Allocation of Radar Resources and Policy Implications: The End-User Community in Oklahoma[1]

Havidán Rodríguez, Ph.D.[*]
Walter Díaz, Ph.D.[**]

William Donner[*]
Jenniffer Santos[*]
Daniel Marks[*]

[*]Disaster Research Center (DRC)
University of Delaware

**Center for Applied Social Research (CISA)
University of Puerto Rico-Mayagüez

ERC-CASA
End-User Integration
Research Brief No. 3

[1]This work was supported primarily by the Engineering Research Center's 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 work of our undergraduate research assistants, Cory Abbey, Desiree Grainger, and Jessica Rothrock whose contributions to this project have been extremely valuable.

Abstract

Social scientists at the Disaster Research Center (DRC) at the University of Delaware, the Center for Applied Social Research (CISA) at the University of Puerto Rico-Mayagüez, and at the University of Massachusetts are conducting a research project focusing on the knowledge, perceptions, and attitudes of end-users (primarily emergency managers and representatives from the National Weather Service – NWS) in the State of Oklahoma regarding severe weather events, warnings, and the development of new radar technology. Particular attention has also been paid to the advantages, problems, and limitations of current weather technology from the emergency manager's perspective. This research brief focuses on the end-users' recommendations regarding the allocation of the new radar resources that are being developed by the Engineering Research Center (ERC) on the Collaborative Adaptive Sensing of the Atmosphere (CASA), which is funded by the National Science Foundation (NSF).

In-depth interviews were conducted with members (n=38) of the emergency management community and NWS meteorologists with diverse experiences in disaster mitigation, preparedness, response, and recovery. Based on the results from the in-depth interviews, we generated seven (7) broad categories that include the recommendations or factors that emergency managers reported should be taken into account in the allocation of radar resources, including a) nature of the hazard event, b) potential impact and outcomes of the hazard event, c) lead time, d) false alarm rates, e) population issues, f) infrastructure, and g) availability of other resources.

Introduction and Background

Social scientists at the Disaster Research Center (DRC) at the University of Delaware, the Center for Applied Social Research (CISA) at the University of Puerto Rico-Mayagüez, and at the University of Massachusetts are conducting a research project focusing on the knowledge, perceptions, and attitudes of end-users (primarily emergency managers and representatives from the National Weather Service – NWS) in the State of Oklahoma regarding severe weather events, warnings, and the development of new radar technology. Particular attention has also been paid to the advantages, problems, and limitations of current weather technology from the emergency manager's perspective. This research brief focuses on the end-users' recommendations regarding the allocation of the new radar resources that are being developed by the Engineering Research Center (ERC) on the Collaborative Adaptive Sensing of the Atmosphere ($CASA^2$), which is funded by the National Science Foundation (NSF).

CASA researchers are currently developing a Distributed Collaborative Adaptive Sensing (DCAS) system that is user driven and that responds to the interests, needs, and recommendations of end-users. CASA's vision is to provide weather information "where and when user needs are greatest." Social Scientists within CASA are exploring the most critical issues related to end-users, technology, and weather forecasts. This research ultimately intends to integrate the feedback and information obtained from end-users into the design of the new radar system currently under development by CASA thus having the system respond to the needs and interests of emergency managers, NWS, and other end-users. By addressing these issues, we attempt to match scientific and technological capabilities, developments, and its implementation with the needs of the end-users (NRC, 1999:35) thereby enhancing the societal value of such technological developments.

Methodology

In order to address the aforementioned issues, researchers from the CASA end-user team have collected detailed data through the use of structured surveys administered to the emergency management community in Oklahoma. Also, the research team conducted in-depth interviews (with a duration of about 90 minutes to two hours) with representatives from Oklahoma's

[2]CASA brings together a multidisciplinary group of engineers, computer scientists, meteorologists, sociologists, graduate and undergraduate students, and industry and government representatives to conduct fundamental research, develop enabling technology, and deploy prototype engineering systems based on a new paradigm, DCAS. CASA's current and long-term research efforts focus on Oklahoma (i.e., wind sensing and severe storm detection, tracking, and predicting with an emphasis on tornadoes); Houston, Texas (i.e., urban flooding), and Puerto Rico (i.e., tropical storms and hurricanes). The lead institution in CASA is the University of Massachusetts-Amherst. CASA focuses its efforts on the development of revolutionary sensing technology that will enable earlier and more accurate forecasts of weather emergencies. CASA's technology is expected to increase the warning time for tornadoes, flash floods, and other severe weather events and provide greater accuracy than existing systems. Also, CASA researchers aim to significantly reduce false alarm rates, generate improved precipitation estimates for flood prediction, enhance the detection of humidity and temperature variables, and "revolutionize our ability to observe the lower troposphere and, therefore, significantly contribute to improve our ability to detect, understand, and predict severe storms, floods, and other atmospheric and airborne hazards."

emergency management community and NWS meteorologists, primarily focusing on the CASA test-bed region, which includes the counties of Caddo, Grady, Stevens, and Comanche although interviews were also conducted with emergency management personnel in other regions in Oklahoma.

