A STUDY OF VISUAL COMMUNICATION:
CYCLONES, CONES, AND CONFUSION

A Thesis

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ABSTRACT

Visuals are at the forefront of providing information in today's society. They are on the front page of newspapers, the evening news, the Internet, and textbooks. They are particularly important in explaining risk and scientific processes such as the intricacies of climate change or the risks of cancer treatments. These visuals do not simply appear in the newspaper or on television without thought but often have distinct objectives or purposes given to them by their designer. The original objective of the graphic may not be achieved, however, if viewers misunderstand or misinterpret the graphic. Misinterpretations of risk visuals, such as hurricane track graphics, may have especially harmful consequences. Therefore, it is critically important to understand how scientific intent translates through visuals to evoke public understanding of science and risk assessment, a process that I call visual validity. To do attain scientific validity, the scientist's objective for the graphic must be known as well as the public's interpretation of the graphic. This thesis looks at the concept of visual validity from the scientist's point of view using a graphic called the "cone of uncertainty," a highly visible hurricane track graphic. Using a grounded theory approach, I conducted 19 in-depth interviews with forecasters and meteorologists from a variety of government and private sector institutions including the National Weather Service, the National Hurricane Center, The Weather Channel, and Weatherbug. I found that the cone of uncertainty has four main message objectives: (1) to communicate uncertainty, (2) to emphasize risks and impacts, (3) to show confidence in the forecast, and lastly, (4) to encourage individuals to listen to their emergency managers. The results suggest that a complicated relationship exists between the design of a visual and its many message objectives. Additionally, two potential characteristics of achieving visual validity emerged out of the data. First, the role of transactional communication between the

designer of a visual and its intended audience appears to play a role in accurate understanding and risk assessment. Second, supplementing a visual with an explanation also appears to play a role in attaining visual validity. These findings have implications for the visual literacy process, as well as the extent to which an individual understands complex science and risk visuals. Future research to seek out additional potential characteristics of the visual validity process will include the public's interpretation of the cone of uncertainty.

BIOGRAPHICAL SKETCH

Gina was a graduate student at Cornell University from 2006 through 2008. While at Cornell, she completed a Masters of Science in Communication. Her research interests include the application of risk, science, and visual communication theories to weather, climate, and natural hazards. Her thesis is part of a larger study focusing on scientific translation through visuals. She is interested in how scientific objectives of a graphic may or may not translate into public understanding of science and accurate risk assessments. In particular, her thesis uses hurricane track graphics as a case study to see how forecasters prioritize and convey weather information for visuals. Her next steps include a study of how the public interprets these graphics followed by an analysis of the forecasters' objectives compared to the public understanding of the graphic.

In addition, Gina is a part-time Communication Research Associate for the American Meteorological Society's (AMS) Policy Program in Washington, D.C., where she conducts research on the effectiveness of hazard and weather messages with a specific focus on visuals. As a full-time employee from 2003-2006, she focused on policy forums as part of the Policy Study Series. Specifically, she worked on the weather and highways study, as well as a policy forum on Hurricane Katrina.

Continuing her passion to combine weather and communication, Gina is an active member of the AMS. She is a member of the Board on Enterprise Communication, as well as a member on the Committee for Forecast Uncertainty. She has also served on the AMS Student Conference Planning committee since 2005. In addition, she was a 2005-2006 Weather and Society*Integrated Studies(WAS*IS) Fellow where she completed a 2-week workshop funded by the National Center for

Atmospheric Research and the United States Weather Research Program. She also participated in the 2004 AMS Summer Policy Colloquium.

Gina has a Bachelors of Science in Environmental Science and Policy from the University of Maryland. While there, she also received a citation in Public Leadership through the James MacGregor Burns Academy of Leadership. In her free time, Gina enjoyed playing her flute in the Cornell Wind Symphony. While living in Maryland, Gina was an active member of Flutes on the Brink, a flute choir that performs through out the Washington, DC Metropolitan area. In 2006, they performed at the National Flute Convention in Pittsburg, PA.

Gina plans to continue her graduate education at the University of Oklahoma (OU). As a PhD student in the Department of Communication at OU, she will focus her attention on risk communication efforts as part of the Center for Risk and Crisis Management. In addition, she will take part in a new initiative to weave the social sciences into the National Weather Center. Her career goals include bridging the field of communication with the weather and hazards community. Following her PhD, she hopes to continue her research career and share her passion by entering academia

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LIST OF ABBREVIATIONS

AMS = American Meteorological Society

FEMA = Federal Emergency Management Agency

NHC = National Hurricane Center

NOAA = National Oceanic and Atmospheric Administration

NWS = National Weather Service

USACE = United States Army Corp of Engineers

CHAPTER 1

INTRODUCTION

Visuals are at the forefront of providing information in today's society. They are on the front page of every newspaper, highlighted on the evening news, all around the Internet, and in every textbook used. They are particularly important in explaining scientific processes and impacts such as the intricacies of climate change or the risks of cancer treatments. These visuals do not simply appear in the newspaper or on TV without thought, but they often have a distinct objective or purpose given to them by their creator. Although visuals may have the goal of conveying a particular message, the person reading or looking at that image also has the power to interpret it in their own way assigning their own purpose or meaning to it. Despite the intended purpose, viewers have the power to maintain or change the objective.

