# Rainfall Estimates or Tornado Detection?: An Assessment Based on the Needs of Emergency Managers[1]

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June 10, 2005

# ERC-CASA
# End-User Integration
# Research Brief No. 4

[1]This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under NSF Award Number 0313747. Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation. We would also like to recognize the contributions of our undergraduate research assistants, Cory Abbey, Desiree Grainger, and Jessica Rothrock whose work and contributions to this project have been extremely valuable.

# Abstract

The following research brief uses data obtained from twenty six (n=26) interviews with emergency managers, National Weather Service (NWS) forecasters, and amateur radio operators (HAM) to determine whether rainfall estimation or tornado detection would more effectively address the needs of the emergency management community in Oklahoma. This study was conducted as part of a broader project on end-user integration, which intends to incorporate the needs and recommendations of end users into the design of radar technology currently under development by the Engineering Center for the Collaborative Adaptive Sensing of the Atmosphere (CASA). In the course of our analysis, we discovered that a majority of emergency managers require tornado detection due to the specific needs of Oklahoma communities, as well as their experiences with severe weather. We identified three reasons for this decision. First, tornados are less predictable than floods. Second, mitigation strategies, such as rain gauges and retention ponds, have significantly reduced the threat of flooding in most regions. Finally, failed tornado warnings *vis-à-vis* flood warnings seem to pose a greater threat to professional credibility and legitimacy. Overall, these findings indicate that emergency managers consider a wide range of factors when making decisions related to severe weather. While much is revealed about the decision-making process, the reasons for which emergency managers chose tornado detection over rainfall estimation were, in some cases, based on incomplete or inaccurate information. Most strikingly, for example, is that according to epidemiological statistics, flooding appears to be a greater threat to life than tornados. Moreover, current flood mitigation practices do not address the fact that a) floods produce long-term and diffuse effects (e.g., insurance costs), and b) mitigation techniques may decrease the level of individual preparedness, putting a population at risk of flash and/or major flooding. It is the recommendation of emergency managers that radar resources should primarily be allocated to tornado detection. It should, however, be remembered that flooding may continue to constitute a major threat to these communities.

## Introduction

Emergency managers interviewed in Oklahoma maintain that flooding no longer constitutes a major threat to public safety in their jurisdictions due to measures that have improved the quality of mitigation and risk assessment. Initiatives such as channelizing local creeks and rivers, monitoring water levels, and adding drainage and retention ponds in flood-prone areas have, according to those interviewed, dramatically reduced many of the hazards associated with flooding. Quantitative Precipitation Estimates (QPE), a form of rainfall estimation, have also been useful in the past for monitoring the threat of flooding. Therefore, in most cases, it appears that emergency managers would prefer tornado prediction, detection, and tracking algorithms over rainfall estimates such as those offered by QPE. The reason for this is threefold: a) tornadoes are more unpredictable than floods b) communities have already taken steps to mitigate flooding effects, and c) emergency managers face stronger public criticism if they disseminate inaccurate tornado-related information. In addition, this research brief examines the continuities and differences between the perspectives of emergency management and other groups on QPE and flooding, as well as emergency management views on flooding and flash flooding. The conclusion addresses the question of whether QPE should be included in DCAS (Distributive Collaborative Adaptive Sensing) system design and the evidence upon which our recommendation is based.

## Project goals

This research brief was written as part of a larger project which deals with end-user integration, a process by which system design is adapted to a broad range of technical and social contexts. In the current case, The Engineering Research Center (ERC) for the Collaborative Adaptive Sensing of the Atmosphere (CASA), based at the University of Massachusetts-Amherst, is designing a series of low-wavelength radars intended to overcome previous limitations in remote sensing design (e.g., the curvature of the earth, low-level scanning, etc.). It is the goal of the end-user component to develop an overall strategy through which this technology can be adapted to the needs of the various groups and organizations for which radar data and weather information is critical. Researchers from the Disaster Research Center (DRC) at the University of Delaware, the Center for Applied Social Research (CISA) at the University of Puerto Rico-Mayagüez, the University of Massachusetts-Amherst, the University of Oklahoma, and the University of Virginia, comprise the end-user research group.

