What makes our partners tick?

Using ethnography to inform the Global System Division's development of the Integrated Hazards Information Service (IHIS)

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Social Science Woven into Meteorology (SSWIM)

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Executive Summary

The Integrated Hazard Information Services (IHIS) project is an interdisciplinary effort led by the National Oceanic and Atmospheric Administration's (NOAA) Global Systems Division (GSD) to 1) integrate three National Weather Service (NWS) applications: WarnGen, the Graphical Hazards Generator (GHG), and RiverPro; and to 2) create a common web-based user interface for the communication of weather information between the NWS and Emergency Managers (EMs) and other partners to enhance two-way communication during hazardous as well as non-hazardous weather.

With funding provided by NOAA Earth Systems Research Laboratory (ESRL) GSD Director's Discretionary Funds, Social Science Woven into Meteorology (SSWIM) social scientists led the social science component of the IHIS project. Collaboration between GSD and SSWIM began in October 2009 and highlighted the need to better understand how early notification, long before official NWS warnings were issued, was used by EMs.

Between October 2010 and March of 2011, SSWIM social scientist Spinney traveled to central Texas and western Missouri/eastern Kansas and used ethnographic research methods to explore EMs' and other stakeholders' needs and uses for weather information as well as the decisions made and their uses of time prior to the onset of, and during, hazardous weather events.

This research study showed that EMs access multiple types and sources of information to learn about approaching weather hazards during the preparation, response, and recovery phases of a weather-related emergency. The process also identified that EM decision-making prior to and during hazardous weather centers on the communication of critical weather information to Decision Makers and on the coordination of resources.

EMs in our study take into account a number of influential factors when determining what information to access and communicate including their perceived needs for weather information over time and across space along with perceptions of risk during weather events. Individual perceptions of risk were shown to be further influenced by an EM's previous experience and their confidence and trust in the source(s) of weather information.

Figures 5, 6, and 7 (embedded within this report) emphasize especially well the broad temporal and spatial variation EMs and other stakeholders exhibit prior to, during, and after hazardous weather. Figure 5 in particular shows how the coordination of resources along with the acquisition and communication of weather information takes place and also illustrates the range of actors involved during a specific tropical storm event in central Texas in the summer of 2010, the

range of coordinated activities that took place, and the different ways that interaction between partners occurred.

Figure 6 demonstrates the varying and unique continuums of time for information acquisition and communication that existed for stakeholders during a winter storm event in western Missouri in early 2011. This Figure shows that while all stakeholders began to pay attention to the approaching hazardous weather system at approximately the same time, each demonstrated unique communication and decision-making patterns during and after the event. Moreover, the Figure clearly illustrates that EMs pay attention to approaching weather patterns prior to the issuance of an official storm watch, storm warning, or blizzard warning, and prior to communication made by TV meteorologists, typically days in advance of the actual occurrence of hazardous weather.

Figure 7 illustrates that each stakeholder has very specific jurisdictional boundaries he or she adheres to, yet our research shows that these boundaries are oftentimes fluid and determine only to a certain extent the spatial range for information that is accessed and how broadly this information is communicated with partners.

Altogether, Figures 5, 6, and 7 illustrate the complexity of the local situation. The examples highlight that each stakeholder individually *chooses* to acquire and communicate specific pieces of information given the timing and nature of the event, as well as individually *chooses* to pay attention to weather and communicate with different groups of partners in varying regions or areas, thus emphasizing the need for IHIS to address the individualistic nature of information acquisition and communication during hazardous weather events.

Stakeholders face several challenges on a day-to-day basis, challenges that can become amplified during hazardous weather. For EMs, these challenges include information overload, limited access and availability to weather information, the difficulty imposed by multiple simultaneously occurring weather hazards, competing operational requirements in Offices of Emergency Management (OEMs), the importance of accuracy and the fear of financial consequences, and lastly, uncertainty regarding when a severe event will develop, the location of precipitation, the amount of precipitation, and the degree of impacts associated with a severe weather event.

Spinney's 14-month research effort with EMs and other stakeholders in the emergency management process was an important first step for enhancing the development, usability, and functionality of IHIS. SSWIM hopes to continue to work in partnership with GSD: by coordinating and carrying out experiments at the newly developed onsite testbed at NOAA; by deepening the current study and returning to OEMs in central Texas and western Missouri/eastern Kansas; by broadening the current study to include stakeholders from other regions who experience a range of hazards into the process of helping to build effective new weather forecasting software, for example, the NWS, emergency management, and flood warning and flood control; and by co-developing and carrying out a formal training effort designed for EMs and other stakeholders with access to IHIS.

SSWIM would like to acknowledge the financial support received from NOAA's Earth Systems Research Laboratory GSD Director's Discretionary Funds and the continued support from Tracy Hansen and her colleagues at the GSD.

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1.0 Introduction

This report is the culmination of a 14-month research study by Social Science Woven into Meteorology (SSWIM) anthropologist, Jennifer Spinney. Spinney conducted ethnographic research with Emergency Managers (EMs) and other partners to understand how they use weather information, their needs and potential uses for weather information, and their decision-making and communication processes across space and time. Specifically*, this study sought to learn how EMs and other stakeholders involved in the emergency management process acquire, display, and integrate weather information during their decision-making process*.

The Integrated Hazard Information Services (IHIS) project is an interdisciplinary effort led by NOAA's Global Systems Division (GSD) to first and foremost integrate into a single program three National Weather Service applications that generate hazardous weather watches, warnings, and advisories: 1) WarnGen, used to create short-fused severe weather warnings; 2) the Graphical Hazards Generator (GHG), used to generate long-fused hazardous weather warnings; and 3) RiverPro, used for creating longer-term river flood warnings. A second goal of the GSD is to create a common web-based user interface for the communication of weather information between the National Weather Service (NWS) and EMs and other partners to enhance two-way communication during hazardous as well as non-hazardous weather.

From conceptual development to operational use, GSD has used a research-to-operations approach inclusive of several partners, most notably social scientists (see Figure 1 below). As GSD software developers began to create new warning tools they recognized early on in conceptual development phase, the need for and value of qualitative research activities to effectively develop IHIS. To this end, SSWIM was contracted to assist with goal two of IHIS: to provide stakeholder input into the development of the web-based user interface.

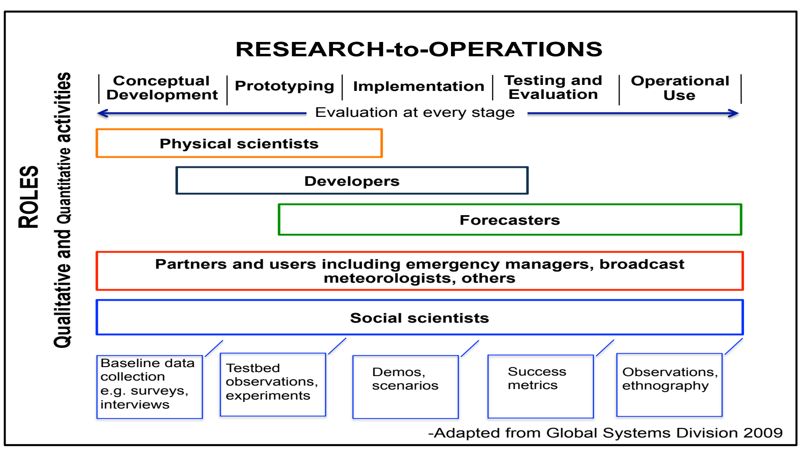

Figure 1. Research to Operations Paradigmatic Approach; adapted from the Global Systems Division (GSD)

Acting as collaborators as part of the IHIS team, the ethnographic findings resulting from the social science research provide GSD with guidance for developing a set of hazard information services based on the expressed needs of users, thereby meeting the highest usability and functionality for the web-based interface.

This report is organized into 10 sections beginning with an introduction and background followed by a description of the methodologies used during the ethnographic research process. The main discussion then begins with a section on stakeholders in the emergency management process. The next section is an explanation of hazards and impacts as described by EMs in our study. Sections on information acquisition and decision-making follow. A description of the challenges associated with and the factors influencing information acquisition and decision-making come next. Embedded within the report and also summarized near the end of the document are findings and recommendations for GSD software developers to consider when developing IHIS. Due to the early stage of development of the IHIS prototype at the time of data collection it is important to note that the prototype was not shown to participants of this study. As a result, the findings are grounded in the data and recommendations are hypothetical proposals based on what the EMs told us. The conclusion is last section and provides an overview of the major findings of our study and includes a sub-section on next steps for continued collaboration with the GSD and for long term SSWIM participation on the IHIS project.

1.1 Background

With funding provided by NOAA Earth Systems Research Laboratory (ESRL) GSD Director's Discretionary Funds, SSWIM social scientists have led the social science component of the IHIS project. Earlier collaboration between GSD and SSWIM included the IHIS I workshop in Boulder, Colorado in October 2009. Five interviews with weather forecasters and software developers in the fall of 2009 helped to bring stakeholder perspectives into that workshop. The initial research conducted by SSWIM established the template found below (Figure 2) showing the differing time and space continuums that user groups are considering during the decision-making process. The initial research highlighted the need to better understand how early notification, long before official warnings are issued, are used by EMs and weather forecasters.

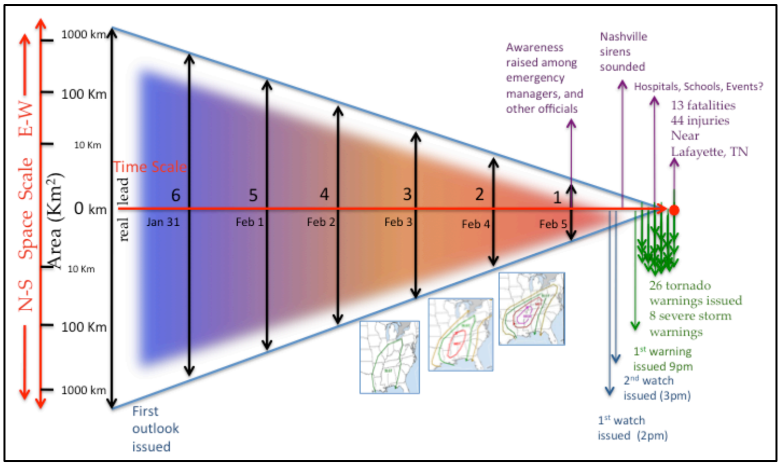

Figure 2. Time-Space Continuum for EMs and Forecasters during the February 5, 2008 tornado in Layfette, TN

Building on the initial interview sample, Spinney continued ethnographic research with EMs and other partners from October 2010 to December 2011.

