, the first knowledge of the tornado threat were phone calls or pages from the NWS indicating a tornado had been spotted or that a tornado warning was being issued for their county. The calls were immediately preceded by or immediately followed by a text based message of the tornado warning for their county utilizing the iNWS mobile alerting software (NWS 2010). Several emergency managers at the conference sought out NWS staff members who were manning a booth outside the exhibition hall for more information (Fig. 6). Other emergency managers sought out a vendor in the exhibition hall who had large screen displays of an incident management system and converted one of the screens to a radar feed from North Texas. The emergency management interviewees who remained in North Texas described similar experiences where a phone call or page regarding an active threat for tornadoes were the first knowledge that tornadoes were imminent or occurring in their community. Once the interviewees had knowledge of tornadoes occurring, each indicated that they sought out additional information sources to determine the extent of the event.

During the event, interviewees indicated that they gathered information about the location and short term forecast of the tornadic storms from mobile radar software, live video and reports from the broadcast media, direct contact with NWS personnel at the conference, telephone contact with NWS personnel in Fort Worth, NWSChat, and through a web-based graphical warning tool called GWARN. GWARN was developed as a joint project between the NWS and the North Central Texas Council of Governments. The tool was developed to provide real-time radar information with an overlay of tax assessor data about the potential population and property damage impact based on locations located within NWS warning polygons. As storm warnings are issued, the GWARN tool allows emergency management officials to capture data about impact of the storm to their community including number and type of properties, population affected, and potential dollar loss based upon property tax valuations (Fig. 7). Many local emergency management officials indicated that they saved screen shots from the GWARN tool as an added layer of information to justify to the public and elected officials why outdoor warning sirens were sounded.

How did emergency managers disseminate a warning message during this outbreak of tornadoes?

While the core function of emergency management is not one of warning dissemination, emergency managers are often tasked with deciding, or writing a protocol to decide, when to activate their outdoor warning siren (OWS) system. The activation of OWSs is a highly politicized issue and because individual jurisdictions own their siren equipment, there are different criteria for activating OWS. In the DFW area, the North Central Texas Council of Governments (2009) has developed a list of guidelines so that local jurisdictions that have OWS have a reference when writing their own OWS activation policies. Outside of mentioning that each emergency manager interviewed

indicated that OWS were activated during this event, motivations behind individual jurisdiction policies are beyond the scope of this study. The primary purpose for OWS activation that all emergency managers agreed upon was that activation of OWS are meant to alert the public to go indoors and seek additional information. A few interviewees indicated that they were able to get warning information posted to electronic billboards along interstate highways to alert travelers of the tornado warnings. All emergency managers interviewed stated that the use of the "Tornado Emergency" language in NWS tornado warning products did not cause them to do anything differently than they would have done without that language in the warning.

Why were there no fatalities during this tornado outbreak?

Many emergency management officials commented on the fact that the time of day when the tornadoes occurred contributed to the lack of fatalities since the tornadoes on 3 April primarily damaged residential areas. If the tornadoes moved through later in the day, more residents would have been at home, and the potential for death or serious injury would have been greater. However, the lack of fatalities cannot be completely attributed to vacant residences because search and rescue efforts resulted in pulling multiple people from their homes shortly after tornadoes moved through their jurisdictions (Tarrant 2012). Another common response pointed to a strong working relationship between the NWS and emergency managers prior to the outbreak of tornadoes. This strong foundation led to quick and effective communications as familiarity barriers were not in place, and communication protocol had already been established. This avoided wasted time in looking up contact information and allowed for rapid dissemination of urgent weather forecasts and updates. Other factors cited by interviewees included the time of day (daylight hours) and the isolated nature of the tornadic storms which allowed good visibility and subsequent rapid response efforts. The last common theme cited by emergency managers was effective public education and outreach programs that had prepared the public by teaching them what protective actions to take when faced with the impacts of hazardous weather events. Several emergency management officials attributed the public education efforts through the KnoWhat2Do program in particular. KnoWhat2Do is a regional program used by North Texas emergency managers to improve their community's emergency preparedness.

c. National Weather Service Fort Worth Interview Summary

On 3 April 2012, the Fort Worth NWS office created and disseminated a total of 74 severe thunderstorm and tornado warnings. Of these warnings, 18 were tornado warnings, and 4 of these tornado warnings were designated as "Tornado Emergencies". Statistically, the NWS warning operations were successful at detecting weather hazards during this event as 77 of the 80 reports of severe weather were recorded within a warning polygon with an average lead time of over 24 minutes. For tornadoes alone, 15 of the 17 tornadoes that occurred within the Fort Worth County Warning Area were contained within warning polygons with an average lead time of just over 20 minutes. Statistical measures of detection do not address the effectiveness of the warnings or take into account the public response to those warnings. Determining what factors contributed to zero fatalities during this outbreak was the impetus for this analysis.