## Methods

"End-users" comprise an extensive network of individuals, groups, and institutions that rely on radar data for the purposes of predicting, detecting, tracking and issuing warnings about weather events (e.g., NWS, media), responding to severe weather (e.g., state, county, and local emergency managers), making decisions about preparedness and evacuation (e.g., general public), and conducting research (e.g., DRC, CISA, and CASA). In total, 37 interviews were conducted with local, county, and state emergency managers; National Weather Service (NWS) representatives; amateur radio (HAM) operators; and a number of other individuals involved either directly or indirectly in Oklahoma's emergency management community. Each end-user group is considered a stakeholder guided by different—and sometimes conflicting—interests,

opinions, and behaviors related to the types of knowledge, information and products they require to carry out their missions. Therefore, technology intended to provide knowledge to end-users must conform to a wide number of needs, interests, and abilities. DRC is currently focusing on the second end-user group—emergency managers and related institutions, such as NWS—through in-depth interviews. Data used for analysis was gathered for a broader study on end-user integration funded by the National Science Foundation (NSF). Content analysis was used to analyze data from twenty-six interviews with emergency managers. All interviewees were informed of their rights as subjects and that all information collected from them would remain confidential. Due to the difficult nature of contacting the population under study, a snowball sampling technique was employed to maximize participation by emergency managers.

## Analysis

### Emergency Managers *versus* Other Groups: Convergence and Divergence of Perceptions

In Oklahoma communities, flooding generates considerable concern over property damage. An emergency manager remarks, "[U]nlike tornadic activity, you can certainly build a safe room or a cellar, but you certainly can't protect the property, and in a flood it's more property than people." A different interviewee mentions, however, that national studies demonstrate flooding to be the biggest killer. For instance, according to a National Weather Service (NWS)[2] report for the entire United States in 1996, there were 131 fatalities due to flooding—94 of which were attributed to flash floods, 31 to river floods, and 6 to small stream/urban floods—while only 25 deaths were attributed to tornados. These data also indicate that floods appear to accumulate larger economic and social costs than tornados. On the other hand, injury data present a different picture of vulnerability. In the same 1996 report, 95 injuries were attributed to flooding while 705 injuries were blamed on tornado events. According to another emergency manager, downtown urban areas constitute one of the biggest risks for flooding. This observation is corroborated in the literature, which argues that urban areas are more at risk due to flooding of impermeable surfaces, reduction in the carrying capacity of river channels due to construction, and the inability of sewage systems to deal with massive urban-generated runoff.[3] Metropolitan communities experience significant building damage, while rural, low-lying regions more frequently suffer damage to roads.

Disasters often have social and economic impacts outside the communities in which they occur.[4] This is related to what is known as "secondary" and "tertiary" impacts: disasters produce immediate effects, but also indirect and diffuse effects beyond immediate perception, such as increased insurance costs, lost wages, and population displacements. For instance, since 1969, the National Flood Insurance Program (NFIP), a program run through FEMA providing subsidized premiums on flood insurance, has paid approximately $12.7 billion in claims and

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[2] National Weather Service (NWS). 1998. "Summary of U.S. Natural Hazards Statistics for 1996." http://www.nws.noaa.gov/om/severe_weather/sum_96.htm.

[3] Smith, K. 1992. *Environmental Hazards: Assessing Risk and Reducing Disaster*. New York, NY: Routledge.