2.0 Methodology- Bringing ethnographic research to the development of forecast software tools

From October 2010 to March 2011 Spinney spent a total of four weeks carrying out ethnographic research with EMs and other partner groups in central Texas, western Missouri, and eastern Kansas. These field sites were selected because each area experiences many different kinds of weather from flash floods to tropical storm force winds, from fire hazards to ice events, from tornados to winter storms and overland flooding. In addition, each of the regions experience different potentials given differences in population, demographic characteristics, degrees of infrastructure, and the routes and methods used for commerce and trade.

Ethnographic research refers to understanding the ways that people view and live in the world. This ethnographic study of EMs and other stakeholders in the emergency management shows how they process use weather information, both during times of hazardous as well as non-hazardous weather. The data were gathered using qualitative methods such as participant observation, semi-structured interviews, and content analysis.

Participant observation is a methodological tool inherent in cultural anthropology. It is commonly referred to as ‘being there’, or immersing oneself to the greatest degree possible in community life and activities. To this end, Spinney spent time at her field sites watching local weather reports on television (TV) to familiarize herself with who is presenting public weather warning information as well as the content and methods for dissemination across the viewing area. Spinney also spent time informally talking with residents in bookstores, city parks, supermarkets, and other venues to develop a broader perspective for what issues residents find salient. By informally engaging residents in this way, Spinney was able to more accurately contextualize the information presented by EMs and their partners during interviews and discussions.

The results in this report are mostly based on semi-structured interviews were carried out with a total of 35 individuals who are intricately involved in the emergency management process including 23 EMs, five individuals from a River Authority, three TV meteorologists, two NWS representatives, and two Public Information Officers (PIOs). Participants included both males and females representing cities and counties, rural and urban areas, as well as areas with varied degrees of resource availabilities.

Interviews were audio recorded and transcribed. NVivo 8, a qualitative analysis program, was used to facilitate analysis of transcripts of recorded talk. Analysis of interview content focused on identifying the different conceptions of hazardous weather, perceived needs for weather information, methods of communication and decision-making, as well as the differing time and space concerns for EMs and other partners during hazardous weather events. Attributes such as gender, jurisdictional responsibilities, resource availabilities, and length of time in current occupation were explored as possible influences on shared and differential needs and uses for weather information.

In addition to data collection, analysis, and synthesis of the findings, Spinney was involved in a number of activities over the 14 month time period. As the social science representative for the IHIS project, Spinney also:

- **10/2010** Attended the International Association of Emergency Managers' Meeting in San Antonio, TX
- **11/2010** Participated in the Latinos a Salvo workshop in San Marcos, TX
- **01/2011** Presented preliminary findings from ethnographic research at the American Meteorological Society Meeting in Seattle, WA
    - Title: A Study of the Culture and Communication of Weather Information: http://ams.confex.com/ams/91Annual/flvgateway.cgi/id/16909?recordingid=16909
- **05/2011**Presented a poster of preliminary findings at the Integrated Warning Team Workshop in Fargo, ND
- **06/2011** Presented the IHIS project and provided a demonstration of the IHIS prototype to NWS forecasters at the Grand Forks FO in ND
- **08/2011** Presented findings from ethnographic research at the Weather and Society * Integrated Studies Workshop in Boulder, CO
- **09/2011** Attended the IHIS II Workshop and presented overall findings from the ethnographic research process to the GSD and facilitated the participation of two Emergency Managers at the IHIS II Workshop in Boulder, CO
- **09/2010-1/2012** Participated in weekly IHIS conference calls
- Co-presented technical project reviews with other IHIS team members

3.0 Stakeholders within the Emergency Management Process

There are several stakeholders within the Emergency Management Process. The following discussion centers on the viewpoints of 23 EMs included in this study. Where relevant, the viewpoints' of River Authority personnel, TV meteorologists, NWS representatives, and PIOs are also included as it was represented by a total of 12 study participants.

The ethnographic process showed that EMs studied in central Texas, western Missouri, and eastern Kansas can be compared based on these six characteristics:

1. They pay attention to a variety of weather hazards;
2. They represent jurisdictions of various sizes including cities, counties and states all of which experience different degrees of impacts resulting from hazardous weather;
3. They have various levels of time commitment. Some are employed full-time, some part-time and some serve as volunteers;
4. They are of various ages, with differing political beliefs, values, and resource capabilities; and
5. They assess risk differently while acting in accordance with specific occupational rules and regulations.

Time spent with EMs also highlighted the heterogeneity, or diversity that each exhibits when it comes to enacting their roles as emergency managers. The diversity is a result of the multiple operational roles and responsibilities each EM has from day to day. These elements as well as one's occupational background, experience, education, and cultural values inform an EM's worldview[1]. In the context of emergency management, worldview refers to an EM's overall perspective of the field along with their individual approach when preparing and responding to emergency situations.

It is their operational roles and responsibilities that cause EMs to approach their positions in emergency management more broadly, or what they referred to as 'looking at the big picture'. Their daily duties may include paying attention to approaching weather hazards. However, weather represents only a fragment of what they are responsible for. Examples of additional tasks that fall under the realm of responsibilities for EMs include: administration, preparing jurisdictions for festivals, parades, or sporting events, and most importantly, building trusted relationships with partners. As one EM representing an urban central Texas City said, "You build those good working relationships on a sunny day so that on a stormy day you know who your partners are."

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[1] Roncoli, C., K. Ingram, C. Jost and P. Kirshen (2003) "Meteorological Meanings: Farmer's interpretation of seasonal rainfall forecasts in Burkina, Faso" In ***Weather, Climate, Culture***. S. Strauss and B. Orlove (eds). Oxford; New York: Berghahn Books. pp. 181-200.

Another EM in rural western Missouri commented on the importance of relationships within emergency management:

> "In emergency management relationships are a huge part of our job. If we don't have good working relationships with the people we work with- the Public Safety, the response agencies, the media, and the weather service, and FEMA (Federal Emergency Management Agency) and [Missouri] SEMA (State Emergency Management Agency) and all those folks … we won't get much done."

In other words, EMs use time during non-hazardous weather to get to know other representatives within the field of emergency management so that during hazardous weather events preparedness and response operations are fluid and streamlined.

FINDING #1: An eastern Kansas EM representing an urban community feels preparation and response for severe weather would be enhanced if he could see other stakeholders and coordinate with them remotely.

RECOMMENDATION #1: Incorporate webcams as an application in IHIS so stakeholders in the emergency management process can coordinate as though they are 'in the same room'.

Prior to working as EMs, participants in our study had a variety of earlier work experience. Some worked as office administrators, firefighters, police officers, paramedics, or pharmaceutical sales representatives. At the time of interviewing, participant EMs had anywhere from less than one year to more than 20 years of experience in the field of emergency management. For most EMs in our study emergency management is a second career. Each EM became qualified by completing formal training and a professional certification process.

Because of the distinct worldviews held by EMs, each has a distinct set of information acquisition, communication, and decision-making processes that he or she practices during hazardous and non-hazardous weather. These examples of diversity demonstrate a need for the development of a set of hazard information services built upon the individual needs of stakeholders, one that accounts for variability and provides flexibility for EMs to select sets of data and ways of representation that best meet their practical needs in their own contexts.

3.1 Hazards

EMs in central Texas, western Missouri, and eastern Kansas pay attention to a variety of hazards. When asked, many EMs reported their location within either Flash Flood or Tornado Alley, further commenting that these particular weather hazards are the biggest issue for the people living along the I35 corridor in Texas, or near Kansas City, Missouri and Topeka, Kansas in the Midwest, respectively. There are additional weather hazards that EMs in each region pay attention to because of their potential impacts on communities. Table 1 shows a complete list of weather hazards EMs noted paying attention to on a daily or seasonal basis.

Table 1. Hazards EMs in central Texas and western Missouri/eastern Kansas are paying attention to on a daily or seasonal basis

Central Texas	Western Missouri/Eastern Kansas
Flash Flooding	Tornado
Fire	Thunderstorms
Thunderstorms	Large Hail
Ice storms	Straight-line Winds
Heat and High Temperatures	Flash and Overland Flooding
Wind	Snow storms
	Ice storms
	Lightning
	Earthquakes
	Heat and High Temperatures

FINDING #2: The hazards listed above do not always fall under local forecast office (FO) warning criteria. For example, straight line winds may or may not qualify for a warning to be issued, however, because these events can have damaging impacts, EMs in our study have activated their outdoor notification system (sirens) without a wind warning in effect.

RECOMMENDATION #2: Develop an icon in IHIS to communicate siren activation to particular FOs.

3.2 Impacts

Without any prompting during interviews EMs in each region mentioned the negative societal impacts associated with the types of weather conditions listed in Table 1. Conversations with EMs in each region revealed that the potential or realized impacts resulting from hazardous weather are what make each weather hazard so critical. The discussion below centers on the actualized impacts experienced by EMs in central Texas and western Missouri/eastern Kansas. By understanding how these participants in our study have experienced the impacts of weather hazards we are better able to make sense of how each begins paying attention to weather information as well as the different types of weather data sets each selects to prepare for, and respond to, hazardous weather.

3.2a Central Texas

In central Texas, EMs reported that deaths occurred as a result of people driving through low water crossings during flash floods. Ice storms were said to occur rarely in this region. When they do occur ice storms pose significant threat to the international commerce and trade occurring every day on Interstate 35. Other noted impacts of ice storms include strains to city budgets resulting from overtime pay to road workers, as well as school closures that cause much of a city's workforce to stay home with children when they have no alternative child care arrangements. In addition, EMs noted that heat and high temperatures have resulted in drought-like conditions, impacting some areas of central Texas so severely that ranchers were forced to sell numerous cattle. Other EMs in this region reported winds, those that don't necessarily fall under warning criteria, have lead to power outages or in other situations have caused fires to ignite during dry conditions.

3.2b Western Missouri and Eastern Kansas

Similar to central Texas, the types of hazardous weather listed in Table 1 cause EMs in western Missouri and eastern Kansas significant concern because of the impacts that occur as a result of the meteorological conditions. According to several EMs in this region, tornadoes are considered the major hazard because of their potential for causing mass casualties. While tornadoes pose a tremendous threat to life safety, they have also been known to pose a significant threat to ranchers in this region. An EM reported that during a recent tornado in rural western Missouri a barn with horses was severely damaged and some of the animals had to be euthanized.

In addition to the impacts of tornadoes, large hail has produced significant damage to vehicles. In rural agriculturally based communities in Missouri hail has destroyed corn and bean crops, for example. Other EMs reported the severe impacts brought on by straight-line winds. For example, a recent straight-line wind event in an urban western Missouri community caused structural damage to commercial properties along with the destruction of over 300 roofs of residential units.