How did NWS meteorologists maintain situational awareness during this event?

Most interviewees indicated that the perceived threat for a tornado outbreak of this scale was low during the early morning hours of 3 April 2012. A scientific analysis of the reasons behind this perception is beyond the scope of this study. However, a detailed analysis of the meteorological evolution of this event can be found by referring to Ryan et al. (2012). An awareness of a change in environmental conditions that indicated a higher tornado potential became evident to most interviewees during the late morning hours, one to two hours before the development of the first tornado. Those interviewed indicated that the combined use of radar, satellite, surface automated weather observations, computer-derived analysis fields, and the application of the science of meteorology all led to this change in threat assessment.

During the period that tornado warnings were being issued by NWS meteorologists, maintaining situational awareness required close contact with members of the IWT. Broadcast media were monitored via a television array in the NWS operations area that allows for simultaneous viewing of 4 different television broadcasts. Each television was tuned to a different local television station, which allowed forecasters to occasionally monitor live video of tornadoes, aiding in the decision to compose more strongly worded language in warnings and follow up text products. Interviewees also indicated that situational awareness relied heavily upon reports relayed to them via amateur radio operators who were in contact with trained storm spotters or organized storm spotter groups that were deployed across the DFW Metroplex. Interviewees indicated that spotter reports of the visual structure of these storms and confirmation of tornadoes and large hail contributed to early warnings by increasing confidence in the threat of hazardous weather and the validity of warnings already issued. Maintaining situational awareness also meant communicating internally. Warning operations were dynamically sectorized, with individuals quickly coordinating responsibilities so that all necessary warnings could be disseminated as fast as possible. All warning decisions were communicated verbally within the office to keep internal situational awareness high and reduce the possibility of

missed events or any duplication of effort.

How did NWS meteorologists communicate warning messages during this event?

Warnings were all generated using warning generation software called "Warngen", which is a part of the Advanced Weather Interactive Processing System, utilized at NWS Forecast offices across the entire country. NWS meteorologists use Warngen on their computer workstation to create a polygon using radar data, and select a list of threats and statements pertinent to the primary hazard. Warngen automatically creates a text product that can be quickly reviewed, edited if necessary, and then disseminated via all available means. After the first tornado warnings were disseminated, interviewees indicated that their primary challenge was conveying the urgency and severity of the tornado threat to encourage a response of protective action from the public. The combination of live video broadcasts of large tornadoes in Dallas and Tarrant Counties, and several spotter reports of large, damaging tornadoes headed towards densely populated areas prompted NWS meteorologists to decide to designate a few tornado warnings as "Tornado Emergencies" in an effort to communicate the severity and rarity of this event to the public.

Aside from including enhanced wording in text products, NWS meteorologists indicated that they relied upon communications via NWSChat to convey the severity of the tornado threat. At the Fort Worth NWS office, nearly every hazardous weather event has a dedicated meteorologist who is tasked with monitoring the flow of information to and from NWS Fort Worth through the NWSChat client. During the 3 April 2012 outbreak, an NWS meteorologist was dedicated for communicating information to partners on NWSChat throughout the entire event. The rationale behind dedicating a meteorologist for NWSChat is to allow discussion with on-air media representatives without interrupting live broadcasts. The goal at the local NWS forecast office is to quickly deliver the most critical storm-related message content to the broadcast media to elicit a public response that may include life-saving actions.

NWS meteorologists also created a few graphical forecasts highlighting the severity of the tornado outbreak during the event, and posted these graphics on the office webpage and Facebook page. The NWS in Fort Worth had not implemented Twitter as of 3 April 2012, but had as of 1 July 2012. NWS meteorologists indicated that in future events, a social media interface such as Twitter may be used to help disseminate warning information directly to the public.

Why were there no fatalities during this tornado outbreak?

Most NWS meteorologists agreed that time of day likely played a role in the lack of fatalities during this event. Because tornadoes occurred primarily during the early afternoon hours, and primarily struck residential areas, there was a reduction in the number of people who were in the damage path because many residents were likely at work or school. Most interviewees pointed to the issuance of good warnings with good lead time as playing a key role in the lack of fatalities. Interviewees indicated that they were unsure as to the impact that the use of "Tornado Emergency" language had on the event, but that the motivation to use this language was to elicit a response of protective action from the public. Most interviewees indicated that they thought the use of strong language, including tornado emergencies, in warnings during this event helped to set this event apart from others which helped save lives. Most also cited the NWS providing frequent information in NWSChat as playing a role in driving the urgency of the tornado threat and helping to provide a consistent broadcast media message to the public. At least one interviewee cited that spotter reports were instrumental in issuing the first tornado warning of the event.

d. Timeline Analysis

During the bulk of the event, from 1800 UTC to 2145 UTC, the NWSChat log contained 314 distinct communications from the NWS. Many of these entries, 184 in total, were automated messages that announced the NWS product suite (e.g. severe thunderstorm warnings, tornado warnings, and local storm reports). However, there were 130 distinct messages where a FWD forecaster typed information into the chat room for partner use. During this time, the media directly relayed communications from NWS meteorologists on 27 different occasions, which represents 21% of total NWS composed messages during this period. On average, it took one minute for the media to broadcast this information to their audience.