Both the creator and the reader of visuals play an important part in a visual message. This is an especially important fact when using visuals to convey scientific or risk messages. For example, there is growing concern within the hurricane community that decision makers, emergency managers, and the public are misinterpreting critical hazard messages leading to ill-informed decisions. Specifically, a visual representing hurricane risks and possible impacts, called the *cone of uncertainty*, appears to be at the forefront of this confusion (See Image 1 in Appendix B). The cone of uncertainty is a common visual used by hurricane forecasters and broadcast meteorologists to communicate the track of a hurricane and its associated risk and uncertainty. The graphic, as it looks today, first appeared in

2002 through the National Hurricane Center (NHC)[1]. Since then, many other weather organizations created variations of the cone. The active and destructive hurricane seasons of 2004 and 2005 tested the effectiveness of this graphic. In fact, in August of 2004, the cone of uncertainty came under much scrutiny during Hurricane Charley. Focusing on the thin black line indicating the center, people misinterpreted their relation to the storm and subsequently did not take appropriate action (Broad, Leiserowitz, Weinkle, & Steketee, 2007).

After the misinterpretations occurred during the active hurricane season of 2004, the United States Army Corp of Engineers (USACE) conducted a report in response to ill-prepared communities, specifically in response to Hurricane Charley. The report concludes that not only did the public focus too much on this particular graphic, but emergency managers did as well. It states, “Some EMA's [Emergency management agencies] may have focused too much on the forecast track and not adequately considered the error cone or hurricane watches and warnings” (USACE, 2004). Despite the forecaster’s intent for people to understand the uncertainty of the track, people chose to focus on specific aspects of the graphic changing the original objective.

Many hazards, both human and natural in origin, are difficult to communicate effectively through only the use of visual messages. Many times, hazard communication involves explaining intricate processes as well as scientific uncertainty. Forecasters grapple with how to take these complex models and formulate a message that is simple, yet successful for each audience. The problem with hazard messages is that there are multiple audiences with many different needs. For example, emergency managers need detailed information about the forecast track

[1] Graphic archives are not available on private sector weather websites. The only historical analysis that is available is the National Hurricane Center’s graphical archive, which can be found at: http://www.nhc.noaa.gov/pastall.shtml.

to make critical evacuation decisions. First- responders need to determine where to set up their supplies to ensure a fast arrival at the disaster scene. Further, citizens in the impacted areas need to prepare their homes or evacuate to shelters. Each of these audiences has a different level of scientific understanding as well as different potential impacts. In all of these cases, graphics can enhance the message by visually capturing what it means.

In fact, Trumbo (1999, 418) suggests, "Language, visual or verbal, is the key to making science communication possible. Learning the visible languages of science and of visual representation is integral to the process of effective communication." To measure the success of "effective communication," public interpretation of visuals needs further research. As the cone of uncertainty shows, not all visuals are effective.

To explore the effectiveness of visuals, three steps in the visual process warrant more research attention. First, there is the role of the creator of the graphic, which in this example is the role of the forecaster[2]. How do they prioritize and convey risk and scientific uncertainty in their visuals? Do they have a specific objective or message that they want their audience to take away? How do forecasters think about their audience? Second, there is the viewer of the graphic, which as explained above includes many different types of audiences. How do different audiences interpret the meaning of the visual? What message do they take away? How do graphics affect the public's understanding of science and their subsequent risk perception? Lastly, there is the visual itself, the cone of uncertainty. What makes a graphic effective or ineffective in communicating scientific uncertainty and risk? How do small changes

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[2] In this thesis, I will use forecasters and meteorologists to describe scientists. All the interviewees in this sample are trained meteorologists, and at one time or another most have all been forecasters. The difference between the two is small, but important. A forecaster is someone who predicts the weather, whereas a meteorologist is a person who is employed in the field doing research, applications or providing weather services, just to name a few.

in the graphic alter public understanding of science and their subsequent risk perception?

These three steps may lead to a better understanding of how scientific intent translates through visuals to evoke public understanding of science and risk assessment, a process that I like to call visual validity. Researchers often consider the validity of their studies asking themselves if their methodologies accurately measured what they intended to measure. For example, when writing a survey, researchers strategically word questions to ensure that the question is asking what they intend to ask. Why not apply a similar process to visuals? Scientists should also consider whether their visual is presenting what they intend to present. Many visual variables complicate this process, though, allowing the individual reading the graphic to take away many meanings. The original objective of the graphic may not be achieved because viewers may misunderstand or misinterpret the graphic. Researching how scientific intent translates through visuals to evoke public understanding and accurate risk assessments will allow scientists and graphic designers to identify the variables that may interfere with accurate interpretations.

Thesis overview

This thesis will take the first step to look at visual validity by focusing on the scientific intent of visuals concentrating on how scientists prioritize and convey information to create a visual and its associated message. Through interviews with hurricane forecasters, it will focus on hurricane forecasters' perspectives on hurricane track graphics, specifically on the cone of uncertainty. Drawing on literature from a variety of disciplines, this thesis will map out the life of a visual from its creation to its dissemination and suggest potential variables that may cause low visual validity, that is, misinterpretations of the graphic.

Chapter 2 provides the necessary background to understand how the meteorological community functions as well as provides the related science, risk, and visual theory to support these ideas. Chapter 3 discusses the data collection methods and approach used in this research. Chapters 4 through 7 present results, as well as related discussion for individual sections. Chapter 4 focuses on identifying actors involved in designing visuals as well as the audience that receives them. Chapter 5 discusses the value of explanation for high visual validity in risk visuals. Chapter 6 outlines the many message objectives (both scientific and behavioral) that emerged from the results and discusses the potential relationships between these objectives and the graphic. Chapter 7 defines visual framing as it relates to specific examples given by the forecasters and discusses the implications of visual framing for visual validity. Finally, Chapter 8 provides commentary on these findings and discusses the implications on future visual research.