Flash and overland river flooding was another weather hazard reported as having varying degrees of impact in this region. For instance, in one agriculturally based community an EM commented that overland river flooding caused the most harm to farmers either lost crops or were forced to delay their seeding or to change their crop choice altogether. Another EM representing a rural, western Missouri community noted that in a 2007 overland flooding event, river water rose so much it nearly covered a railway track, thus threatening the operations of a railway responsible for transporting goods and materials across the country. According to this EM, had the swelled river covered the track and caused the operations of the railway to be temporarily shut down this would have cost approximately one million dollars per hour. Another EM from a second rural, western Missouri community reflected on past floods in his area, commenting that people residing in a local trailer park often require water rescues when their neighborhood is inundated. EMs in urban Missouri communities are also concerned by the impacts of overland or flash flooding, namely that residents have on occasion driven through flooded roads and/or have driven around barricades.

The impacts of snow and ice storms also pose a significant threat to EMs in this region. These events have lead to slick roadways, treacherous driving conditions for motorists, closed highways and Interstates, power outages, and additional costs to already extended city budgets. Power outages caused specific concern for one urban Missouri EM because of the increased likelihood of death by freezing and/or the inability of residents to travel for much needed medical supplies or food. The financial burdens to city budgets associated with extreme snow events was mentioned by a rural Missouri EM who noted the increase amount of salt that is required for spreading on roads, the heavy wear and tear on city plows, and the need for additional personnel to handle the increased volume of citizen calls.

The experienced impacts associated with heat and high temperatures in this region are also critical and cause EMs concern. One urban Missouri EM reported residents having developed heat exhaustion as a result of high heat and humidity during the summer months.

Our overall analysis of hazard type as it relates to impacts shows that the impacts resulting from varying types of hazardous weather are more important than the type of hazardous weather itself. This point was reinforced during interviews when nearly all EMs in both regions referred to weather hazards in association with the societal impacts experienced within their respective jurisdictions. Overall we found that the impacts associated with meteorological conditions are the driving force behind what conditions are closely monitored.

4.0 Information Acquisition

EMs in both central Texas and western Missouri/eastern Kansas access multiple types and sources of information to learn about approaching weather hazards during the preparation, response, and recovery phases of a weather-related emergency. As one EM in rural western Missouri said, “I use this information to find out what’s happening here, right now…”. See Appendix B for a list of the different technological sources accessed, the range of information sought, and the rationale behind each acquisition decision for several EMs and others within the Emergency Management Process who participated in this study.

The list shows the importance of NWS products for acquiring information, specifically those issued by local FOs. The list also attempts to distinguish between sources and information initially accessed from sources and information retrieved in addition to, or after a hazardous weather event has begun.

Our data show that EMs add to the sources and types of information acquired as a weather-related emergency progresses from preparation through to recovery phases. For example, in Figure 3, an EM representing an urban central Texas community during a tropical storm event initially accessed multiple sources of information, and then added different sources, such as maps and Police, Fire and EMS calls to gain situational awareness and reroute field crews.

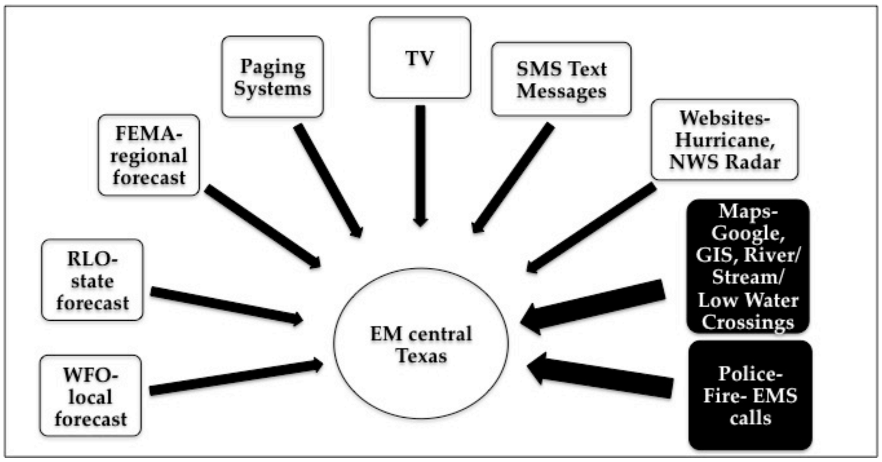

Figure 3. Example of the sources and types of information one EM in central Texas acquired during a tropical storm event

Conversely, in Figure 4, an EM representing an urban, western Missouri community accessed fewer sources and types of information during a thunderstorm event with high winds. In terms of adding sources and types of information, this EM reported using a Power and Light map with coverage into eastern Kansas prior to the event as an indication of what was approaching his jurisdiction. He also used NWS Chat during this phase as a pre-event monitoring tool. Radar, information accessed from pagers, Police, Fire, and EMS calls, as well as rain gauge data were types of data added as the thunderstorm with high winds became an ‘event’. Lastly, this EM reported that HAM Radio Operators are only utilized as a last resort in the event the Emergency Operations Center (EOC) loses electricity and communication capability.

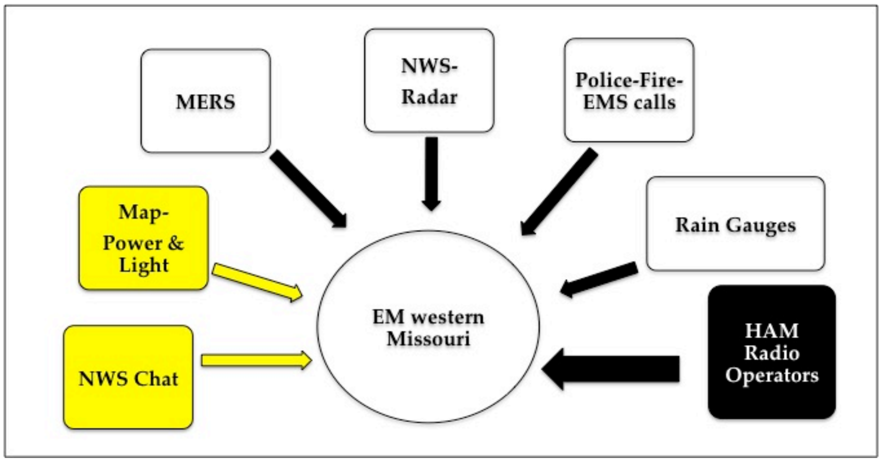

Figure 4. Example of the sources and types of information one EM in western Missouri acquired during a thunderstorm event with high winds

FINDING #3: The comparison shows GSD software developers that EMs access various types of data both sequentially and simultaneously based on their particular needs during any given situation. The examples illustrate the simultaneous need for diverse sets of information from region to region and from hazard to hazard.

RECOMMENDATION #3: Include spatial overlays in IHIS that EMs can selectively choose to view including but not limited to: resource databases, location of water mains and water main breaks, Department of Transportation databases showing type, amount, location and scope of precipitation as well as temperature on roadways, the location of and beds available in shelters, GPS enabled spotter networks, location of and beds available in Hospitals, location of schools and restaurants, FOs' radar and river gauges, and sports complexes.

5.0 Decision Making

Emergency Managers make decisions on a daily basis that may or may not be directly related to weather and approaching weather hazards. The decisions EMs make during hazardous weather center on the communication of critical weather information and coordination of resources over space and time. Our data show that EMs rarely considered themselves *the* Decision Maker during hazardous weather events:

> "My job is not to make decisions, my job is to make sure those decisions are made"
> – Urban-based western Missouri EM

> "We make recommendations, we don't make decisions"
> – Urban-based central Texas EM

Instead, EMs often see their role as conduits of information. They provide information and make recommendations to the Decision Makers during hazardous weather events to ensure that these people have the necessary details to make informed decisions. In our study, Decision Maker refers to City Managers, County Judges, or heads of Departments and Companies such as Public Works, Road and Bridge, and Power and Light.

5.1 Communication of Weather Information

Similar to information acquisition, the communication of weather information largely depends on the approaching weather system. EMs individually determine to whom, what, when, how, and how frequently hazardous weather information is communicated.

Stakeholders have differing, targeted audiences for communicating weather information. An EM in central Texas, for example, contacts different partners depending on what the particular situation calls for (see Table 2 below).

Table 2. Communication with Partners by Hazard Type

PARTNER	HAZARD TYPE		
	Flood	Ice	Shelter
Flood Early Warning System (FEWS) Engineers	X		
Public Works Crews	X	X	
Street & Bridge Crews	X	X	
Texas Department of Transportation (DOT)	X	X	
Schools			X
American Red Cross			X

Another EM in Missouri noted that during a high wind or cold snap he talks regularly with the Power and Light Company and during a drought he calls the Water Company.

EMs use discretion when processing the weather information they receive, individually determining if and how the content of information acquired will be communicated with partners. Once EMs decide that communication of weather information is warranted it can be cut and pasted or transformed and redelivered. For instance, an EM in rural western Missouri cuts and pastes the map from a NWS graphic cast and combines this with the text from Hazardous Weather Outlooks (HWOs).

Another EM representing a rural western Missouri community commented on how he transforms weather information from his local NWS website:

> "I take that information, because a lot of people don't necessarily understand it … and I condense it down and put it in a common sense language that our folks will understand…"

and then followed this statement with whom he communicates the weather information to:

> "… I send that out by email to a … list, and it's got anything from our Housing Authority, all of our nursing homes, our school district, Mayors, past Mayors, EM folks in the 4-county area, our staff here at the Police Department, the Directors at the City level- there are probably 80-100 people on that email list."

From the perspective of a TV meteorologist in an urban central Texas city who broadcasts weather information on-air, it is important to ensure the content of the information includes "something [people can] hang their hat on…give them something to make them…[make] an intelligent decision."

This TV meteorologist also selectively chooses what is communicated on-air. Primarily determined by the severity of the imminent threat, this stakeholder reported: "…by necessity…[you] sort of have to humanly start load-shedding and really pay attention to where things are happening." In this sense, irrespective of general areas receiving rainfall this TV meteorologist focuses the content of his on-air communication on area(s) most severely affected.

5.2 Coordination of Resources

For the purposes of this study, the coordination of resources refers to the coordination of partners, information, as well as jurisdictional services and infrastructure. Similar to both information acquisition and the communication of weather information, the coordination of resources is also hazard specific. In other words, different hazardous weather situations call for the coordination of different resources. EMs and their partners make decisions regarding coordination at various points in time such as on sunny days when hazardous weather is not occurring, as well as prior to, during, and after the hazardous weather system has passed. Some examples include

- An EM in urban western Missouri facilitates bi-monthly in-person meetings with partners to build and maintain relationships;
- An EM in urban central Texas facilitates weekly in-person meetings with partners to build and maintain relationships;

- Prior to the issuance of a watch, an NWS representative at the Pleasant Hill, MO FO initiates coordination calls with neighboring FOs who may be impacted by the watch;
- An EM in rural western Missouri calls in Storm Spotters to the EOC's Communication Room during a severe storm where the group "chats back and forth trying to coordinate the response";
- An EM in central Texas arranges for the State Department of Transportation and City and County Public Works Departments to co-locate in the EOC during significant ice storms; and
- An EM in rural northwestern Missouri arranges for someone to be in the EOC with her when weather situations 'look tricky', including times prior to an official NWS watch.