However, several NWSChat responses were answers to location-specific questions, or were a simple 'thank you' for a report. Our analysis found 63 occurrences where NWSChat relayed messages were classified as urgent in nature. Urgent messages were subjectively defined as those messages that the NWS meteorologists would have wanted broadcast to a wider audience. The 27 messages that the broadcast media relayed were all classified as urgent in this context. When looking at just this subset of NWS meteorologist chatted information, the media relayed 43% of the NWSChat messages within one minute of being transmitted. The messages from the NWS Fort Worth meteorologists did appear to play a part in what information was broadcast by the media during the outbreak. Figure 8 shows the frequency of messages relayed by NWS meteorologists via NWSChat from 1800 UTC (1:00 PM CDT) to 2145 UTC (4:45 PM CDT). These analyses of chat frequency showed that NWS-led communications were fairly

consistent during the period of peak tornado frequency and intensity. This consistent presence in NWSChat was cited by broadcast meteorologists as vital because it helps to satisfy their need to provide updated information about the event that is less repetitive. If broadcast meteorologists can rely upon consistent, deliverable message content in NWSChat, they are more likely to utilize NWSChat, and rely upon NWS driven communications, as situational awareness tools during hazardous weather events.

NWSChat communications were also found to play a large role in the information flow during those periods when NWS meteorologists used the "Tornado Emergency" language in tornado warnings (Table 1). There are several interesting observations that can be made from this table. The first issuance of an NWS tornado warning with the tornado emergency language was at 18:16 UTC (1:16 PM CDT) for the cities of Lancaster and Dallas in Dallas County. The phrase "tornado emergency" was mentioned by every broadcast meteorologist included in this study, but the average time before this phrase was mentioned on air was 4 minutes after it appeared in the tornado warning. Perhaps more importantly, the tornado emergency language was not communicated by most broadcast meteorologists until after the NWS communicated the use of tornado emergency in the tornado warning via NWSChat. One of the broadcast meteorologists mentioned a tornado emergency at 18:14 UTC, or two minutes prior to the NWS use of this phrase in the tornado warning. This news station was not included in the 4 minute average media response time from Table 1 because this broadcast meteorologist used the phrase tornado emergency without knowledge that the NWS was going to include this language in a text product.

The second time the tornado emergency language was used in a NWS warning was for the Arlington and Kennedale areas in Tarrant County. The average time from product issuance to mention on-air by the media was less than one minute in this instance. In this instance, a NWS meteorologist communicated that the tornado emergency language was going to be used in a tornado warning for these areas one minute before it was transmitted. As a result, two stations were able to talk about the tornado emergency before the text product was transmitted, while the other two stations mentioned the tornado emergency within the same minute of the transmitted tornado warning by the NWS.

Table 1 shows a difference in media communication regarding tornado emergencies depending on whether the tornado emergency information was communicated in NWSChat. NWS Fort Worth communicated a tornado emergency in NWSChat 5 times, and did not chat about the use of tornado emergency in text products the other two times. When the decision to use tornado emergency language in tornado warning products was shared in NWSChat, it was broadcast by the four local television stations 89% (16 of 18 opportunities) of the time. In the two instances where there was no NWSChat communication relating to the inclusion of tornado emergency in a text product, the information was never mentioned by broadcast meteorologists. While it is difficult to draw conclusions from such a limited dataset, these data seem to imply that the communication of a tornado emergency via NWSChat has a more consistent response from broadcast media than including this language in text products alone. It is possible that some broadcast meteorologists chose not to mention the tornado emergency language with these text products because they felt the dramatic nature of the images and video portraying tornadoes and tornado damage conveyed an emergency situation more effectively than words alone.

After tornado emergency language was included in tornado warning products for Tarrant County, it must be noted that two stations used the term tornado emergency during times when the NWS was no longer using this language in tornado warning follow up statements for Tarrant County. Unlike the tornado warning text product which can includes an explicit expiration time, there is no language in NWS warnings that indicate that the phrase "tornado emergency" has been dropped from follow up statements when the tornado warning continues. Unless the tornado emergency language expires at the same time the tornado warning expires, the NWS would have to communicate dropping the emergency language to the media via NWSChat. This is a delicate proposition because the motivation to drop the tornado emergency language from a follow up statement is usually driven by spotter confirmation that a tornado has dissipated. A tornado warning may still be appropriate in these instances because of radar indication of persistent strong rotation or spotter confirmation of persistent low-level cloud rotation. These data seem to indicate that if the tornado emergency language is used in a NWS tornado warning text product, this should be preceded and frequently followed up by communication to ITW members via NWSChat for improved response and clarification.