CHAPTER 2

THE LITERATURE REVIEW

Overview

To track the life of a visual, it is important to provide the context in which the visual derives not just from the point of view of the case study, but also why visuals play an important role in communication altogether. To do this, this chapter:

- Outlines the role of visuals in science education and in science learning;
- Argues that meteorologists play an analogous role to science educators, except as it applies to their type of communication
- Provides a discussion of visual literacy and its potential effects on the success of a visual message, specifically where it pertains to risk.
- Begins to discuss the life of a visual.

Throughout this chapter, questions are posed that will be explored and discussed in the following chapters. There is a summary of research questions at the end of this chapter. Additionally, throughout the literature review and results chapters, I refer to many visuals. These visuals are located in Appendix B.

Science Visualizations: How Did Visuals Become the Face of Science

Have you ever seen a science book without graphics? Or, a newspaper without pictures? Graphics, visuals, and pictures all help to tell a story, create a message, or present information. Educators have long known that visuals enhance the learning process. Studies show that visuals with text compared to text alone have an impact on levels of understanding, and further that some people prefer to think spatially rather than to think from verbal cues augmenting the idea that visuals may enhance learning (Rieber, 1994; Halpern, 1996).

Furthermore, students and professionals in scientific disciplines “are characteristically visual-spatial thinkers and communicators” (Mathewson, 1999, 37). It is not surprising, then, that a new field of scientific visualizations emerged out of science disciplines. According to Gordin and Pea (1995), scientific visualization: stands for diverse scientific and social enterprises that include a new type of graphic representation; the creation of dramatic scientific images and their animation; an emerging academic field that combines elements of science, computing, semiotics, and

1.) Usually incorporate massive amounts of data
2.) Aim for verisimilitude with the phenomena they represent
3.) Aim to represent entire phenomena represented holistically by interpolating from data
4.) Use color extensively to encode the magnitude of variables
5.) Animate sequences to show the progression over time
6.) Rely on high-speed computation (e.g. supercomputers)
7.) Usually represent spatial phenomena

Figure 1. Characteristics of Science Visualizations

the visual arts, and the coordination of a suite of advanced technologies to collect, store, process, and image large data sets (249).

This emerging field allows scientists to take complex information and transform what is an abstract or intangible concept into a concrete, tangible visual. There are seven defining characteristics for scientific visualizations as outlined in Figure 1 (Gordin & Pea, 1995, 252).

For example, in relation to vast amounts of data, Image 2 shows a scientific visualization of a potential storm surge for Hurricane Katrina on August 29, 2005 (Van Heerden, 2005). Storm surge models, sometimes known as SLOSH (Sea, Lake, Overland Surges from Hurricanes) models, help to visualize the potential flooding from a rise in ocean level waters. Although this visual is not as popular as the cone of uncertainty graphic, TV meteorologists may use this visual to convey the storm surge risks to the public. To make this graphic, forecasters consider both historical as well as predicted levels of surge for each individual storm. Additionally, the models may include estimates of the storm surge based on its pressure, size, forward speed, track, as well as the wind intensity (National Oceanic and Atmospheric Administration (NOAA, 2006).

This one image shows the complexity of creating scientific visualizations under the defining characteristics (See Figure 1). The model may include a substantial amount of data, especially if it incorporates all of the estimates for pressure, size, forward speed, track, and wind intensity. Secondly, the purpose of the model is to predict the storm surge using the most accurate, up-to-date information for that storm for that particular area. This combines the scientific visualization goals of showing truth while also interpolating the data for future prediction. In addition, the image uses extensive color to differentiate among the potential storm surge heights. The power of scientific visualizations lies in their ability to convey a message while incorporating multiple data points. One can imagine how many graphics forecasters would have to create if scientific visualizations did not exist.

Storm surge visuals only tell part of the hurricane impact story, however. There are complex, technical models to explain wind intensity, track uncertainty, potential inland flooding, and potential areas for tornado watches and warnings. All of these dimensions could potentially use their own scientific visualizations, and indeed, many already have their own visualizations through public, private and academic institutions (See NOAA, 2006; Van Heerden, 2005). Image 2 and other scientific visuals provide a unique and powerful tool to communicate with other disciplines or to non-scientific audiences. It is easy to see why forecasters and other scientists use visuals to assist in communicating their message.

Learning with Visuals

In addition to scientific visualization's powerful communication function, scientific visuals also provide a unique tool for educating the public about hazards. In fact, the use of scientific visualizations is common in training young scientists about complex scientific models. As Gordin and Pea suggest, "SciV [scientific visualizations] can provide a more accessible inscriptional system for students to understand the subject matter, processes, and results of science. Through the use of color and animation, SciVs aim at achieving verisimilitude with the phenomena they represent" (1995, 261). The inclusion of scientific visualizations into curriculums is part of a larger curriculum design called inquiry based learning. Inquiry based learning stems from the idea that the propagation of science is through questioning using current knowledge to explore or gain future knowledge (National Research Council, 2000). Inquiry based learning through scientific visualizations generates inquiry through questioning visuals, but also through creating visuals. The combination of inquiries helps to develop science content understanding in four main ways as expressed by Edelson, Gordin, & Pea (1999, 394).

- Allowing the student to question their knowledge leads them to "confront the boundaries of their knowledge or recognize gaps in that knowledge,"
- "Successfully completing a scientific investigation requires science content knowledge,"
- "Inquiry activities can enable learners to uncover new scientific principles and refine their preexisting understanding of scientific principles in the answers that they construct,"
- "Inquiry activities can give learners the opportunity to apply their scientific understanding in the pursuit of research questions."

The classroom is not the only environment in which inquiry based learning occurs or the only environment in which science content understanding is essential. Emergency managers and the public confront scientific visualizations on a daily basis. Acknowledging the fact that scientific visualizations are on different technical levels, the inquiry process is still quite analogous between students of science and those interpreting science such as emergency managers or the public.