Figure 5 (below) is a timeline providing a graphical representation of how the coordination of resources took place prior to, during, and after the June 9, 2010 flood event in New Braunfels, Texas. The illustration shows the range of actors involved, the range of coordinated activities that took place, and the different ways that interaction between partners occurred.

During this event, the Emergency Management Coordinator (EMC) coordinated with the City of New Braunfels (NB) Executive staff, the Fire Chief, Geographic Information Systems (GIS) mappers, Southwest Texas Regional Advisory Council (STRAC) representatives, and the area's Regional Liaison Officer (RLO). Coordinated activities such as activating the EOC, arranging for PIOs, GIS mappers and Operations Chief to co-locate in the EOC, requesting aid from the RLO, requesting rescue boats from STRAC, and coordinating debris removal took place prior to the peak of the storm and continued after the rain had concluded. Coordination took place via door-to-door interaction, email correspondence, the City's Emergency Notification System (ENS), and telephone requests.

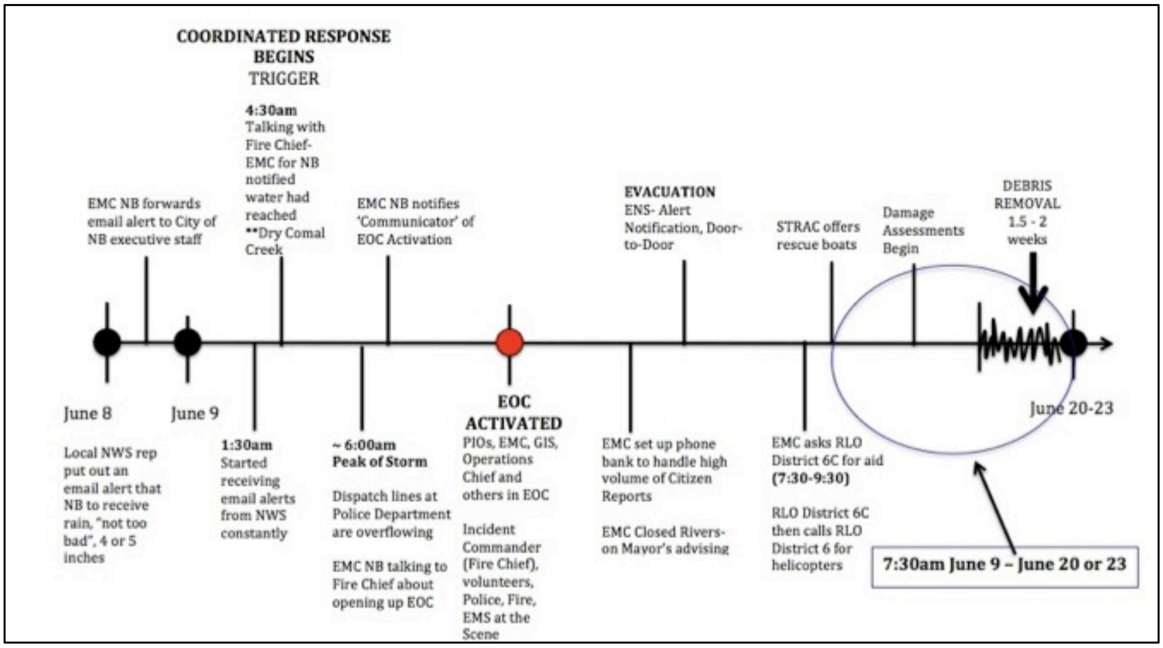

Figure 5. Timeline depicting the coordination of resources prior to, during, and after the June 9, 2010 flood event in New Braunfels, Texas

6.0 Factors influencing Acquisition and Communication of Information

EMs use judgment when accessing weather information. Each EM takes into account a number of influential factors when determining the information to access and communicate such as their individual needs over time and across space, perceptions of risk, previous experience, as well as confidence and trust in the source(s) of weather information.

6.1 Perceived Needs for Weather Information

The types of weather information accessed, the frequency with which they are accessed, plus the communication and coordination actions taken are based upon each particular EM's perceived needs in any given weather-related situation. One urban-based, western Missouri EM said, "on all events we'll kind of pick and choose [our] favorite [information sources] of what [we] think is best".

The nature of the weather event is an influential element when it comes to EMs' perceived needs for weather information. For example, short fused, long fused, and hydrological events take place on various time scales, influencing the amount of time EMs have to acquire information about the approaching weather systems. Furthermore, the differing degrees of threat or risk that each EM perceives influences the time each *chooses* to pay attention to the approaching weather system. EMs indicated that when their perceptions of threat are elevated they pay attention to weather intermittently, for varied durations, as it travels toward their jurisdiction.

Seasonal changes establish the likelihood for different types of weather events to develop as well, influencing EMs' perceptions for what types of weather information they need. For this reason, at different times of the year EMs pay attention to the possibility of different hazardous weather systems and access differing types of information accordingly. For instance:

- During severe weather season an EM in central Texas pays attention to tornadoes and wind shear more than he considers flooding potential.
- During spring and summer months an EM from western Missouri watches for tornadoes and severe thunderstorms and during winter months the same EM watches for blizzards and snow.
- A rural Missouri EM watches for severe weather and winter weather year round, but only adds hydrological products in the spring.

While the nature of the hazard and perception of threat are common factors influencing when and why weather information is accessed, forecasters, TV meteorologists, and EMs are temporally heterogeneous when it comes to communicating weather information, individually choosing when and how frequently information is shared. Forecasters and TV meteorologists in particular are responsible for informing the public with the most current and potentially hazardous weather information and because of this will focus their time on the most imminent threats. For these stakeholders, who must adhere to institutional rules for communicating about approaching hazardous weather systems, information is acquired at the first indication of hazardous weather, however, distant weather systems are simply watched while emphasis is placed on communicating the potential for immediate danger to the public. This differs from EMs who commonly begin communicating with their partners at the first indication of an approaching hazardous weather system. Overall, the timelines for communicating weather information are different for different stakeholders.

Figure 6 (below) provides a good example of the ranges of time that forecasters, a TV meteorologist, and an EM initiated and concluded communicating the threat for hazardous weather during a January 27-February 6, 2011 snow event in western Missouri. In this case, where the snow fell over a matter of hours (Day 6), varying sequences and continuums of time for information acquisition and communication existed for each stakeholder. The diagram shows that an EM, forecasters at the Pleasant Hill, MO FO, and the TV meteorologist begin paying attention to the possibility of hazardous weather at approximately the same time (Day 1). The EM, however, begins communicating with partners at the first indication of an oncoming storm (Day 1), whereas forecasters elevate their communication of threat with a 'watch' two days later (Day 3), and a TV meteorologist begins reporting the event on-air three days after the first sign that hazardous weather was suspected (Day 4).

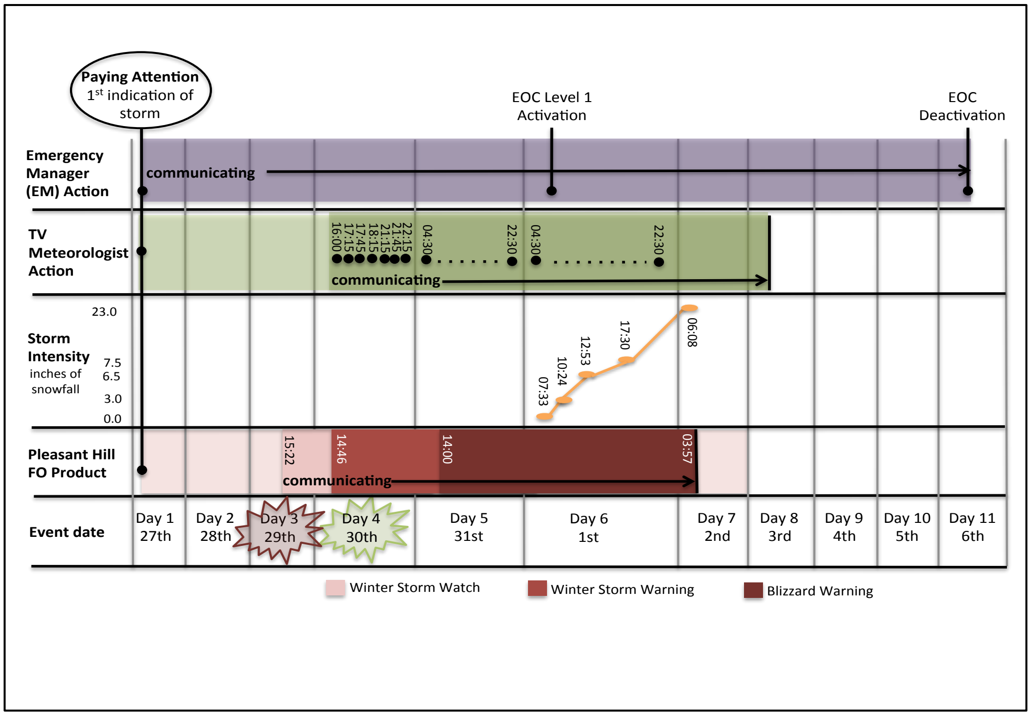

Figure 6. Ranges of time that Forecasters, a TV meteorologist, and an EM initiated and concluded communicating the threat for hazardous weather during the January 27-February 6, 2011 snow event in western Missouri

FINDING #4: EMs pay attention prior to the Pleasant Hill, MO FO's issuance of an official storm watch, storm warning, or blizzard warning, and are typically paying attention days in advance of the actual occurrence of hazardous weather.

RECOMMENDATION #4: Incorporate into the IHIS temporal display additional NWS products including but not limited to: Storm Prediction Center convective outlooks and watches, local FO HWOs and Area Forecast Discussions (AFDs), and products issued by neighboring FOs for areas at the initial part of the storm track. For specific tropical storms and hurricanes include weather information from the time the system touches down in the Gulf Coast (5 days out).

FINDING #5a: EMs pay attention prior to communication made by the NWS and the TV meteorologist.

RECOMMENDATION #5a: Incorporate into IHIS an area where NWS representatives and TV meteorologists have access to and can view an EM initiated impacts-based catalogue outlining the potential impacts associated with certain events.