4. Observations and Preliminary Conclusions

One of the primary goals of this study was to understand why there were no fatalities despite the presence of significant tornadoes in densely populated portions of the DFW Metroplex. To gain insight into factors that may have influenced this outcome, the authors interviewed IWT members and asked them to provide their thoughts on why there were no fatalities during this tornado outbreak. While this summary of interview responses cannot be considered conclusive, all of the interview participants were actively involved in the warning dissemination, search and rescue response, or tornado damage survey phases of this event. Due to their participation in the warning and response aspects of this event, it can be argued that these individuals have an understanding of the most likely factors that resulted in a lack of weather related fatalities on 3 April, 2012.

The most common reasons given for a lack of fatalities on 3 April 2012 include:

- Circumstance or luck – Because the tornadoes occurred during the early afternoon hours, and

primarily damaged residential areas, many people were at work or school when the tornado damage occurred reducing the number of people in the direct path of the tornadoes.

- Consistent media coverage – all DFW-area media outlets took the warnings seriously, talked about the severity of tornadoes headed for densely populated areas, and showed dramatic video of tornadoes and tornado damage that likely led those in the path of tornadoes to take protective action.
- Emergency managers had the information they needed to make fast, effective decisions - While the magnitude of the outbreak was not well anticipated before April 3rd, emergency managers and the NWS had already established communication protocols that allowed for quick dissemination and understanding of short term forecast information and updates.
- The NWS issued effective warnings – The NWS was able to issue warnings with sufficient lead time so that people in the path of the tornado had time to process the warnings and transition to a response to take protective action before the tornadoes damaged their homes. The use of "tornado emergency" or other strong language in warning products may have helped set this event apart from others early on, encouraging a response for protective action from those in the path of tornadoes.
- The members of the IWT worked and communicated well with one another – The internal communication amongst members of the IWT likely contributed to the consistent message development and delivery during this event. While many types of communication occurred amongst members of the IWT, NWSChat in particular was one of the most important tools that helped IWT members communicate with one another.

An analysis of the North Texas IWT and its internal communications during the tornado outbreak of 3 April 2012 resulted in a better understanding of the role that each member of the IWT played in communicating a warning message to the public. An examination of those factors that were not circumstance or luck based strongly suggests that a consistent warning message from an IWT leads to a public that is better informed, aiding in quicker processing of the warning message and a quicker response to take protective action. From the NWS perspective alone, there is evidence that implies that information provided on NWSChat is just as important as information provided in the standard suite of warning products.

The primary role of the NWS in detecting severe weather hazards seems to be reinforced by this analysis, but dedicating effort to communicate with all members of the IWT during high impact events seems to be nearly as important. Understanding and utilizing each member's strengths in the IWT, and communicating effectively during high impact weather hazards seems to result in a positive response which ultimately limits serious injuries and fatalities. The authors cannot ignore the important role that circumstance seems to have played in limiting the impact to life in this event. However, despite the likelihood that many people were away from their homes at the time of the tornadoes, there were people in direct damage paths from significant tornadoes, and the majority of these individuals seem to have taken cover before tornadoes damaged their homes based on information received from the North Texas IWT.

5. Future Work

In addition to the information already collected from members of the IWT, the authors plan on conducting telephone surveys to collect data from residents who were in the DFW Metroplex during this event. These surveys were being conducted at the time of the Severe Local Storms Conference, and are a necessary source of data to consider before drawing more concrete conclusions about how the public processed warning information during this event. Once the results of the surveys have been evaluated, it may be necessary to revisit interview responses and the IWT communications timeline to see if there are correlations between public responses to specific actions of the IWT. One of the motivations to take this work to the Severe Local Storms Conference was to introduce the research to the meteorological community to collect feedback on research methodology. Please feel free to contact dennis.cavanaugh@noaa.gov with any constructive feedback on this ongoing work.

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List of Table and Figures

Table 1 - This table shows the amount of time (in minutes) that it took for four television stations to mention the phrase "tornado emergency" (TE in the table) after the NWS used this language in a text product or sent a message via NWSChat mentioning tornado emergency on 3 April 2012. The first column indicates the time that the NWS communicated a tornado emergency. The second column indicates how the tornado emergency was communicated, whether it was chatted, or contained in a traditional text product (either tornado warning or follow up statement). The remainder of the columns indicates the amount of time it took for the phrase "tornado emergency" to be broadcast by each television station, concluding with the average time it took for all stations to broadcast this phrase. If the average media response time was less than 0.5 minutes, the average response time was listed as "immediate", and if all stations never mentioned tornado emergency, the average response time was listed as "never". There was a block of missing archived video from Station 4 from 18:35 UTC (1:35 PM CDT) to 19:30 UTC (2:30 PM CDT); therefore, these data have been listed as "not available", or N/A, in the table. (* The average was calculated using only Stations 1, 3, and 4 because Station 2 mentioned "tornado emergency" without any communication with the NWS.)