For example, during a hurricane event[3], the public must confront the boundaries of their hurricane knowledge and seek additional information to make informed decisions. Looking at Image 1, New Orleans is in the far west section of the

[3] According to the American Meteorological Society Glossary of Weather and Climate, the definition of a hurricane is "a severe tropical cyclone with maximum 1-minute sustained surface wind speed greater than 64 knots" (Geer, 1996, 114). The definition does not cover the multiple impacts that a hurricane can have on local communities. Hurricane Katrina proves how one event brings a variety of impacts on different communities. In terms of weather impacts, Louisiana mainly had a flood event, whereas Mississippi experienced category 4 strength winds. Thus, a 'hurricane event' includes both the idea that a hurricane according to scientific definitions exists, but also includes the possible social and scientific impacts of the said hurricane.

cone of uncertainty, which means that the center track may travel through this location. The public must follow hurricane forecasts and visuals such as this one. What is this visual telling them and should they be concerned? Those are the questions of concern to the public. Similar to the inquiry process, the public assesses the information they know and the information they need to know. They create questions, and investigate the current science in pursuit of many answers. Should they listen to evacuation orders or take shelter at an emergency operation center? They may gather information from an online weather site, or compare forecasts from their local TV meteorologists. Through their process of inquiry, they gain scientific knowledge regarding hurricanes and the potential impacts on their city or region.

The main difference between students experiencing inquiry based learning and a TV audience experiencing it is that the students have a teacher or a professor present to answer their questions. Further, they have someone present to ensure that they understand the material. The analogous figure for the public is a forecaster. What role do forecaster's play in the public's learning process? Do they also ensure that the public understands the science or the risks present during a hurricane?

Transmission View: No One to Clear the Confusion

Hurricane information comes in a variety of flavors from TV to the newspaper from the NHC to ABC to NBC to CNN to the Weather Channel. Just like students, emergency managers and the public must sift through the "scientific literature", and interpret what the graphics and forecasts mean to them. As Gregory and Miller (1998, 104) suggest, "Media audiences have to do work: they have to understand the visual and verbal languages of media communications and absorb their content, if they choose, into their own set of personal and cultural experiences." What happens when an emergency manager or a member of the public does not understand the science?

What happens when they are unsure of how to interpret the message or the possible impacts from a hurricane?

With the student example, the classroom always has a teacher to respond to the inquiry. TV meteorologists and hurricane specialists are the analogous figure to teachers. Although many forecasters may see themselves as simply givers of weather information, the case can easily be made that TV forecasters are educators of natural hazard information. During a hurricane event, TV meteorologists, hurricane specialists, and many other forecasters are communicating and explaining where the hurricane is most likely to hit, and its potential impacts on that area. Often times, the information is complex and uncertain, which makes it difficult to present. Showing graphics allows the viewing audience to visualize the location of the hurricane as well as allows the forecaster to present visuals for the areas and types of potential impacts.

It is at this point, though, that the analogy breaks down. Students and teachers interact constantly through out a classroom setting. When there is confusion regarding a topic or visual, a student asks the teacher for clarification. Where does clarification enter into the forecaster to public or emergency manager relationship? Like much of science communication, the forecaster to public relationship may follow a transmission view of communication where the forecaster sends a message, and the public simply receives it (Dornan, 1999; Lewenstein, 1995). Forecasters may not be readily available to answer the public's questions, in large part due to the size of the public. Thus, the public must make their own assessment, right or wrong, regarding the uncertainty of the hurricane track and their potential risks. This may explain one of the potential reasons why the public and emergency managers are misinterpreting the cone of uncertainty; there is no one present to clarify their confusion.

Another potential reason that misinterpretations occur is that the public may not be capable of understanding the visuals. According to the 2008 National Science

Foundation's Science and Engineering Indicator studies, citizens in the United States still do not have high awareness about the scientific process, nor do they have the ability to answer simple scientific questions. The report notes that the ability to answer the scientific questions is positively related to formal science education (National Science Board, 2008). Additionally, the deficit model, although widely criticized, suggests that the public lacks the scientific knowledge required to function in a scientific society (Miller, 1998). Scientists must fill the public's knowledge gap. Knowing this and combining it with the public's poor performance on the indicators study, journalists simplify their science communication techniques. Although some meteorologists are in the journalist setting, little is known about how they simplify their communication techniques. Further, the simplification process referred to above is concerning science writing or science reporting. It, however, does not include visuals. If the public has a deficit of knowledge, as the Science and Engineering Indicator Study suggests, then forecasters should potentially simplify their graphics as well to reduce any public confusion.

Visual Literacy: Scientists' versus the Public(s)'

As stated earlier, graphics and visuals provide a unique tool for scientists to communicate about complex issues, such as hazards, with larger audiences. To scientists, these objects represent a common and formal language describing intricate, scientific processes while at the same time allowing further interpretation from lay publics (Lammers & Barbour, 2006). Graphics, then, act as a boundary object. Boundary objects are objects that sit between more than one social world such as that of the forecaster and the public. Boundary objects may "have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star & Griesemer, 1989, p.393).

For Image 1, meteorologists may see the graphic as expressing the 67th percentile of the mean average track error over the last 5 years, whereas the public may see it as a representation of their risk. Neither group is necessarily wrong, but it shows how different audiences use the object for distinctively different purposes. The implications of different audience interpretations may make the difference between evacuating or not, which subsequently may lead to saving lives or not. This not only indicates the power of visuals, but also the influence of individual perceptions.