FINDING #5b: Communication for all stakeholders takes place prior to the initiation of and after the conclusion of snowfall.

FINDING #5c: EMs communicate impacts-based information regarding the snow event three to four days after the forecasters at the Pleasant Hill, MO FO and the TV meteorologist have discontinued communicating to the public about the event.

RECOMMENDATION #5b/c: Incorporate into IHIS a communication mechanism so that stakeholders can remain apprised of each other's actions prior to and after the occurrence of precipitation.

Spatial range also influences EMs' and other stakeholders' perceived needs for weather information and communication during hazardous weather events. Our data show that this factor plays a critical role in determining the likelihood for EMs, forecasters, and TV meteorologists to acquire and communicate hazardous weather information.

EMs, forecasters, and TV meteorologists all exhibit a wide and varying spatial range for the weather information they acquire and communicate. Each stakeholder has very specific jurisdictional boundaries he or she adheres to for decision-making about the coordination of resources. The boundaries determine only to a certain extent, however, the spatial range for information that is accessed and how broadly this information is shared with partners. As an example, Figure 7 (below) illustrates the diverse and at times overlapping boundaries for forecasters at the Pleasant Hill, MO FO (shown in red), a Kansas City TV meteorologist (shown in green) and an EM based in a rural, western Missouri community (shown in purple).

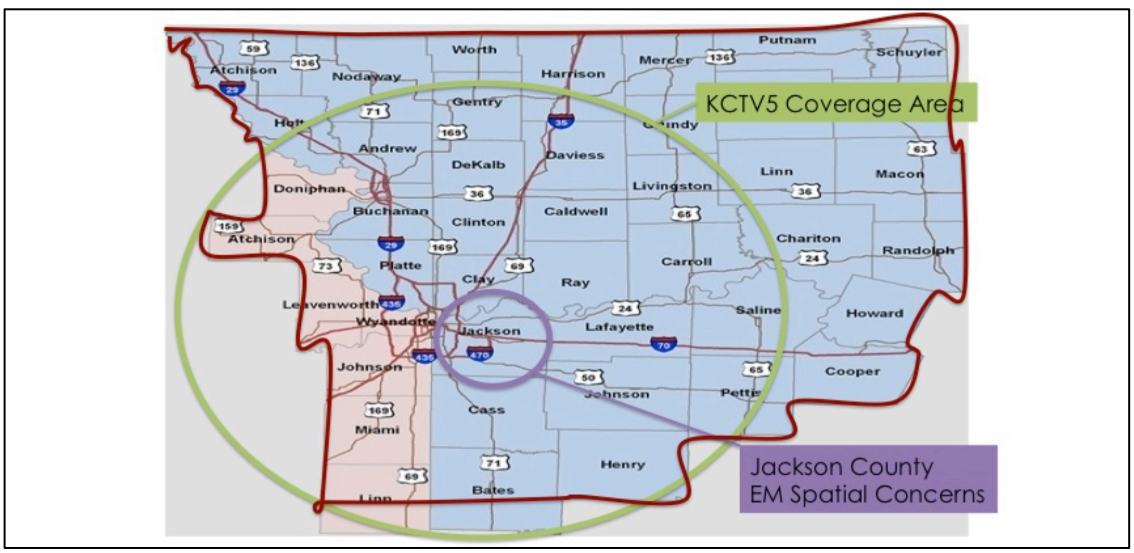

Figure 7. Jurisdictional boundaries for forecasters at the Pleasant Hill, MO FO (red), a Kansas City TV meteorologist (green), and an EM based in rural, western Missouri (purple)

In particular, the graphic shows how the County Warning Area (CWA), or the forecasters' area of jurisdiction includes 44 counties and is much larger than that of the TV network coverage area, and larger still than that of the Jackson County EM's area of jurisdiction.

Despite the distinct spatial boundaries representing each stakeholder's areas of jurisdiction, as individuals, EMs in our study look at developing weather patterns within *as well as* beyond their immediate area of jurisdiction to learn about approaching hazards. Most often EMs reported paying attention to areas west of their jurisdiction, however, one EM based in urban Travis County, Texas included a seasonal element to the areas he perceived important: "I want the [warnings for] Travis and then I want … the southeast counties where we get a lot of summer stuff, and then I want northeast counties where we get the winter stuff from."

Similarly, an EM based in rural western Missouri pays attention to flooding potential in his community by way of accessing hydrologic information within and beyond his immediate area of jurisdiction. For instance, he watches for changes in the Missouri and Mississippi Rivers and also pays attention to river gauges located north and northeast of his jurisdiction because he is concerned that changes in these main rivers and their tributaries could cause the rivers in his area of jurisdiction to rise, thereby increasing the flooding potential.

In addition to information acquisition across space, EMs, forecasters, and TV meteorologists reported communicating with partners well beyond their areas of jurisdiction about the possibility for hazardous weather. EMs said they call EMs in neighboring counties or cities, forecasters said they call other forecasters at neighboring FOs, and participants representing all three groups confirmed logging onto neighboring FO chat rooms on NWS Chat to communicate with each other about the likelihood for severe weather in their immediate areas. The temporal and spatial examples above show the complexity of the local situation and also demonstrate that each EM, forecaster, and TV meteorologist *chooses* to pay attention to specific regions or areas, thus emphasizing the individualistic nature of information acquisition and communication.

FINDING #6a: Jurisdictional boundaries are fluid when it comes to acquiring and communicating weather information. Rather than confining their acquisition of information to warnings or gauges found within their jurisdiction, EMs demonstrate a broad spatial scope for learning about the possibility of approaching weather hazards.

FINDING #6b: EMs, forecasters, and TV meteorologists communicate with partners across jurisdictional boundaries and their choice of partners depends on local conditions and particular sets of information requirements.

RECOMMENDATION #6a/b: Include in IHIS's 'zoom out' feature a regional spatial display with adequate resolution where icons in pre-selected locations could (when hovered over or clicked) inform the EM of current weather conditions, current NWS products in effect, the names and contact information for NWS representatives, TV meteorologists, and EM representatives in those particular areas.

While stakeholders in the emergency management process exhibit broad temporal and spatial scopes for acquiring weather information and communicating with their partners about the possibility for hazardous weather, each has very specific jurisdictional boundaries they adhere to when making decisions about the coordination of resources. Table 3 (below) highlights the point by showing how during a tropical storm event EMs and River Authority representatives located in an urban Central Texas city make decisions about coordination that are relevant to their specific operational roles. Specifically city based EMs coordinate crews and barricades *within the city*, regional EMs coordinate with partners *along the coast* about evacuation and the need for buses and ambulances, and the City River Authority representatives coordinate with field crews about dam structures they are responsible for maintaining *within particular watersheds*.

Table 3. Decision-Making by EMs and River Authority in an urban central Texas city during Tropical Storm Hermine in September 2010.

Who	Sources	Show	Decide
San Antonio City EMs	Public Works & TXDot websites	Road closures	How to position crews and barricades
San Antonio Regional EM	Hurricane updates sent via email	Hurricane Track	Call ambulances and buses
	HAM Radio Operators	Ground reports near landfall	
San Antonio River Authority (SARA)	Weather Tap website	Visual updates- radar	Consult with watershed field crews, advise which dam structures require attention
	Rain gauge data	Water collected at streams, rivers, low water crossings	
	NWS website	Forecast & model discussions	

6.2 Perceptions of Risk Prior to and During Hazardous Weather Events

EMs in central Texas and western Missouri/eastern Kansas pay attention to a number of weather hazards because the potential or experienced societal impacts brought on by such conditions elicits heightened perceptions of risk. To fully understand why such weather hazards and their related impacts are perceived as threatening it was necessary to delve deeper into our data and ascertain what it is specifically about these conditions and impacts that amplify perceptions of risk and prompt EMs to begin paying attention to weather information. Our data show that meteorological conditions in combination with geographical and societal factors to be most important when it comes to EMs deciding which hazards pose the greatest risk or threat to their areas of jurisdiction.

As hazardous weather approaches a community, EMs assess the severity of the situation, characterizing the weather first as ‘bad’ or ‘not bad’ followed by a consideration of different factors to determine ‘how bad is bad?’ In doing so, each begins the process of defining for his or her community what weather situation is or is not ‘bad’, problematic or threatening.

As the process of determining whether or not a weather situation is ‘bad’, problematic or threatening continues, EMs answer the impacts-based ‘what-ifs’. For example, what if drivers lose control of their vehicles on the interstate during a snowstorm and become stranded? What if a river floods, inundating a water facility, leaving a community without access to water?

The impacts-based ‘what ifs’ each EM attempts to answer coupled with their previous experiences of similar or different types of severe weather as well as their confidence in the source of weather information are important determining factors for eliciting heightened perceptions of risk.

6.2a *Previous experience*

Previous experience has taught the 23 EMs in our study that meteorological factors such as storm intensity and spontaneity of the system influence the degree of severity associated with each weather event. The time of day and the day of the week also contribute to the degree of harmful and dangerous impacts associated with each weather event, thus contributing to participant EMs’ understanding of the potential negative societal impacts or the ‘how bad is bad’ factor, and ultimately assisting them in their assessment of how risky or threatening the event could be.

At least one-third of the EMs who participated in our study commented that when a particular threshold is crossed during a weather event their desire to access weather information increases, communication of that information increases and coordination between and among partners begins to focus on the allocation of crews and the deployment of resources in order to effectively respond to the weather hazard. Different examples of meteorological conditions and thresholds for heightening perceptions of risk include:

- Where EMs are on alert for the possibility of flooding we found the extent, volume, reach, rise, location and spread of water to be influential elements in raising perceptions of risk.

- EMs’ perceptions of risk in San Antonio are amplified when thunderstorm events occur with short lead times, especially those that distribute large volumes of water in a short period of time. These EMs mentioned the effect of topographical changes from one side of the city to the other, and how the spontaneous rainfall combined with the varying geography leads to uncertainty surrounding where fallen rain will collect and spill through causing deadly conditions.

- An EM representing an urban, central Texas community reported that he is prompted to pay closer attention to the weather when the NWS radar shows a line of thunderstorms bowing in the middle.

- In the Midwest where flash and overland river flooding is a concern to EMs, our data show considerable snow fall over the winter, continuous spring rains, ground saturation, reduced drainage resulting from increased construction of impermeable surfaces, and knowledge of aged infrastructure to heighten perceptions of risk and prompt retrieving weather information.