Time	Action	Station 1	Station 2	Station 3	Station 4	Average
1:16 PM	TE Text - Dallas	5	-2	4	4	4*
1:20 PM	Chat about TE - Dallas	1	-6	0	0	Immediate
1:25 PM	Chat about TE - Tarrant	1	0	0	0	Immediate
1:26 PM	TE Text - Tarrant	0	-1	-1	-1	Immediate
1:26 PM	TE Text - Dallas	Never	Never	Never	Never	Never
1:33 PM	TE Text - Tarrant	5	3	Never	2	3
1:34 PM	TE Text - Dallas	Never	Never	Never	Never	Never
1:35 PM	Chat about TE - Tarrant	1	Never	2	N/A	2
2:02 PM	Chat about TE - Dallas	7	9	Never	N/A	8
2:02 PM	TE Text - Dallas	7	9	Never	N/A	8
4:26 PM	Chat about TE - Hunt	0	1	1	1	1
4:27 PM	TE Text - Hunt	0	0	0	0	Immediate

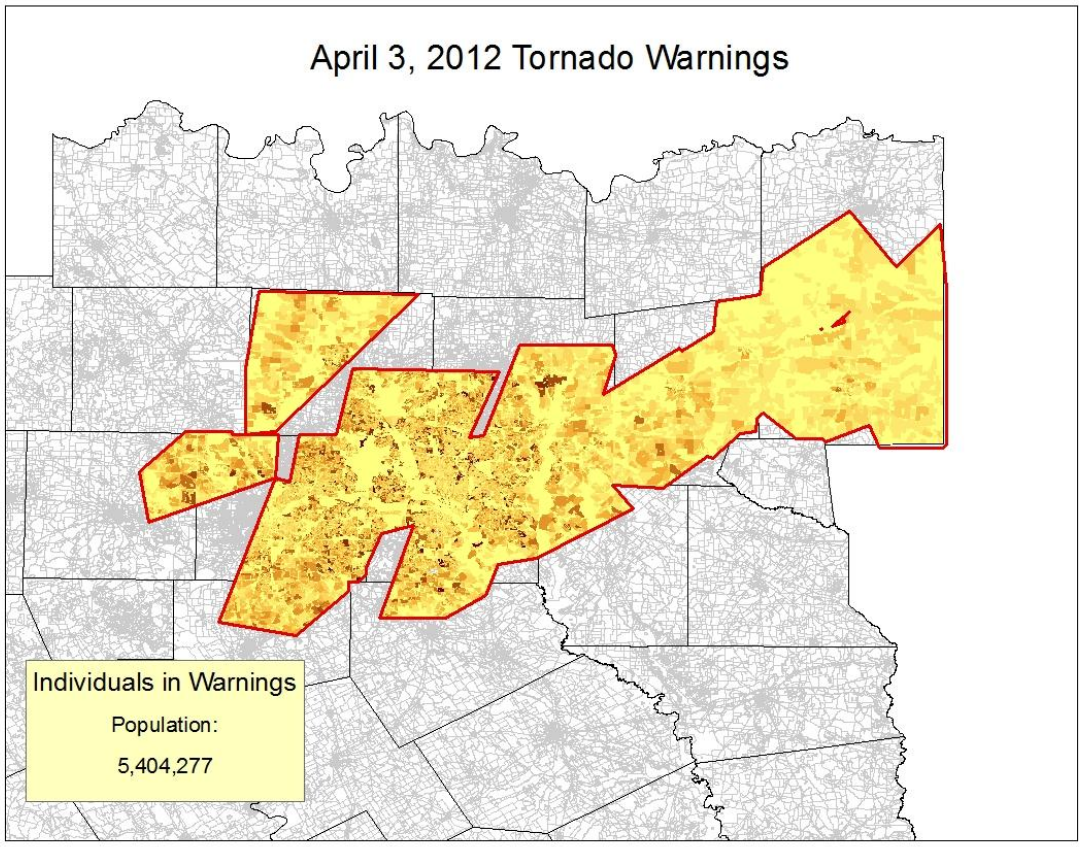

Fig. 1. A composite of tornado warnings issued by the NWS office in Fort Worth, TX on 3 April 2012. The solid red outlines are the borders of the composite tornado warning polygons issued by the NWS. The background image is population per census block from 2010 census data, where darker colors represent higher population density. There were over 5 million residents in tornado warnings on this day.