The problem is science communicators tend to group “the public” into one main audience treating this public as one entity (LaFollette, 1992). This allows scientists to assess one group, the public, and express their scientific goals and objectives through only the communicator’s point of view, the scientist. There is relatively little attention given to the audience’s goals and objectives for the same topic. For example, the needs of emergency managers, homeowners, or first responders are all very different. Although it is impossible to cater to everyone’s needs, researchers suggest evaluating the different types of your audience before creating a message. Most messages are not one size fits all. That is, one message will not satisfy every division of an audience. Using a visual as the message then, one visual will not satisfy every division of an audience either.

In fact, the literature on visual literacy suggests that people bring multiple interpretations to graphics. Defined by Wileman, visual literacy is “the ability to ‘read,’ interpret, and understand information presented in pictorial or graphic images” (Wileman, 1993, 114). Further, Sinatra offers that visual literacy is the “active reconstruction of past visual experience with incoming visual messages to obtain meaning” (Sinatra, 1986, 5). Many people have some prior experience with hurricane graphics whether it is a satellite image seen online, in a newspaper, or viewed on TV. When a new hurricane is approaching, prior knowledge of past visuals combines with the new information presented. Each hurricane event is like a fingerprint. Every hurricane is unique with its own sensitivities, i.e., track behavior and uncertainty, wind speed, size, etc., which requires the processing of new information.

Indeed, all hurricanes are unique, but the graphics to some extent stay the same. For example, the cone always represents the 67% percentile of the 5-year mean average track error. Since the graphic stays relatively the same, the public should have the ability to understand it. As the visual literature shows, though, some images require an individual to have higher analytical abilities, or perhaps spatial abilities in the case of a map. Research shows that there are two modes of map processing, holistic, a gestalt approach of taking in the visual as a whole, versus analytical, an approach that takes in individual features (Hunt, 1974). Kirby suggests that within these two processes there are levels of abilities that people may possess, which changes how they process different types of maps (Kirby, 1994). This has implications on people's varying abilities, then, to 'read' or become visually literate with various maps. This could potentially explain why there are varying interpretations of the cone of uncertainty. The public possesses varying abilities to interpret the graphic.

Although there are varying abilities, everyone is visually literate who has the ability to see. The difference in literacy stems from the meaning that one takes away from the visual. As stated earlier, forecasters may have a distinct purpose, or meaning, that they are trying to convey when designing their graphic. In this sense, the creator of the visual expresses their meaning. However, independent from the forecaster's intent, the audience viewing the visual may create their own distinct meaning despite the intended purpose. Creating meaning from the visual requires many intricate cognitive processes that go beyond the scope of this thesis. However, it is important to understand that these processes are a factor in how people create meaning, and an indication of why there are many different interpretations to the same visual. Knowing this though, forecasters may influence an individual's meaning of the graphic by associating a verbal or written message.

As Duchastel (1978) outlines, there are three purposes for graphics associated with verbal or written messages, the most applicable of which is the explicative role to explain features that are too intricate to describe verbally. Reversing this idea then, readers of visuals may need to see and hear both the graphic and the written or verbal message, as graphics associated with a complicated verbal or written message may lose their meaning without that description. Further, Braden suggests that "as the number of words needed to describe the object increases, so does the need to illustrate it" (1994, 200). Again, reversing this concept, if one is showing a visual representing complex science, for example, then it is possible that the reader must hear the written or verbal message while seeing the image. From this literature, two questions emerge. First, can the cone of uncertainty stand alone, or does it need supporting written or verbal messages? Second, if forecasters suggest that the visual does need a verbal or written explanation, what does this message entail? What are the message objectives? All of this is key to an individual's visual literacy success with the cone of uncertainty, which subsequently affects their public understanding of science and their risk assessment.

In addition to taking away different meanings, the public and emergency managers have different motivations when looking at a hurricane visual. First, members of the public and emergency managers have different responsibility levels. Members of the public have a responsibility to themselves, their family, and their property. For emergency managers, they have a responsibility to protect people and property in a much larger geographic area. The difference in motivation and responsibility may change their approach to visual literacy.

Furthermore, the difference in motivation may also alter the meaning they take away from a visual, and consequently their behavioral responses. Protection motivation theory (PMT) suggests that a hazard must pose a harmful threat as well as a high probability of occurrence to prompt motivation to protect oneself (Rogers, 1975). Building off PMT, Neuwirth, Dunwoody, and Griffin (2000) suggest that the initial threat appraisal of the hazard may affect the next steps of information seeking, and the type of information sought. Differing levels of responsibility as well as their motivation to look at a visual may influence their initial threat appraisal and may or may not prompt them to seek more information. For example, when emergency managers perceive a hurricane threat, understanding visuals becomes critical. However, only having one visual does not provide enough information for them to make accurate decisions. In response to this need, software developers designed a sophisticated program to express the physical threats and uncertainties involved with a hurricane (see Hurrevac, 2006). For emergency managers, their visual meaning of the cone of uncertainty may prompt them to seek out more information; whereas meanings from the public may vary from making decisions based on the cone to seeking additional information.

Information seeking, in addition to gathering more information about a storm, may also include finding ways to alleviate the risk. In fact, behavioral responses to risk messages are stronger when the message includes both the communicated risk as well as the components to efficacy (Witte, 1992). The cone of uncertainty, in its current form, does not present potential behavioral responses, just the risk. Although there are many positive behavioral actions an individual may take after seeing the cone of uncertainty, there are also many decisions that cause harm or injury. If the visual has a corresponding verbal or written message, does that message include communicating positive behavioral actions? Do forecasters think about including the components of efficacy in their messages to the public? Further, what are the appropriate actionable items from looking at the cone of uncertainty?