- Where the development of tornadoes is prominent, and the possibility of mass casualties exists, EMs in western Missouri and eastern Kansas exhibited heightened perceptions of risk and are prompted to pay attention to weather on a continuous, seasonal basis because according to one EM, "[tornadoes] can happen any time". One urban Missouri EM relates the uncertainty for when a tornado could come up with the Faith-based population who he considers vulnerable because of their lack of access to weather information during religious services. In addition to having a heightened alertness during 'severe weather season', another rural, Missouri EM is specifically prompted to pay attention to the threat of a tornado when the radar shows yellow, orange, red, purple and/or white images. For this EM, when the radar turns to any of these colors, "it's bad. That's the bad stuff".

- During the winter months, EMs in the Midwest demonstrate heightened perceptions of risk and are prompted to begin paying attention to weather when a high volume of snow in a short period of time is expected to fall, or when ice is included in the forecast. The depth of snow elicits greatest concern for EMs because of its potential to settle on buildings thereby diminishing the integrity of the structure. Similarly, wind speed and forecasted snow trigger EMs to pay closer attention because of the potential hazardous impacts drifting and piled snow over roadways causes.

- An EM based in an urban, western Missouri community reported that weather systems bringing about conditions in excess of the following thresholds: one-half inch of ice, approximately two inches of rain an hour, two inches of snowfall, and 80 mile per hour winds, cause him concern.

Additionally, EMs in this particular OEM use “the blue lights on the Power and Light map” as a determining factor to show the potential for damaging winds in their area as well as a threshold for picking up the phone and calling staff and partners to the EOC.

- EMs use the gut reactions of local meteorologists (including TV and those employed in private sector) as thresholds to determine the degree of risk their communities face and how seriously the event may impact their community.

FINDING #7a: Uncertainty and hazardous weather systems that arise suddenly heighten perceptions of risk.

FINDING #7b: The processes of risk assessment and the determination of ‘bad’ weather or ‘bad’ situations are relative to each particular EM. ‘Bad’ is a term that is defined locally, and may not always correspond equally to NWS assessment of threatening situations.

RECOMMENDATION #7a/b: Incorporate into IHIS spatial overlays of CWAs and within each CWA have EM icons (representing each city or county) that when hovered over will list each EM’s individual risk thresholds. Forecasters can use these thresholds to determine if, when, and how communication should take place with EMs.

6.2b Confidence and Trust in the Source of Weather Information

EMs’ perceptions of risk and their resultant decisions to act, both prior to and during hazardous weather events, is influenced by the degree of trust and confidence each has in the source of weather information. In addition to technological sources for weather information, EMs are often provided with similar information and confirmation of conditions by trusted ‘partners’ in the emergency management process. It is because of the relationships EMs have built over time with partner groups that when ‘bad’ or problematic weather is approaching and the EM or partner notifies one or the other, each will react differently than if somebody unknown to him or her cites the same information. The rapport that is developed between and among EMs and partners- knowing that voice on the other end of the line for example, goes a long way to believing the level of threat associated with the hazardous weather information that is being communicated.

All EMs who participated in our study noted that their local FO is a trusted source for weather information. Moreover, EMs in our study reported having great confidence in the information provided by their local FO. In particular, if and when their local FO considers a weather situation to be hazardous, most EMs shift gears immediately. For example, an urban-based eastern Kansas EM noted “we get a call from [the Warning Coordination Meteorologist at the local FO and] then the priority on everything just shifts." An urban-based western Missouri EM echoed this sentiment when he reported: "[when] we get some kind of heads up…we become more focused on [the weather] and spend more of our attention [on it]."

FINDING #8: Trusted partners, including local FO representatives, are reliable sources for weather information.

RECOMMENDATION #8: Provide trusted partners with access to IHIS, including but not limited to: Public Works, Power and Light Companies, Electricity and Gas Companies, Water Companies, Departments of Transportation, the Flash Flood Coalition in central Texas, the School Safety Consortium in central Texas, TV meteorologists, Faith Based Organizations, Hospitals, Health Departments, Parks and Recreation Departments, private businesses such as Bexar Corporation, Road and Bridge Departments, Fire Departments and Law Enforcement, University EM Departments, the Safe Schools Task Force in western Missouri, HAM Radio Operators, and State Emergency Management Agencies.

7.0 Challenges associated with Information Acquisition and Decision-Making

Analysis of interview data show that information overload, access and availability, the presence of simultaneously occurring weather hazards, competing operational requirements, financial consequences for making the wrong call, and uncertainty are challenges associated with information acquisition and decision-making.

7.1 Information Overload

Information overload is a challenge for the EMs involved in our study. According to one rural-based central Texas EM, having "access to too much information makes acquiring weather information overwhelming and ineffective." This EM further commented that consolidating the information so that multiple sources are available in one location would be beneficial.

7.2 Access & Availability

Our data show that EMs' access and availability to weather information has a great deal to do with their proximity to FOs and urban centers. While forecasters best efforts are to investigate the meteorology of each event and forecast the likelihood for a severe event to occur, a representative of the Pleasant Hill, MO FO commented that providing information about a tornado to EMs in rural areas is more challenging:

> "[Forecasters are] just looking at the meteorology [of each event]…[and not] whether it's in a super rural county that a

> 1000 people live in or whether it's downtown Kansas City, MO. In some ways it may be a little easier to do it in the Kansas City area because if it's during the daylight and there's a tornado risk we're probably going to have one of the biggest helicopters on it at least, if not three of them- we're going to, it's more likely that we are going to get reports and we've got great coverage from the radar right here. If it's in some place on the edges of our radar then the data is not as good, population is more sparse, and it's more likely we're not going to [see or] hear anything about the storm."

Although rural based EMs in our study successfully manage with the limited radar and forecast coverage, this element does influence the methods they use to learn about and respond to approaching weather hazards. In a rural northwestern Missouri community, for example, an EM reported: "A lot of what we use [NWS Chat] for … is [to] talk to [the] Pleasant Hill forecast office because sometimes they don't always see what's coming at us and so we say, "hey, what do you think about what's coming at us in [X] County, Missouri?"

This is opposite to what an urban based EM in western Missouri commented while being interviewed:

> "And I'll be honest, we as the big city, there's a little attitude. I mean, NWS watches for us. They'll call us up and say, "the stadium could have an issue". Quite frankly, the smaller jurisdictions a hundred miles out don't get that kind of service."

These examples show first that EMs located both in close proximity to and more distantly from radar and forecast coverage have different levels of access to and availability of weather information. Second, the examples demonstrate that FOs somewhat rely on information from EMs in rural areas about presently occurring hazardous weather conditions. Lastly, the examples show that with decreasing proximity to a local FO and thus from radar and forecast coverage, the more likely an EM is to initiate contact with partners, including the NWS.

FINDING #9: NWS Chat is an important tool for communicating weather information among and between partners.

RECOMMENDATION #9: Incorporate a Chat feature into IHIS or a mobile option so that all partners in the field have the ability to report into the EOC.

7.3 The presence of simultaneously occurring weather hazards

EMs often deal with multiple hazards simultaneously. These can include multiple weather hazards in the same jurisdiction such as overland river or flash flooding and the presence of other weather systems, such as a tornado; and/or the same weather hazards occurring in different jurisdictions such as flooding, but also the potential for flooding in jurisdictions upstream and downstream. Preparing for and responding to simultaneous hazards strains their ability to effectively manage emergency situations. This reinforces the simultaneous need for multiple data sets across jurisdictional boundaries at any given time when accessing weather information.

7.4 Competing Operational Requirements

Preparing for and responding to weather hazards is only one part of an EM's job. On non-hazardous weather days, or on days leading up to a forecasted hazardous weather event, have, "got a lot of other stuff going on in the office-administrative [tasks], regional meetings…" said one urban-based western Missouri EM. These competing operational requirements influence the degree that EMs are able to allocate each day to monitoring weather conditions.

7.5 Financial Consequences

Calling in extra staff and ordering the deployment of resources, for example, when a weather event doesn't develop into the severe event EMs thought it would be leads to severe financial consequences. Because of this, EMs are especially cautious and depend on reliable, accurate information before 'pulling the [EOC activation] trigger'. According to one EM representing an urban western Missouri City:

> "…accuracy matters…if we pull the trigger and spend a lot of money, and it doesn't happen …we will have a real problem getting [Decision Makers] to pull the trigger the next time when we need it."

7.6 Uncertainty

Uncertainty regarding when a severe event will develop, the location of precipitation, the amount of precipitation, and the degree of impacts associated with a severe weather event challenge the ability for forecasters, TV meteorologists, and EMs to acquire information and make decisions. A forecaster at the Pleasant Hill, MO FO commented on uncertain impacts of hazardous weather events along with additional elements that drive uncertainty up, further challenging decision-making:

> "The impacts are easier to predict and you can pretty much bank on them for the super high end event, but it's the other [in the middle] events … where emergency response

> controls what the actual impacts on people lives are that is a bit of a moving target and it's just more unknown. [For example] … where does two inches of snow stop being a problem, how far away from [a] metro area do you have to get before you just drive around the snow, and what time of day is it occurring, what day of the week is it occurring, is it a holiday, is it the first snow of the year? There's all of these things that complicate or make it more difficult to predict] what the impacts will be."

In an urban eastern Kansas city, an EM echoed the comments made by the Pleasant Hill, MO FO representative above when he discussed the uncertain impacts brought on by the unpredictable nature of secondary streams spilling over in his jurisdiction:

> "Blue River, Turkey Creek, all the little streams and stuff, low-lying spots- those are the things that we really stay awake nights worrying about. …[there are] a lot of car dealers, a lot of strip malls that are along those secondary streams and it could be millions of dollars in losses. …nobody is going to drive into the Missouri River when it's flooded, but they're going to drive into Brush Creek, they're going to drive into these streams- so that's the stuff that we watch."

EMs and other stakeholders reported that increased lead time improves the ability to access information, thus decreasing uncertainty and leading to a more effective, coordinated response during hazardous weather. From this it is evident that lead time is an important determinant of risk and increased lead time decreases uncertainty.

8.0 Summary of IHIS Findings and Recommendations

Below is a summary of the IHIS findings and recommendations embedded within this report.