[4] Mileti, D. 1999. *Disaster by Design*. Washington, D.C.: Joseph Henry Press.

costs related to flooding; today, 4.5 million people in 20,000 communities across the United States hold flood insurance policies.[5] However, as of 2002, according to NFIP, only 10-20% of individuals living in Special Flood Hazard Areas (SFHA)[6] were protected by flood insurance, whereas "the remaining 80-90% must rely on taxpayer-funded Federal disaster assistance, which is very limited, loans which must be paid back, tax write-offs, or savings to help them recover." Thus, the costs of flooding appear to be distributed over a large number of people.

It is these often unseen impacts that make it difficult to estimate the true costs of weather events. Economic losses from a disaster are difficult to determine with precision due to incidental costs such as those described above, for they often emerge later than the initial event and are not directly related to the weather disaster[7]. Similar problems affect accurate assessments of fatalities and injuries.

We should also note that an emergency manager reported that while many people work in floodplain areas, a relatively small portion of the population actually lives there. While this may have been true in the past, recent advances in infrastructural design, according to Oklahoma floodplain managers, may have induced Oklahomans to move into dangerous flood-prone areas. According to the Oklahoma Floodplain Managers Association (OFMA), "In years past, flood control structures created a false sense of security and encouraged development in floodplains."[8] Thus, despite the perceptions of some emergency managers, there may actually be an increasing risk to flooding in some communities in Oklahoma**.** However, this is an issue that merits further research.

**Flooding *versus* Flash Flooding**

Emergency managers distinguish between two types of flooding situations: minor flooding, which is reportedly predictable and easily mitigated, and flash flooding, which can occur rapidly and without warning. Most residents of Oklahoma must deal with flooding on a regular basis. An emergency manager states, "They're used to floods in our area. We could issue a flood warning and they're going to go 'Yeah, okay.'" It is in these areas that mitigation efforts to curb flood damage have been instituted. However, it remains possible that residents in these areas have become so acquiescent to the effects of the minor and regular flooding that they have, in turn, become more vulnerable to flash flooding. Flash flooding appears not to be as prevalent as it used to be in most areas as a consequence of mitigation initiatives, yet it nevertheless occurs

[5] Federal Emergency Management Agency (FEMA). 2002. "National Flood Insurance Program: Program Description." www.floodsmart.gov.

[6] Defined by FEMA as "as an area of land that would be inundated by a flood having a 1% chance of occurring in any given year (previously referred to as the base flood or 100-year flood)." Source: http://www.fema.gov/fhm/fq_term.shtm#frequt5.

[7] Cutter, S. 2002. *American Hazardscapes*. Washington, D.C.: Joseph Henry Press.

[8] Oklahoma Floodplain Managers Association (OFMA). n.d. "Hazard Mitigation Funding." http://www.okflood.org/html/hazardfunding.htm.

from time to time and is of particular concern in low-lying rural areas. An emergency manager explains, "We have a lot of low-lying areas and we have to deal with a lot of flooding events. We have a lot of rural areas that are dependent heavily on county roads and when we have flash flooding, a lot of our water runs across roads."

Flash flooding raises an important concern: it is theoretically possible that the recent improvement in mitigation strategies has had a negative effect on the level of individual flood preparedness. If this is the case, there exists a strong potential that major flooding (particularly flash flooding) might result in significant casualties. Individuals residing in communities protected by mitigation initiatives may have forgotten—or worse, never learned—the location of escape routes, their major points of access, and how to interpret the meanings and instructions of flood warning messages. Strong consideration should be given to the role played by acquiescence in producing vulnerability.

## Discussion: Determining the Importance and Necessity of Rainfall Estimation

The previous section suggests the possible need for rainfall data in regions prone to severe flooding. However, the question remains whether emergency managers specifically felt that more precise flood information due to additional improvement of QPE algorithms would significantly enhance the safety of their communities.