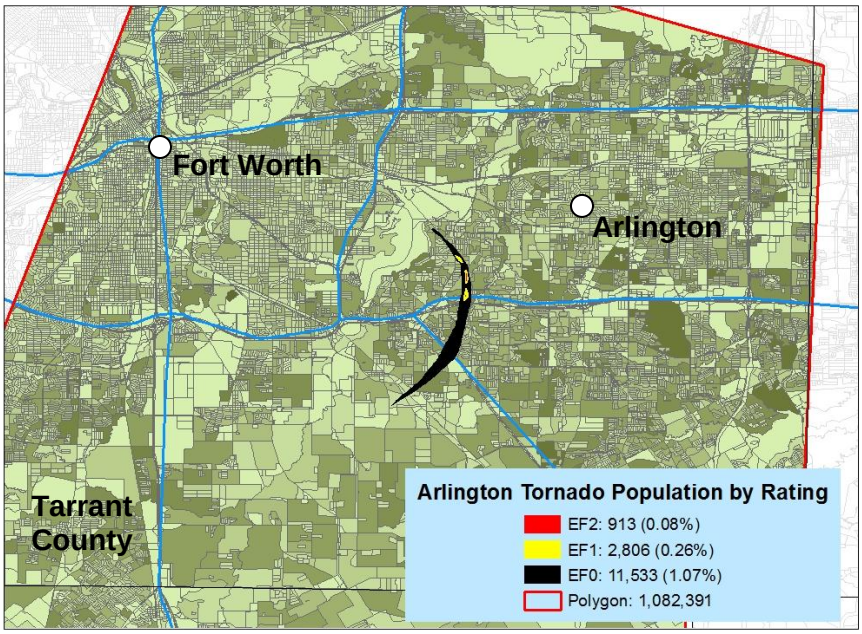

Fig. 2. Damage path of the tornado that affected Tarrant County Texas, including the city of Arlington, on 3 April 2012. The path length of the tornado was 10.3 km long, and at its widest, the tornado was 137 m wide. Background image represents the population per census block from 2010 census data, with darkest green shades representing a greater number of people living in a particular census block. The city labels and white dots mark the approximate centers of the cities of Fort Worth and Arlington. The overlay is the areal coverage of EF-rating as surveyed by NWS damage survey teams near the city of Arlington, TX on 3 April 2012. Solid blue lines represent major highways, and the solid red line represents the NWS tornado warning polygon that was in effect at the time of the tornado. Populations affected were determined by intersecting the population density layer with the EF-rated polygons. This is simply an analysis of people who lived in the path of damage as of the 2010 census; there is no way to know for certain how many people were actually in the damage swath at the time the tornado occurred.

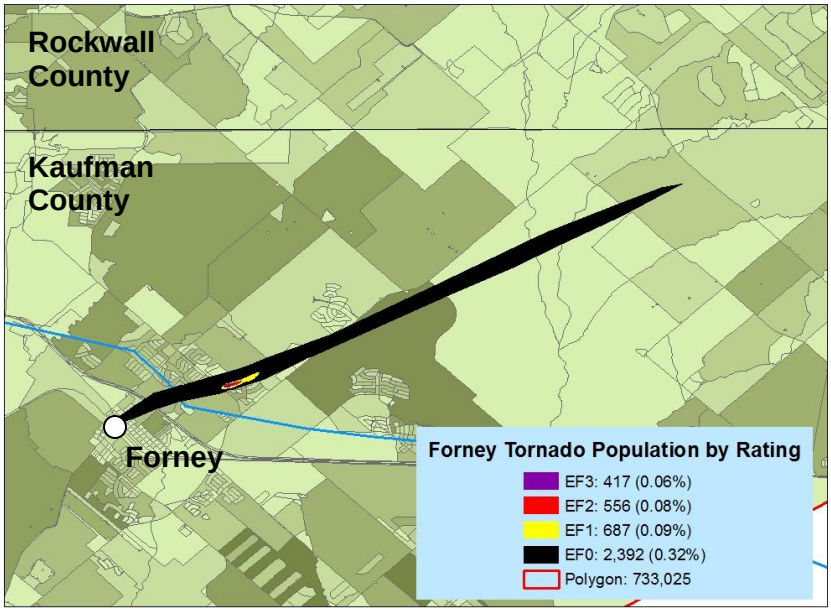

Fig. 3. Same as Fig. 2, but for the tornado that affected the city of Forney in northern Kaufman County TX on 3 April 2012. The path length of the tornado was 12.4 km long, and at its widest, the tornado was 137 m wide. The thin black line near the top indicates the Kaufman and Rockwall County border.