#	Finding	IHIS Recommendation
1	An eastern Kansas EM representing an urban community feels preparation and response for severe weather would be enhanced if he could see other stakeholders and coordinate with them remotely.	Incorporate webcams as an application in IHIS so stakeholders in the emergency management process can coordinate as though they are 'in the same room'.
2	Not all critical hazards fall under local FO warning criteria. For example, straight line	Develop an icon in IHIS to communicate siren activation to particular FOs.

	winds may or may not qualify for a warning to be issued, however, because these events can have damaging impacts, EMs have activated their outdoor notification system (sirens) prior to or without a wind warning in effect.	
3	EMs access various types of data both sequentially and simultaneously based on their particular needs during any given situation. The examples illustrate the simultaneous need for diverse sets of information from region to region and from hazard to hazard.	Include spatial overlays in IHIS that EMs can selectively choose to view including but not limited to: resource databases, location of water mains and water main breaks, Department of Transportation database showing type, amount, location and scope of precipitation as well as temperature on roadways, the location of and beds available in shelters, GPS enabled spotter networks, location of and beds available in Hospitals, location of schools and restaurants, sports complexes, Public Works information, the National Hurricane Center's hurricane track and ground reports provided by HAM Radio Operators, and data sets from private subscriptions, NWS, and River Authority rain gauges.
4	EMs pay attention prior to the Pleasant Hill, MO FO's issuance of an official storm watch, storm warning, or blizzard warning, and are typically paying attention days in advance of the actual occurrence of hazardous weather.	Incorporate into the IHIS temporal display additional NWS products including but not limited to: Storm Prediction Center convective outlooks and watches, local FO HWOs and Area Forecast Discussions (AFDs), and products issued by neighboring FOs for areas at the initial part of the storm track. For specific tropical storms and hurricanes include weather information from the time the system touches down in the Gulf Coast (5 days out).
5a	EMs pay attention prior to communication made by NWS and the TV meteorologist.	Incorporate into IHIS an area where NWS representatives and TV meteorologists have access to and can view an EM initiated impacts-based catalogue outlining the potential impacts associated with certain events prior to the issuance of official NWS products.
5b	Communication for all stakeholders takes	Incorporate into IHIS a communication

	place prior to the initiation of and after the conclusion of snowfall.	mechanism so that stakeholders can remain apprised of each other's actions prior to and after the occurrence of precipitation.
5c	EMs communicate impacts-based information regarding the snow event three to four days after the forecasters at the Pleasant Hill, MO FO and the TV meteorologist have discontinued communicating to the public about the event.	
6a	Jurisdictional boundaries are fluid when it comes to acquiring and communicating weather information. Rather than confining their acquisition of information to warnings or gauges found within their jurisdiction, EMs demonstrate a broad spatial scope for learning about the possibility of approaching weather hazards.	Include in IHIS's 'zoom out' feature a regional spatial display with adequate resolution where icons in pre-selected locations could (when hovered over or clicked) inform the EM of current weather conditions, current NWS products in effect, the names and contact information for NWS representatives, TV meteorologists, and EM representatives in those particular areas.
6b	EMs, forecasters, and TV meteorologists communicate with partners across jurisdictional boundaries and their choice of partners depends on local conditions and particular sets of information requirements.	
7a	Uncertainty and hazardous weather systems that arise suddenly heighten perceptions of risk.	Incorporate into IHIS spatial overlays of CWAs and within each CWA have EM icons (representing each city or county) that when hovered over will list each EM's individual risk thresholds. Forecasters can use these thresholds to determine if, when, and how communication should take place with EMs.
7b	The processes of risk assessment and the determination of 'bad' weather or 'bad' situations are relative to each particular EM. 'Bad' is a term that is defined locally, and may not always correspond equally to NWS assessment of threatening situations.	
8	Trusted partners, including local FO representatives, are reliable sources for weather information.	Provide trusted partners with access to IHIS, including but not limited to: Public Works, Power and Light Companies, Electricity and Gas Companies, Water Companies, Departments of Transportation, the Flash Flood Coalition in central Texas, the School Safety Consortium in central Texas, TV meteorologists, Faith Based Organizations, Hospitals, Health Departments, Parks and Recreation Departments, private businesses such as

		Bexar Corporation, Road and Bridge Departments, Fire Departments and Law Enforcement, University EM Departments, the Safe Schools Task Force in western Missouri, HAM Radio Operators, and State Emergency Management Agencies.
9	NWS Chat an important tool for communicating weather information among and between partners	Incorporate a Chat feature into IHIS or a mobile option so that all partners in the field have the ability to report into the EOC.

9.0 Conclusions

This ethnographic research study is part of a larger effort to reframe the way IHIS is created and operationalized. The intent is to bring stakeholders actively into the process by enhancing two-way communication among and between NWS, EMs and other partners. Over the past 14 months our research has helped to bring the perspectives of EMs in central Texas and western Missouri/eastern Kansas to GSD's software developers. Analysis of interview data showed the diversity between and among EMs, the variety of hazards each EM is paying attention to, and the importance of partner relationships when EMs are preparing for and responding to hazardous weather events.

A discussion of weather hazards and their societal impacts revealed that EMs' weather information needs are governed by the potential and/or realized impacts associated with the hazardous weather. The research highlighted that EMs access weather information both sequentially and simultaneously based on their particular needs in any given situation. This emphasizes the need for IHIS to be equipped with diverse sets of weather information available to EMs from region to region and for a multitude of hazard and impact types.

The research also revealed that during hazardous weather events EMs rarely consider themselves the "Decision Makers". Instead, the EMs who participated in our study saw their role in decision-making as communicators of weather information and coordinators of resources. Communication and coordination decisions were influenced primarily by an EM's perceived needs for weather information over broad and diverse temporal and spatial ranges along with their individual perceptions of risk.

Figures 5, 6, and 7 emphasized especially well the broad temporal and spatial variation EMs and other stakeholders exhibit prior to, during, and after hazardous weather. Figure 5 in particular showed how the coordination of resources along with the acquisition and communication of weather information takes place and also illustrated the range of actors involved during a specific tropical storm event in central Texas in the summer of 2010, the range of coordinated activities that took place, and the different ways that interaction between partners occurred.

Figure 6 demonstrated the varying and unique continuums of time for information acquisition and communication that existed for stakeholders during a winter storm event in western Missouri in early 2011. This Figure showed that while all stakeholders began to pay attention to the approaching hazardous weather system at approximately the same time, each demonstrated unique communication and decision-making patterns during and after the event. Moreover, the Figure clearly illustrated that EMs pay attention to approaching weather patterns prior to the issuance of an official storm watch, storm warning, or blizzard warning, and prior to communication made by TV meteorologists, typically days in advance of the actual occurrence of hazardous weather.

Figure 7 illustrated that each stakeholder has very specific jurisdictional boundaries he or she adheres to, yet our research found that these boundaries are oftentimes fluid and determine only to a certain extent the spatial range for information that is accessed and how broadly this information is communicated with partners.

Altogether, Figures 5, 6, and 7 illustrated the complexity of the local situation. The examples also highlighted that each stakeholder individually *chooses* to acquire and communicate specific pieces of information given the timing and nature of the event, as well as individually *chooses* to pay attention to weather and communicate with different groups of partners in varying regions or areas, thus emphasizing the need for IHIS to address the individualistic nature of information acquisition and communication during hazardous weather events.

The second major influential factor: individual perceptions of risk, or 'how bad is bad', were further affected by other elements such as an EM's previous experience with hazardous weather as well as their confidence and trust in differing sources of weather information. These findings highlight the importance for IHIS to permit access to multiple trusted partner groups and to include user-defined risk thresholds.

Overall the ethnographic process showed the individualism of EMs and other stakeholders during hazardous weather events, the personal choice each makes to access weather information, the varying methods each chooses to acquire such information, and the discretion each displays when determining the need for and the way in which communication and coordination takes place. The importance of the local situation, the individualistic nature of information acquisition and decision-making, and the broad temporal and spatial ranges that each stakeholder exhibits emphasizes the importance of developing IHIS based on the expressed needs of users.

Our study represents an important contribution for changing the research to operations process from a top-down approach to one that is more end-to-end-to-end and inclusive of the expressed needs of all the stakeholders (see Figure 8 below).

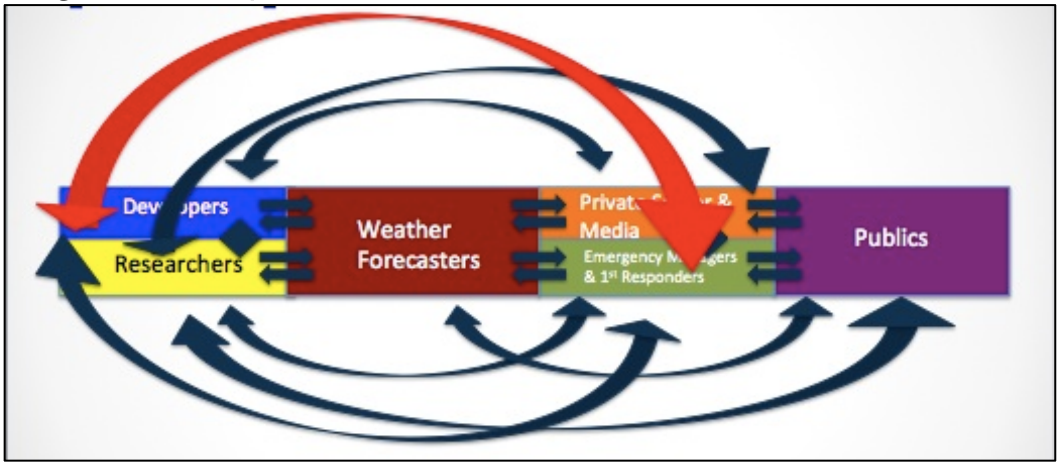

Figure 8. Representation of SSWIM collaboration with GSD; a process that is end-to-end-to-end and inclusive of all stakeholders

SSWIM's collaboration and affiliation with GSD, and the increased understanding our study has provided of EMs' and other stakeholders' perspectives and needs for weather information, specifically confirms the value of our social science contribution and the integral need for continued social science research for improving the usability and functionality of IHIS.

9.1 Next Steps

This 14-month research effort was an important first step for enhancing the development, usability, and functionality of IHIS, however, SSWIM foresees several opportunities for additional collaboration with GSD on the IHIS project.

First SSWIM proposes to work in partnership with GSD, coordinating and carrying out experiments, at the newly developed onsite testbed at NOAA. SSWIM's roles in this effort would be to design ways to embed social science experiments in the new testbed and to build and maintain relationships with local stakeholders and to facilitate the introduction of the IHIS prototype to forecasters, EMs, and TV meteorologists in the Boulder, Colorado area.

Second, SSWIM proposes to deepen the current study and return to the OEMs in central Texas and western Missouri/eastern Kansas to introduce the IHIS prototype to EMs, enhancing its development by requesting EMs' feedback and recommendations for added usability and functionality in iterative fashion so they are included in the design through research and web conference calls.

Third, SSWIM proposes to broaden the current study by visiting stakeholders in other regions who experience a range of weather hazards. Our objective in this effort would be to obtain a more representative sample and to bring communities of stakeholders from NWS, emergency management, flood warning and flood control, planning, transportation, law enforcement, schools and universities, and others into the process of helping to build effective new weather forecasting software.