It is important to note that this was a convenience (non-random sample) and, therefore, it is not representative of the Oklahoma emergency management community. The sample consisted of members (n=38) from this community with diverse experiences in disaster mitigation, preparedness, response, and recovery. The results from this survey provide important insights regarding how the emergency management and NWS community use, manage, and disseminate weather related information, such as weather forecasts; the problems and limitations of current weather technology; and the needs, interests, and recommendations that this community has in order to enhance disaster preparedness and response. In the following section, we report on the general issues, conflicts, and recommendations of the end-user community included in this sample regarding the allocation of radar resources proposed by CASA.

Preliminary Findings

During the interview process with the end-user community in Oklahoma, we asked the following questions regarding the potential allocation of the new radar resources, to be developed by CASA, in their region:

1. If two communities are in danger of being impacted by a hazard event (for example, floods and tornadoes, respectively), what factors should be taken into consideration in the allocation of the radar resources provided by CASA in order to address the needs of each community? Follow-up questions included:

    a. How de we allocate those resources?
    b. Based on what criteria?
    c. Who should make these decisions (i.e., NWS, emergency management organizations, local politicians, etc.)?

This research brief will focus on the data and information provided by the interviewees in response to the aforementioned questions. It is important to note that we are still in the process of analyzing the transcripts and conducting additional interviews. Therefore, the results discussed below should be viewed as preliminary.

There was some tension/conflict among respondents in terms of what factors should be taken into account in the allocation of radar resources for a) communities that may be in danger of being simultaneously impacted by two separate events; or b) communities that may be competing for these resources given that separate severe weather events are simultaneously threatening each community. For example, some respondents indicated that total population or population density should be a primary factor which should be considered in the allocation of radar resources given that their primary responsibility is to “save lives and property.” However, other emergency managers strongly disagreed with this position indicating that all lives are valuable and even losing one life is “one too many.” This is an important and critical conflict

which all emergency managers (but particularly those in small, remote, and rural areas) are confronting.

In the following section, we have generated seven (7) broad categories that include the recommendations or factors that emergency managers reported should be taken into account in the allocation of radar resources. We have classified them into the following areas: a) nature of the hazard event, b) potential impact and outcomes of the hazard event, c) lead time, d) false alarm rates, e) population issues, f) infrastructure, and g) availability of other resources. It is noteworthy that these categories are not exhaustive or mutually exclusive. To be sure, some categories may be correlated. Therefore, we may eventually decide to collapse and prioritize these categories in order to reduce specification error, improve accuracy, and promote efficiency during the system design phase. Efficiency will thus be increased by reducing the number of redundant or overlapping allocation categories for system designers. We should also note that the responses provided by the end-users should be examined and interpreted in the social, institutional, geographic, and economic context of those providing the responses.

The Hazard

- *Nature or type of event*: Respondents placed particular emphasis on tornadoes, severe storms, lightning, straight line winds, and ice storms, and, to some extent, floods. Some events are perceived by respondents as being easier to mitigate, prepare for, control or manage. For example, according to some respondents, their communities have made significant investments and improvements in flood control measures (e.g., mitigation). They also report that their communities have significant experience in preparing and responding to floods. Therefore, many respondents seem to be "less concerned" about flood events (relatively speaking) and would prefer to allocate radar resources to other types of hazard events, particularly tornadoes, under competing hazard events. Nevertheless, a smaller group of respondents indicated that floods were still a primary concern for their communities. In such cases it should be noted, however, that emergency managers perceive flooding as more threatening to property than to life. Nevertheless, we should consider that flood mitigation measures may potentially provide respondents and their constituencies with a "false sense of security" thus increasing their vulnerability to such events. The second research brief (currently under review) will focus on these particular issues.