To complicate the scientist to public relationship further, research shows that there are differences in expert versus lay judgments regarding risks. Some researchers suggest that scientists think about risk quantitatively whereas laypeople think about risks more qualitatively. Scientists tend to associate risk with probability, whereas the public tends to think more about past experiences, or past impacts (Tverskey & Kahneman, 1974; Slovic, 1999). It is clear from the design of Image 1 that forecasters do indeed think more quantitatively. Recall that the white cone represents the 67th percentile of the mean average track error over the last five years. How does this quantitative depiction appeal to the public? Furthermore, when designing visuals, do forecasters account for the fact that the public may think more heuristically, and less quantitatively?

Moreover, when communicating scientific uncertainty, it is particularly important to evaluate the audience's comfort level with uncertainty. Science communicators should not necessarily limit uncertainty information assuming that the public will not understand. Researchers suggest that science communicators should negotiate with the public to determine what level of scientific uncertainty is helpful in a decision-making process (Wynn, 1992). To what extent do forecasters actually negotiate this level with the public?

The varying views, interpretations and motivations of the audience all influence the effectiveness of a graphic. People's prior knowledge affects how they 'read' the visual. Cognitive processes transform the individual's creation of visual meaning. Lastly, differing motivations and responsibilities may alter the message they take away as well as subsequent behavior. Although the creator of graphics may intend a specific meaning, it is clear that the audience plays a powerful role in interpreting graphics. How do forecasters choose to convey information in light of this information? How do they treat multiple audiences, and their subsequent variety of interpretations?

The Life of a Visual

By focusing only on the scientists' role in creating and thinking about visuals, it is not surprising that visual communication can cause a copiousness of confusion. Although the literature suggests that learning with visuals is more effective, the literature also poses a number of ways that scientists may negatively alter the visual process. From a top down design, to not conducting an audience analysis, to not negotiating the level of uncertainty, there are many places where scientists could potentially miss a step. What the literature does not tell us is how scientists think about visuals. Although the science and technology studies literature shows what visuals represent, i.e., the scientific process (Lynch, 2006), or how science graphics become visible through complex instruments (Lynch, 1985), or further, how visuals, specifically graphs, mark the distinctiveness of science (Latour, 1986), the literature tells us very little about how scientists think about communicating visuals with the public. The greater objective of this research is to explore how scientists think about visuals in addition to how they convey and prioritize risk and uncertainty information. What role do visuals play from a scientist perspective? How do they see the many divisions of the public using such a visual?

This research is beginning to track the life of a visual from its conception to its interpretation. Tracking this life will allow a deeper understanding of the steps involved in creating visual validity. Scientists, in this case, forecasters, can help uncover the first piece: how it is that a visual is born. To do this, I developed the following research questions that are grouped into the following four categories.

  - Section 1 - Types of communication and audience analysis
    - What types of communication (transmission or transaction) do forecasters use when communicating with visuals?
    - Who do forecasters identify as their multiple audiences or stakeholders?
    - How do forecasters characterize their audience's scientific abilities?
    - Do forecasters think about visuals from a deficit model of science communication?
- Section 2 – An analysis of visual validity
    - Can the cone of uncertainty stand alone, or does this visual require verbal or written explanation?
    - What are the implications of this for risk visuals as a whole?
- Section 3 – Exploring relationships between a visual and its message objectives
    - What are the communication objectives of the cone of uncertainty?
    - What are the appropriate behavioral responses to the cone of uncertainty?
- Section 4 – Visual framing
    - How do the message and behavioral objectives relate to the actual design of the visual?

This study will examine all of these questions as the first step of a visual's life. Using the cone of uncertainty as a case study offers a closer look into the life of one visual with the additional hope that it will help identify key factors that might apply to other graphics, as well. This study is one phase of a larger area of research that will require many more years of research. Future research is discussed in the discussion sections in chapters 4-7, as well as in the conclusion, Chapter 8. The next chapter focuses on the research methodology.

CHAPTER 3

METHODOLOGY

Overview of Research Approach

Current research in visual communication is primarily atheoretical, which does not provide a substantial foundation from which to pose hypotheses. The purpose of this thesis, then, is to pose testable questions established from a body of qualitative data. The methods used in this study are therefore based on a grounded theory approach. Grounded theory provides a technique to conceptualize categories, explain and understand the data as well as identify patterns (Charmez, 2001, 335). Grounded theory first emerged from Glaser and Strauss (1967) who emphasized the importance of exploratory research, which is summarized as looking at subjects or ideas that we know a limited amount about, and knowing this, allowing the qualitative data to lead the researcher to pose new theories. The qualitative focus of this study is critical to identifying those patterns and further developing theory in the area of science and risk visuals.

I chose one visual, the cone of uncertainty, to begin to understand the creation of a visual from a scientist's perspective. As Patton (2002, 13) so poignantly states, "If you want to know what something means to them [in this case scientists], how it affects them, how they think about it, and what they do about it, you need to ask them questions, find out their experiences, and hear their stories." As one of the goals of this study is to gain insight into how scientists think about visuals, I chose to ask forecasters what the cone of uncertainty means to them, how it has worked for them, and how they think about how their audience interprets it. I designed this study to answer these types of questions within the limits of the case study on the cone of uncertainty.

To answer these questions, I conducted in-depth interviews with meteorologists who have experience creating or communicating about the cone of uncertainty. According to Weiss, qualitative interviews are defined as, "interviews that sacrifice uniformity of questioning to achieve fuller development of information" (1994, 3). As Patton suggests above, it also allows you to hear the participants' experiences and stories. The intent of this study is to gain a fuller understanding of how visuals function from a scientist's perspective, which means gaining insight into how meteorologists think about the cone of uncertainty, a controversial graphic. Conducting interviews is a useful approach for this objective as it allows me to hear the stories of how the graphic originated, and provides me with a fuller understanding of the meaning of this graphic. Visuals may seem like artistic additions to scientific research projects, but as the interviews showed me, they represent much more than a picture.