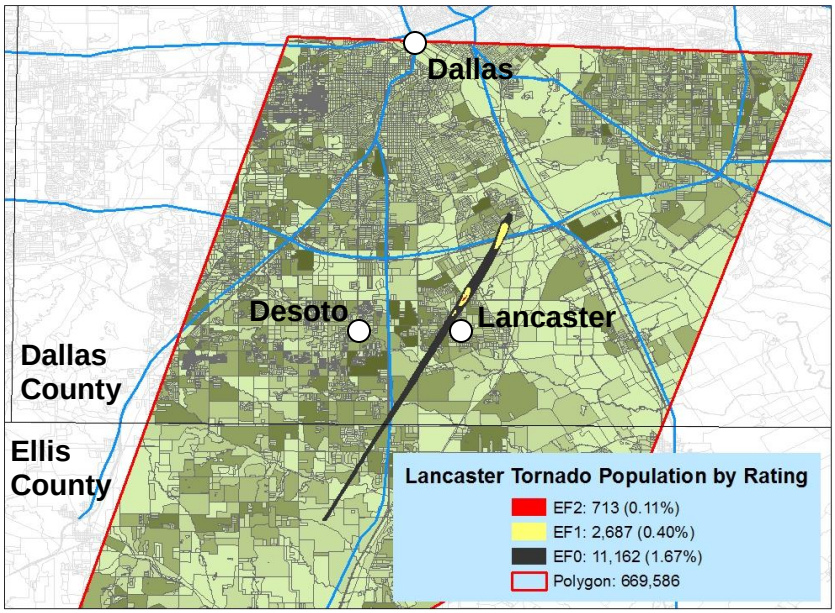

Fig. 4. Same as Fig. 2, but for the tornado that affected parts of Ellis and Dallas Counties in Texas, including the city of Lancaster, on 3 April 2012. The path length of the tornado was 15.0 km long, and at its widest, the tornado was 183 m wide. The horizontal, thin black line indicates the Dallas and Ellis County border.

Fig. 5. Screen captures of Dallas/Fort Worth area broadcast media outlets providing non-stop, live coverage of the 3 April 2012 tornado outbreak. Broadcast meteorologists utilized radar data, live video feeds from mobile storm spotters, mobile news crews, and helicopters to convey the threat of tornadoes to the public.

Fig. 6. Photograph taken at the Texas State Emergency Management training conference in San Antonio, TX on 3 April 2012. NWS Fort Worth meteorologist Mark Fox (center, holding orange phone), was attending the annual conference along with dozens of DFW-area emergency management personnel. During the outbreak, Mark gave briefings on tornadoes around the Dallas/Fort Worth Metroplex to emergency management personnel whose jurisdictions were being threatened by the tornadoes. The briefings and updates helped DFW area emergency management personnel coordinate response efforts remotely from the state conference.