Fourth, SSWIM proposes to work as partners with GSD to co-develop and carry out a formal training effort designed for EMs and other stakeholders with access to IHIS.

10.0 Acknowledgements

SSWIM acknowledges the financial support received from NOAA Earth Systems Research Laboratory (ESRL) Global Systems Division's (GSD) Director's Discretionary Funds. We would also like to acknowledge the continued support from Tracy Hansen and her colleagues at the GSD for their vision and dedication for bringing social science into the IHIS process.

Appendices

Appendix A. List of Acronyms

AFDs- Area Forecast Discussions
CWA- County Warning Area
EM/EMs- Emergency Manager/Emergency Managers
EMC- Emergency Management Coordinator
EMS- Emergency Medical Services
ENS- Emergency Notification System
EOC- Emergency Operations Center
ESRL- Earth Systems Research Laboratory
FO- Forecast Office
GHG- Graphical Hazards Generator
GIS- Geographic Information Systems
GPS- Global Positioning System
GSD- Global Systems Division
HWOs- Hazardous Weather Outlooks
IHIS- Integrated Hazard Information Services
NOAA- National Oceanic and Atmospheric Administration
NWS- National Weather Service
OEM- Office of Emergency Management
PIOs- Public Information Officers
RLO- Regional Liaison Officer
SSWIM- Social Science Woven into Meteorology
STRAC- Southwest Texas Regional Advisory Council

Appendix B. Sources and Types of information used by EMs and other partners to learn about approaching weather hazards

Who	Region or Site	Sources	Type	Why
EM	Austin, Texas		Traffic Cameras	
		FEWS Website	Stream and River gauges	To see the rise and monitor which roads need to be closed
		Communication with Public Works, River, Street, and Bridge crews		To learn about washed out/impassable and or flooded roads
		Local TV		
		Local NWS Website	Radar	
		WeatherTap		
EM	Williamson County, Texas	Rain gauges		To see the rise and pooling areas; to see how much has fallen in certain areas
		StormPulse Website		To see the track of a hurricane in case of sheltering
		ISP Geeks Website	Radar	To see a compilation of all 15 different radar, water temperatures, airflows
		Wunderground Website		To see the ceiling height of the storm, possible size of hail, rotation, vortex signatures, speed of the storm.
		NOAA Website	Radar	To see what's going on 'a little further out'.
Engineer	San Antonio River Authority	Weather Tap	Radar	Real time, automatic, good spatial coverage
		Local NWS website	Text bulletins, forecasts and model discussions	To read the text provided
			Stream gauges	To see if gauge information agrees with radar
		UNISYS Website	Model information	To look at the graphics
TV Met	Austin, Texas	Email from viewers and County officials		
		Phone calls		

		NWS Chat		
		Scanner	Fire department reports	
EM	Independence, Missouri	SPC	Convective 4-8 day outlooks	Situational Awareness
			Mesoscale discussions	To learn about approaching weather conditions
				Wind shear
TV Met	KC, Missouri	UNISYS Website		Quick- he can look at the next 24 hours split into 4 panels
				Look at multiple data sets at one time
		UCAR Website	Select a time frame and a variable ie. 84 hours out and precipitation	To see weather outlook- ease of access, quick
		NWS	Model Output Statistics	To see the two main computer models along with temperature, cloud, and precipitation forecasts for the next 48 hours- likes the specificity
		SPC		
		Local NWS Website	HWOs	
			AFDs	
		NWS Chat		To see what people are saying about the hazardous weather and its impacts *during severe weather
		Topeka or Springfield NWS Website	Forecast discussions	Because part of the TV station's viewing area is located within these office's CWA *during severe weather
		Newstation weather station	Radar	
			Traffic cameras	Particularly during winter rush hour to see how snow is impacting the motorists on the road
			City cameras	These point to the sky; to see what is going on storm wise Their 'eyes in the sky'
EM	Oak Grove, Missouri	Local NWS Website	HWO	

		Weather oriented radio channel	Weather message	To see information related to the selected watches and warnings
		Storm spotter network		*during severe weather
		NWS Chat		*during severe weather
		MERS (Metropolitan Emergency Radio System)	Summary of HWO broadcast over radio network	To capture the 'quick and dirty' of what the weather will be in the next 24 hours
		Local NWS Website and other weather stations nearby	Radar	Moisture flows, surface data
		USGS Website	Earthquake data	
		NOAA Weather Radio		
		Skywarn		
		TV Weather Channel		
		SPC		To see longer range forecast
EM	Austin, Texas	WeatherTap Website	Map of all weather stations in the US	To see elevation and the occurrence of weather warnings
				To see a big picture view or zoom in to see locally or drag to see what's approaching
		Radio system	Information shared by 10 counties within CAPCOG	
		Local meteorologist with LCRA		To see how he is forecasting the weather
		TV		
		Pagers		
EM	Jackson County, Missouri	NWS Website	Hydrology reports	Particularly in the summer; to see the flooding situation for areas within jurisdiction
				Looks at 5 year history of highest crests, current river level, projected flood stage, what the flood stage is, and what over the levy flood stage is

			Radar	To see amount of rainfall, wind direction, wind velocity, if hail is coming, types of clouds, altitude of clouds, the temperature
		KCScout Website	Traffic cameras	To verify radar, confirm what radar is showing in particular areas within jurisdiction
		TV		
Fire Chief	Independence, MO			Wind speed and direction
				Cloud cover
			Atmospheric pressure	Because the atmospheric pressure can push the smoke from a fire down.
		Wunderground		
EM	Johnson County, KS		Creek gauges	
		NWS web briefings		
		Local NWS Website	Decision Support page/decision matrix	
			Radar	
			Convective Outlooks	
			Weather hazards	
			Flooding hazards	
		County radar		
		KCScout		To see weather on the roads
		Citizen Reports		
		WeatherTap Website	Radar	
EM	Johnson County, MO	NWS Chat		
		Local NWS Website	Radar	To see anything above green; yellow, orange, red, purple, or white.
			HWOs	
			Weather forecasts	
			Decision support information	
		NWS web briefings		
		Weather station at nearby campus (Institute for Rural Emergency Management)		To see the latest actual temperature, wind, high and low, wind speed and direction, dew point,

				humidity, barometer, and rainfall
		TV- mostly Fox and CNN		To see a national picture
TV Met	KC, MO	NCAR Website	Satellite pictures	To gain situational awareness
			Real time weather data	
			Surface maps	Showing temperatures in red, dew points in green, wind arrows
				To see the temperature contrast between regions
		NCAR or Local NWS Website	Radar	Where precipitation is falling currently
		Weather Balloons		To see the temperature profile of the atmosphere, the moisture in the air and winds
		NCEP Website		To see an animation of the models, to see a 16 day outlook.
		IWIN Website	Text data	To pick out the snow, actual ground truth, how much rain or snow has fallen
				To read various forecast discussions from individual forecast offices
				Briefly look at where all of the watches and warnings are
		www.severestudios.com	Chaser feeds	
		Penn State Website		
		StormVista Website	European model	Because it does a good job of forecasting the weather
			Other models	Because it rapidly updates and provides the latest information
EM	Platte County, MO	Local NWS Website	Radar	Direction of the image
				To see the colors
			Decision Support Page	
			HWOs	
			AFDs	
		NWS Website	Hydrology Reports	To see the Missouri

					River data
				National Mosaic	To see base reflectivity
				Surface maps	To see inflows
		GR2 Analyst	Denver’s station	Radar	To see the beginning of the storm as it crosses the front
			Witchita, Tulsa, Topeka, Springfield, St. Louis, Kansas	Radar	Will look at these if there are a lot of colors on the GR2 Analyst radar
				The cross section/3D view	To see how high the clouds are in the atmosphere, the presence of rotation, and the likelihood that rotation will touch the ground
		APRS network		Amateur Radio Operators	See the information that particular weather stations are reporting
					To confirm if rotation meteorologists are seeing in the radar at 10K feet is touching the ground
		Weather station at the Sheriff’s Office			To see the humidity and barometric pressure
					To see dew points in winter
		NWS Chat			To have ground report from other communities
		Cell phone		Mobile.weather.gov	To see KC current conditions
		Citizen reports			
		TV		FOX4	To see national view of weather
				Local station	*If weather becomes severe on the national view then tuning into the local station to learn about local weather
		Mississippi River and Missouri River Forecasting Group			To learn about flood capability
EM	Cameron, MO	GR2 Analyst			To see the base

				reflectivity
				To see storm relative velocity
		StormLab		
		Local NWS Website	HWOs	
			AFDs	
			Special weather statements	
			Watches, warnings, public information statements	
		SPC		
EM	San Antonio, Texas	Local NWS Website	Forecasts	To stage equipment
			Predictions	
			Rainfall, wind	
		National Hurricane Center Website	Maps	To track the hurricane
		State Ems	SMS messages	To learn what part of the state is going to be affected by the weather
		FEMA	Weather briefing	To see a one-day outlook
		Local NWS WCM		
		Rain gauges		
		Public Works Website		*during severe weather, once EOC Activated, pull up the road closure system
		River Stream data		*during severe weather, once EOC Activated, to look at low water crossings
		Google Maps		To look at upcoming weather
		Real time Fire, Police and EMS calls		GIS plotting the location of calls related to weather in order to have a geo-located reference of where severe weather is happening on the ground
EM	Atchison County, MO	NWS Chat		
		NOAA weather radio		
		Cell phone	Integrated weather warning	
EM	Nodaway County, MO	Email from local NWS FO		Provides a head's up of what's approaching
		Email from other		

		EM		
		NWS	Hydrology reports	To see the level of water on the river gauges
		NWS Chat		*These brought in when bad weather is confirmed to be approaching
		Local NWS Website	Radar	*These brought in when bad weather is confirmed to be approaching
		Local NWS WCM	Web briefing	
		Looking out window		
		Local NWS Website	HWOs	Situational awareness
EM	Shawnee County, KS	SPC	Outlooks	*Only when prompted by link in an email or on the local NWS Website
		Local NWS WCM	Email	Provides a head's up of what's approaching
		Local NWS Hydrology reports	Streams and river gauges	
		Local NWS website	Radar	*During an event to see the different colors
Regional EM	San Antonio Texas	National Hurricane Center Website	Storm surge information	To see a graphic of where the storm is headed and where it is plotted to go: for possibility of rain and tornado
		Local NWS Website	Forecasts	Precipitation, wind speed, wind direction, watches
		FEMA	10 slide presentation	During heightened fire and flood risk, looking at updates to red flag watches and flood watches

		3-1-1 Citizen Reports		To learn local weather and impacts
		HAM Radio Operators		To learn local weather and impacts
			Rain gauges	To learn the rate in feet/sec of water flow in City’s rivers and streams