- *Unpredictability*: Generally, tornadoes were deemed more unpredictable and damaging than other hazard events such as floods. Therefore, the overwhelming majority of those interviewed indicated that the new radar technology proposed by CASA should focus on generating data focusing primarily, but not exclusively, on tornadic events.

- *Severity/strength of the eve*nt: According to emergency managers, stronger tornados should receive priority in the allocation of radar resources over weaker tornados.

- *The track that the storm is following:* This will allow us to project the path of the event, if and how it is impacting other communities, and the potential for loss of life, injuries, and property damage that may result as a consequence of this hazard. Emergency managers

want to be able to track tornados with as much precision as possible when their communities are being threatened by them.

- *Proximity of the event:* The closer the hazard event to a given community, the greater the probability that it will impact that community and, therefore, respondents indicated that these communities should receive priority in the allocation of radar resources.

- *Credibility:* Hazards present different threats to the credibility of emergency managers. Although flooding, ice storms, and tornados may result in damages of similar magnitude in particular situations, a failure to effectively respond to tornadoes in general reportedly introduces the greatest threat to an emergency manager's image. Thus, under two competing severe weather scenarios, an emergency manager's subjective assessment of his/her own credibility needs may cause him or her to focus more closely on the tornado. As highlighted by one emergency manager:

  "If I don't give the warning for a flood, I'm still going to be here tomorrow...if I don't blow the sirens before the tornado hits the city limits, I won't be here tomorrow."

Potential Impact and Outcomes of the Hazard Event

- *What is the immediate threat to life?*
- *Where is the threat greatest?*
- *Where do we have the greatest ability to save lives and mitigate property damage?*
- *Economic impact*: *What are the potential costs of the damages caused by the hazard event?*

According to the respondents, radar resources should be allocated to weather events that may have the most significant outcomes in terms of the loss of life and damage to property. Again, emergency managers indicate that given the unpredictable nature of a tornadic event, radar resources should be directed to tornadoes vis-à-vis other types of events that may be simultaneously threatening the community. Emergency managers report that a severe tornadic event may result in a significant loss of life. However, the existing data on weather caused fatalities show that death tolls as a consequence of tornadoes in the United States are declining; they also show that floods, particularly flash floods, are the leading cause of weather related deaths.

Lead Time

- *Warning or lead time to take action*: Radar resources should be allocated to allow emergency managers to provide adequate lead time in order for the population to take protective action given the impending nature of a hazard event. On the other hand, if there is limited lead time, resources should be allocated to the community to enhance their response to this imminent event. It is important to note that data from the NWS warning database shows that the average lead time for tornadoes in the state of

Oklahoma, for the period between January 1, 1986 and December 31, 2003, was 12.7 minutes compared to 8.8 minutes for the United States. It is expected that the proposed CASA technology will increase lead times and should, therefore, address this issue.

False Alarm Rates

- *Probability of impact of the hazard event*: What is the relative probability that the hazard event will impact any given community within the region in which it is occurring? All else equal, communities with higher probability of being impacted should receive priority in the allocation of radar resources.

The generation of significant numbers of false alarms regarding tornadoes poses a potential threat to emergency manager's credibility but, most importantly, it can negatively impact community awareness, preparedness, and response to severe weather events. If radar resources are not allocated in a manner that result in a significant reduction in the false alarm rates, which are estimated by NWS for the state of Oklahoma to be about .675 (compared to .756 for the United States), this will influence individual perceptions and attitudes regarding the "impending" threats and will have a negative impact on their response to these severe weather events. Although emergency managers generally reported that false alarms were "not a major problem" in their communities; a number of respondents agreed that false alarms do, nevertheless, pose significant problems to credibility and public response. Therefore, radar resources and weather technology must be allocated in a manner that finds a balance between reasonable lead times and the reduction of FAR, since the two are negatively correlated.

Population Issues

The overwhelming majority of our respondents indicated that population issues were instrumental in the allocation of radar resources. For example, if one of the goals of the emergency management community as well as of NWS is to "safe lives" or to reduce the number of fatalities as a consequence of these severe weather events, (see ***NWS Strategic Plan for 2005-2010: Working Together to Save Lives***), then population size, density, and distribution are key variables. As stated in the mission statement of the NWS Strategic Plan for 2005-2010:

> "The National Weather Service provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas *for the protection of life and property and the enhancement of the national economy* [our emphasis]."