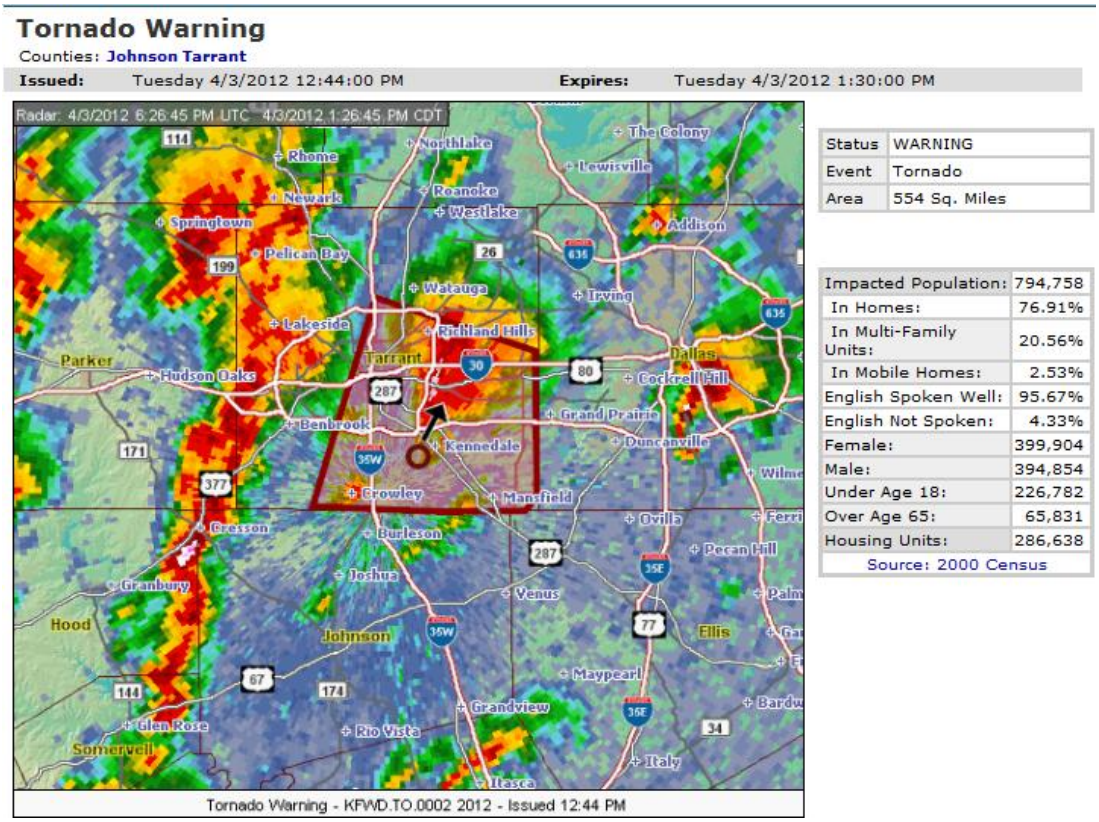

Fig. 7. A screen capture of the GWARN product output from 3 April 2012, highlighting the tornado warning polygon issued for the supercell thunderstorm that produced the Arlington, TX tornado. Emergency managers have access to this tool from the NWS Fort Worth webpage [available at: http://www.srh.noaa.gov/fwd/gwarn/data.php?file=nwswarning]. The colors on the image are base reflectivity from the NWS radar, KFWS, located 22.5 km south of Fort Worth, TX. The small red circle is a low-level shear marker from KFWS Level 3 data, and the arrow represents the radar derived direction of movement of the shear marker. The heavy red outlined and light red shaded polygon is the NWS tornado warning polygon that was valid at 18:25 UTC.

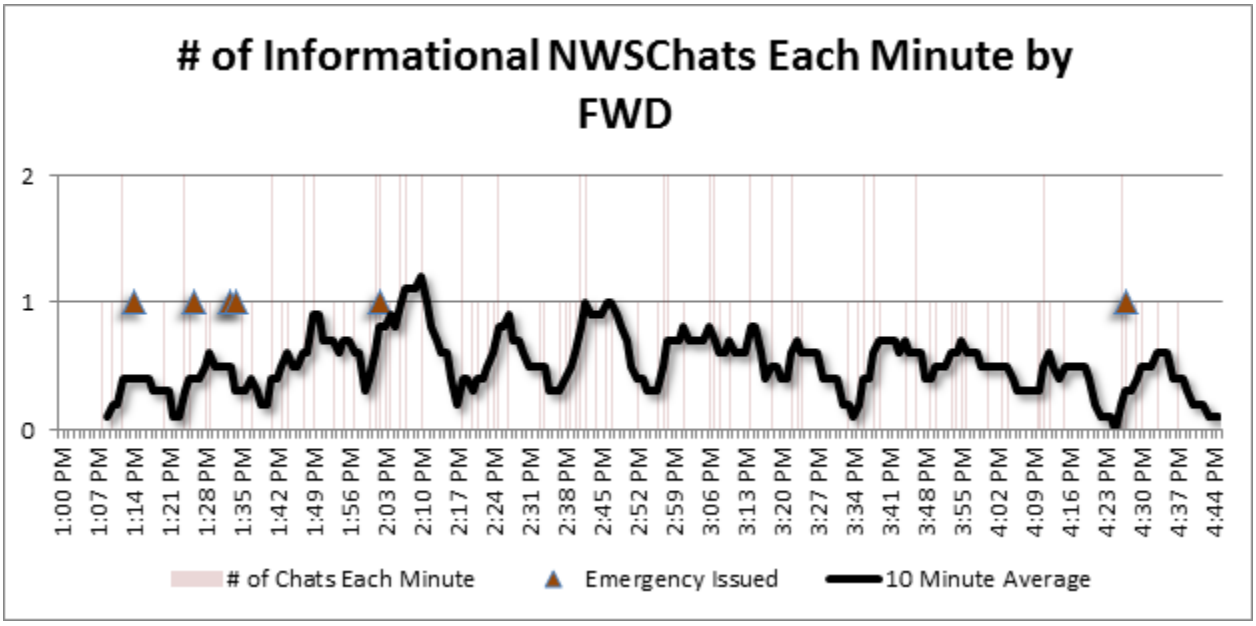

Fig. 8. Chart depicting frequency of messages issued by NWS Fort Worth via NWSChat during a 3.75 h period on 3 April 2012. Vertical axis is number of messages transmitted, and horizontal axis represents time of day starting at 1800 UTC (1:00 PM CDT) and ending at 2145 UTC (4:45 PM CDT). The grey vertical bars in the background represent the number of messages sent each minute by NWS Fort Worth meteorologists while the solid black line is the 10-minute running average of chat frequency in messages per minute. The red triangles indicate those times when NWS Fort Worth meteorologists used the language "tornado emergency" in tornado warning products.