Data Collection Overview

Question development and interview setup.

The best characterization of the interview protocol is synchronic, as it did not use time to structure the order of the questions. In this case, the best way to achieve coherence, that is to ensure that the data collected flows naturally or fits together, was to organize the questions in a categorical manner. The original protocol focused on three main areas, the history of the cone, the science of the cone, and the objective of the cone. The Cornell University Committee on Human Subjects reviewed the interview design and questions, and determined that the study was exempt from any further review (See Appendix A for the complete set of questions as well as the USHC approved consent form.)

After I conducted a few interviews, I realized that the protocol was falling short of providing the necessary data. As Weiss states, "the risk in synchronic reports is that they will lack a strong conceptual framework, and so will appear to be merely a collection of observations" (1993, 45). The advantage of using a grounded theory approach is I could alter the protocol to ensure that the interviews are capturing the necessary data.

The second protocol included similar questions regarding the cone of uncertainty, but I categorized them in the following four areas: audience analysis, message objectives, behavioral response, and design techniques. Providing categories for the questions gave better structure for the interviews, and also helped with the data analysis discussed later in this chapter. With this revised protocol, the interviews followed a semi structured, tree and branch approach, as outlined by Rubin and Rubin (1994, 159). The order of the questions did not add to the methodological rigor. As long as I covered all the categories in the interview, and the interviewees felt comfortable providing information, then I considered the interviews successful. Often, interviewees shared a story that prompted another discussion. I took notes throughout the interview to make sure off track discussions, that is, related stories that did not specifically answer the question, shifted back on track to ensure an actual answer to the question. In addition, I recorded all of the interviews with permission of the participant. With the help of an undergraduate student, I transcribed all of the interviews.

The 19 interviews ranged in length from 30 minutes to 2 hours and 45 minutes. The average length was about one hour. The longest and shortest interviews warrant further explanation, as the interview context and location played a large role. This is discussed in reference to the validity of the responses later in this chapter.

My intent was to do all interviews one-on-one. However, due to workspace setups, time constraints, or interest in participating, there were a few interviews done in small groups. Two interviews included two participants each, and one interview included three participants.

Interviewee selection.

There are two characteristics of the interviewees that I identified as extremely important. First, they had to have extensive experience in knowing how to design the cone of uncertainty, and second, they had to have extensive experience in communicating to the public (or other key audiences) about the cone of uncertainty. After these two requirements, my goal was to include a wide array of views from the weather field including interviewees from different agencies within the government, private sector companies, and broadcast meteorologists. With all of this in mind, the sampling strategy was purposive in design.

The interviews started with a key informant who is a former director of NOAA's NHC. This interviewee provided names and contacts for other potential interviewees creating a snowball sampling effect. I still used purposive sampling to round out the institutional dimensions of the interviewees. Additionally, with the informant's help and another work colleague's assistance, I also conducted interviews at the NHC in Miami, FL. The NHC was supportive of this research, and provided much assistance in coordinating interview times.

Sample.

In total, there were 19 participants in the study. Eleven participants are employed with the government, though they come from a variety of backgrounds. The government interviewees include employees from the NHC, National Weather Service (NWS) local offices, NWS Headquarters, the National Center for Environmental Prediction, and the Federal Emergency Management Agency (FEMA). Out of the sample, four participants are currently employed as broadcast meteorologists, though it should be noted that the sample includes a total of six experienced broadcast meteorologists. The sample also includes four participants who are currently employed in private sector weather companies, which includes both weather forecasting companies as well as weather graphic companies. The sample includes 17 males and 2 females. Although the weather community has made great strides to encourage more women to enter the field of meteorology, at high levels it is not entirely surprising to see such a low balance between male and females. Because the sample of females is so small, I will refer to the interviewees using male pronouns to disguise the identity of the two females.

Validity and Bias

A closer look at interview locations and their effect on interview responses.

Interviews started in March of 2006 and continued through to January 2007. I conducted most of the interviews at the interviewee's place of employment, but four of the interviewees were conducted at conferences such as the American Meteorological Society's Annual Meeting, and the National Hurricane Conference. Two locations in particular raise questions about the validity of the data. I discuss the implications of these locations in more detail below.

I conducted three out of the four broadcast meteorologist interviews at their respective stations. As with many TV stations, desk space is not always in private offices. Rather, the desks are located among many colleagues at times making it difficult to hear. Further, there were times where the interview was interrupted, as another meteorologist had to record their weather forecast preventing the interviewee from continuing their thought. More importantly, interviews conducted in these locations raise validity concerns.

As Weiss (1994, 148) states, “But while we as interviewers can anticipate that we will be told the truth, we cannot assume that we will be told the whole truth nor the precise truth.” Although the interviewees appeared candid in their responses, other coworkers, colleagues, or even supervisors might have been in the room preventing the interviewee from speaking openly about a particular topic. Although this case study does not seem controversial or in conflict with a more senior colleague, some interviewees expressed frustrations with institutional constraints, abrupt software changes, or marketing pressures. With the possibility of a colleague overhearing these statements, an interviewee may not offer the ‘precise truth,’ impacting the validity of this study.

Another interviewee location of concern was at the NHC. There are two main reasons why the interview conditions may affect the validity of this data: The aftermath of the Bill Proenza term, and the formation of Hurricane Dean. First, the interviews conducted at the NHC took place in August of 2007 just after the then Director of the NHC, Bill Proenza, was asked to leave. In light of the controversy, a study was conducted, and the results uncovered many concerns. A Miami Herald article on May 2, 2008, states,

> Last year’s leadership crisis and staff mutiny at the National Hurricane Center exposed deep-rooted personal and departmental jealousies and frustrations that left many employees thoroughly demoralized, according to a study by independent experts.