Emergency managers expressed the common opinion that they would rather allocate resources specifically to tornado prediction, detection and tracking than to flooding and rainfall threats. Current mitigation strategies, they argue, do much to offset the impact of flooding. In fact, while half of the emergency managers interviewed mention flooding as a frequent weather event, the vast majority indicate that tornados are the most dangerous weather event faced by their communities. Why? *First*, it is the perspective of emergency managers that flood and rainfall threats imperil communities less these days due to effective mitigation. While more resistant structures mitigate tornado impacts well, there are a broader and more effective range of flood-protection options available to communities. *Second*, greater levels of uncertainty are associated with where tornados will occur, where they will end, and how long they will last—accurate and effective tornado tracking has yet to be developed and implemented. On the other hand, as one emergency manager cogently states, "[F]loods are more of a nuisance than anything." Tornados, according to a majority of emergency managers, should have more resources devoted to them because of their irregularity, while flooding can be predicted relatively well. One emergency manager comments on this issue: "Whether I have the other resources or not I'm still going to concentrate on it [the tornado] because that's the most unpredictable catastrophic of the two events, even though given the right conditions the flood could be more catastrophic, history tells me here that it's not." Another emergency manager expresses his views on allocating resources: "[W]e can monitor the flooding threat or the rainfall threat pretty well. And so I would be biased towards allocating, splitting the resources and putting more resources into the tornado detection."

*Finally*, more accurate tornado information would enhance the credibility of emergency managers because the public relies heavily on tornado warnings in order to make personal safety decisions in times of severe weather. Thus, there appears to be an underlying political

motivation behind preferences for tornado detection over QPE. One emergency manager indicates that his job depends on the warnings he is able to provide: "[I]f I don't give the warning for a flood, I'm still going to be here tomorrow; if I don't give the warning, if I don't blow the sirens before the tornado hits the city limits, I won't be here tomorrow." In contrast to most other interviewees, however, only a few emergency managers expressed a need for more accurate rainfall estimation. Thus, while many emergency managers may not be overly concerned with rainfall, others still find it to be a necessary or useful part of their job. However, these emergency managers were in the minority, and it is obvious that emergency managers are overwhelmingly supportive of the development of technology and algorithms intended to detect and predict tornadoes. This preference arises because mitigation strategies are perceived by emergency managers as having effectively reduced the impact of floods, whereas tornadoes are more unpredictable, and, in comparison to flood events, erroneous tornado reports are more likely to weaken confidence in public institutions.

## Conclusion

It is not easy to answer "Is QPE a fundamental need for CASA's system design?" As mentioned in earlier sections, this difficulty arises from the contradiction between what emergency managers recount are the most dangerous weather events and what the NWS, NFIP, and OFMA organizations argue are the most dangerous and have the most broad and hard-hitting impacts. A majority of emergency managers believe that tornadoes appear to be more dangerous than flooding. If "dangerous" refers to tornado injuries, then they are correct in this assessment, for NWS statistics confirm that tornados are more likely to cause injuries than flooding. However, if "dangerous" is taken to mean fatalities, then clearly emergency managers' perceptions do not seem to be based on actual data, given that the NWS shows that flooding is responsible for a majority of fatalities relative to other severe weather events. There is no contradiction, however, between what the emergency managers report about property damage and what NWS data show, and, in fact, flooding is much more threatening to property than tornadoes. Despite these inconsistencies, what might be considered in terms of system design is what emergency managers have mentioned as an important criterion for resource allocation: population density.[9] If local development increased in floodplain areas, as is occurring according to OFMA, then allocation policy may need revision, with a greater need for resources devoted to flooding events. Because flooding is the most dangerous weather event to life, QPE may be necessary in flood prone regions that contain a high population density. Nevertheless, a significant number of emergency managers regard tornadoes as more unpredictable than flooding and their persistent requests for more algorithms to predict these violent storms should be taken into account in CASA's system design. It should be noted, however, that although emergency managers are a useful and effective source of information (particularly about the needs of specific communities), their perceptions of severe weather in some cases diverged from that of NWS.

[9] For a more detailed discussion of this issue, see End-User Integration Research Brief No. 3.