One of the key recommendations provided by a significant number of emergency managers is that, *ceteris paribus*, areas with greater population size and/or higher population density should receive priority in the allocation of radar resources given an imminent hazard threat. As reported by a representative from NWS:

> "Population is always a factor, I think. Sometimes it's not as verbalized, but if you have a million people in a few counties, the chance of having a loss of life is statistically much greater than if it's a low population. And our primary mission is to protect life. So it has to be a factor. Other things… you know, the nature of the hazard is a factor, how many people

> does it affect, is it a particularly damaging sort of phenomenon, it might get more attention even if the population is less."

This perspective was supported by a significant number of other respondents. However, it is important to reiterate that this was a contentious issue which caused conflict among emergency managers. For example, a non-trivial group of respondents (particularly those located in rural or remote regions with relatively small population numbers) vehemently opposed the allocation of radar resources based on population size. This perspective is summarized by two emergency managers:

> "I don't agree with any of it [allocating radar resources based on the size of the population]. I don't think any town should be…lives are at stake…I don't care if it's a big town or a small town, you still got lives."

> "We know towns with 200 people. Each one of their lives is as important as each one of ours no matter…see that's what the media does [gives greater coverage to areas with larger population concentrations]. They do it for most people that are watching, for the ratings…I'd be afraid of the possibility of doing that based on population. Then you get to the point where, well, the GM [General Motors] plant is more important than the apartment buildings over there because it's got more money involved there...do you start breaking it down by financial standpoint?"

Infrastructure

Infrastructure was another component reported as being important in the allocation of radar resources. Respondents indicated that critical infrastructure (i.e., buildings, hospitals, nursing homes, schools, power plants, nuclear plants, factories, stadiums and parks, roads, etc.) that may be impacted, destroyed, or damaged by severe weather events must be taken into account in this allocation process. One of the important concerns highlighted by the interviewees was how much property would be destroyed by the hazard event and what are the economic and social costs of such destruction to the community. The respondents generally agreed that areas with critical infrastructure, as described above, should receive priority in the allocation of radar resources. Nevertheless, this (once again) poses an important dilemma for respondents in small, rural or remote areas with relatively limited critical infrastructure vis-à-vis large urban or metropolitan areas.

Availability of Other Resources

Emergency managers and NWS personnel agreed that it is important to have multiple sources of information (e.g., building redundancy into the system) that will allow them to verify the severe weather information that they are receiving in order to determine if the hazard poses a threat to their communities and if protective action needs to be taken. The following section provides a summary of the most important issues, questions, and concerns provided by respondents regarding the availability of other resources or sources of information and the allocation of radar resources.

- Is there another region tracking the hazard event or a community that has been impacted by the same that can provide additional information to the other regions/communities that are in the path of the hazard event?

- Are there other technological (e.g., other radar resources, internet access, access to OK-FIRST, etc.) or non-technological resources (e.g., spotters, ham radio operators, etc.) in that particular region/community to deal with other hazard events (e.g., floods)? For example, some geographical areas already have radar resources to allocate to detection, tracking, and pinpointing of storms while others do not. If this factor was taken into account, radar resources (such as those being developed by CASA) should generally be allocated to regions or communities with limited or no radar resources to allow them to receive continuous and up-to-date weather information particularly regarding severe weather events. It was also indicated that spotters could be used to focus on potential flooding problems while radar technology should be used for unpredictable hazard events such as tornadoes.

- *Media Coverage*. Due to factors such as population size and geographical location, among others, some communities receive extensive and/or more precise weather coverage from the media than others. For example, larger towns or cities typically receive increased coverage during a severe weather event. Large urban/metropolitan areas may have an extensive network of television and radio stations and newspaper agencies while these facilities may be extremely limited or simply non-existent in rural or poor communities. Therefore, smaller towns are in greater need of radar resources that could potentially make up for the "absence" of the media or for their reported coverage bias of larger towns or cities. Nevertheless, the role of the media in the communication of warnings and risk information is very important and should be expanded to provide greater coverage to rural areas.

"Joy Sticking" the CASA Radar System

A key difference between DCAS and present day weather radar systems is that the former may be dynamically reconfigured in response to end-user requests, whereas present day Doppler radar systems operate with fixed configurations. This raises an important issue, who should control, or "joystick" the reconfiguration process? We asked respondents who or what agency should be responsible for managing or controlling the new radar resources proposed by CASA. Respondents overwhelmingly agreed that NWS should have the primary responsibility for managing or "joysticking" this system. Many respondents indicated that, generally speaking, emergency managers do not have the training or expertise to manage this type of system. Moreover, they agreed that NWS personnel have the necessary expertise, knowledge, training, and experience and, that in fact, this type of task or responsibility falls within the jurisdiction of the NWS. A limited number of emergency managers indicated that OK-FIRST should also play a role in "joy sticking" the proposed radar system. An even smaller group indicated that they would like the system to be managed at the county or local level. However, the majority of respondents, citing a lack of economic resources, personnel, and adequate training and experience, as well as conflicts that may emerge at the county, city or local level in the

management of radar resources, among others, disagreed with this position. Nevertheless, all or almost all respondents agreed that they would like to place requests on the system regarding information and data on severe weather events that are in their vicinity or that are likely to impact their communities.

Closing Remarks

The aforementioned discussion shows that respondents generally agreed that the type of hazard, its severity, and the potential impact and outcomes of severe weather events should play a primary role in the allocation of radar resources. However, there were some conflicts or concerns regarding the role that population size should play in the allocation of such resources. While respondents agreed that their primary mission is to "save lives" it was difficult for some to come to an agreement that population size (or even infrastructure) should play a primary role in the allocation of radar resources.

The aforementioned factors, cited as important variables that should be taken into account in the allocation of CASA's radar resources, reflect more general issues and concerns among the end-user community that formed part of our sample. They also reflect significant differences between the communities represented by our interviewees, particularly as they relate to their demographic and socio-economic characteristics and their levels of economic and technological development. Communities that formed part of our sample can be classified into two general or broad categories: regions/communities that have fairly sophisticated weather technology and those that have very limited technological resources which consist of urban and rural communities, respectively. Economic and technological resources were unevenly distributed between urban and rural areas, the latter primarily representing poorer communities.

Regions with large population concentrations in this sample are generally urban (including metropolitan) areas with extensive infrastructure (i.e., hospitals, schools, hotels, and industries, among others) and urban development. These regions tend to have more "favorable" demographic and economic characteristics (i.e., higher levels of education and income and lower levels of poverty, among others), and significant technological resources for weather prediction and detection, not to mention the extensive media infrastructure that provides continuous coverage to these urban developments. On the other hand, there are rural regions or communities that have relatively smaller population concentrations and lower population density. These communities can be characterized by limited infrastructure (relatively speaking); lower levels of education and higher levels of poverty; inadequate economic resources; weather technology can be limited or non-existent; and media coverage can be significantly reduced, particularly when major urban areas are simultaneously being impacted by severe weather events. Therefore, although improved technology may increasingly contribute to enhancing disaster mitigation and preparedness in these regions, it is the social, demographic, economic, and political characteristics that primarily and significantly impact a community's level of preparedness and response (or lack thereof) to severe weather events. The inequities between urban and rural areas, discussed in this research brief, may be exacerbated if the CASA technology exclusively or primarily targets urban regions at the expense of small, rural, and "remote" communities.

The CASA end-user research is based on the premise that further development in technology aimed at enhancing the detection or prediction of severe weather events must respond and take into account the needs, interests, and concerns of the end-user community (see NRC, 1999). As argued by Rodríguez, et. al. (2004:7) "in order to be made useful, scientific research must be generated and integrated with the needs of individuals and organizations seeking to address the problems, challenges, or opportunities that they confront" (also see Pielke and Pielke, Jr., 1997; NRC, 1999). It is further argued that "in order for weather forecasts and warnings to be useful to individuals and communities, they must be understood, must meet their needs, and must provide accurate and reliable information as well as sufficient lead time to allow them to take appropriate action" (Rodríguez, et. al. 2004:7). The results presented in this research brief provide important information and recommendations that must be taken into account in the development and implementation of the DCAS system that is being developed by CASA researchers.

References

National Research Council. (1999). ***Making Climate Forecasts Matter***. P.C. Stern and W.E. Easterling (Eds.): Washington, DC: National Academy Press.

National Weather Service (NWS) (2005). ***Strategic Plan for 2005-2010: Working Together to Save Lives.*** http://www.weather.gov/sp/NWS_strategic_plan_01-03-05.pdf (Final - January 3, 2005).

Pielke, R.A. Jr. and Pielke, R.A. Sr. (1997). ***Hurricanes: Their Nature and Impacts on Society***. New York: John Wiley and Sons.

Rodríguez, H., Diaz, W., and Aguirre, B. (2004). "Communicating Risk and Warnings: An Integrated and Interdisciplinary Research Approach." University of Delaware, Disaster Research Center, Preliminary Paper No. 337.