> The study found that support personnel described hurricane forecasters as "prima donnas," "elitist" and "arrogant," female employees struggled to be heard, management allowed problems to fester and some "introverted" scientists were intimidated into silence.

The sentiments expressed in this report represent the feelings of the interviewees at the time the interviews were conducted. This turmoil could have undeniably influenced what the interviewees said, and how they stated it.

To complicate the responses at NHC, Hurricane Dean formed in the Atlantic during my visit at NHC. The timing of my visit had been carefully planned with the trip not scheduled until the Atlantic looked clear from storms. However, shortly after my arrival, a tropical low formed off the coast of Africa. Forty-eight hours into the trip, Hurricane Dean formed and the NHC turned into a well-oiled forecasting machine. The issue was that an interview to discuss the cone of uncertainty was clearly not as important as actually designing the cone for a current hurricane, Dean. In addition, after the hurricane formed, the forecasters who had volunteered their time to participate in this study either could not make their interview or had to cut it short due to weather briefings. The longest interview as part of this study was conducted at the NHC, but it was before Hurricane Dean formed.

The concern about all of these interview conditions is their combined effect on the validity of the data. According to Brinberg and McGrath (1982, 12), there are two specific validity concerns. First, they describe a concept called validity as value, which describes the efforts by the researcher to ensure the gathering of truthful or real data. The interviewees in the above conditions were not dishonest, but because of the environment the interview was conducted in, they may not have been wholly candid. With all of the negative press that the NHC received during the Proenza term, the participants may have held back information, or perhaps stated positions that went with 'party lines.' To counter this, I tried to ask many follow up questions including questions focusing on the history of the graphic. Historical discussions allowed me to see if there were any gaps or large changes in their statements, and further allowed me to compare their statements for consistency with the other participants.

The second validity issue concerns the extent to which all the data has the ability for comparison. Called comparison validity (Brinberg and McGrath, 1982, 15), this applies to those interviews that were in the above conditions compared to those that were in private settings. The question raised is whether the data are comparable. Although there are concerns about the openness of all the interviews, the data collected from these interviews were consistent with the privately conducted interviews. Most, if not all, of the questions in the interview protocol could be answered without providing contentious information. If respondents offered contentious information, it was because they felt comfortable doing so, not because they were prompted. Additionally, potentially 'contentious information' often times did not specifically pertain to the discussion of the cone of uncertainty, but rather on institutional constraints.

Further, another concept of validity known as communicative validity suggests that validity requires testing the knowledge claims provided, in this case, through the interviews. Kvale (2002, 313) states, "Valid knowledge is not merely obtained by approximations to a given social reality; it involves a conversation about the social reality: What is a valid observation is decided through the argumentation of the participants in discourse." The social reality happened to include environments that may have restrained the forecaster from providing some information, or as in the NHC case, may have authorized them to give a critical point of view. Neither of these situations, in the view of the researcher, ever jeopardized the data collected.

In addition, any data that included an institutional opinion, which may have been tainted by some of the above situations, were coded as such, and are not included in this particular study. The institutional components are very informative, but unless the data pertained to the research questions at hand, they were not included in this study. To ensure the inclusion of relevant institutional components, I doubled coded certain quotes. For example, some broadcast meteorologists expressed time constraints coming from their management level, which subsequently diminishes their time to spend on graphics. For this example, I doubled coded it under institutional dimensions as well as under design of graphic (a limitation of the graphical design). Another example, which I did not use in this study, is how NBC is owned by another parent company. Some NBC affiliates are making money while others are not. This adds pressure to both the profiting and not profiting stations, but in particular places additional stress on those who do make money to make even more profit. Although this is an interesting dimension, it was not clear from the interview data how this directly related to visuals. I may not have asked the right questions, as I was not expecting to hear such stories. A grounded theory approach often discovers new issues or concerns. These dimensions are important, and I may use them for future research, but I did not use all of these quotes in this thesis.

Additionally, the information presented in all the interviews is generally consistent with one another further indicating their validity. This is particularly true for the discussion of the message objectives for the cone of uncertainty, which is discussed in Chapter 6.

Potential biases from the participants.

When using snowball sampling to find interview participants, the researcher must always consider the biases of the informant as well as the subsequent interview participants. For example, the key informant, a former NHC Director, was very forward about his dislike for the cone of uncertainty. Knowing this, he might have also provided names of potential participants who feel similarly, potentially skewing the data. As is noted in the chapters that follow, another graphic, the wind probability graphic, often came up in discussion possibly indicating the interviewees dislike for the cone, and their fondness for newer probabilistic graphics. Although some interviewees mentioned their aversion for the cone of uncertainty, most admitted that this graphic would continue to play a vital role in communicating about hurricanes. While it is possible that the informant's interviewee suggestions biased the results, the use of purposive sampling of other key hurricane communicators rounded out the sample.

In addition, when I conducted interviews at the NHC, I did not choose who participated in an interview. Rather, a high-level NHC administrator coordinated the interviews based on the employees' forecasting schedule. I briefed the administrator about the project and the types of experiences or backgrounds that were necessary to participate. Once I arrived, the administrator provided names and times of available forecasters.

There are a number of possible concerns with this process. Although work schedules determined who participated, I have no way of knowing if all forecasters who met the criteria (of designing or communicating about the cone) were given an equal opportunity to participate. Further, as stated earlier in this chapter, the office atmosphere at the NHC was tense due to infighting and conflict with a new director. It is possible that the potential participants' behavior, attitudes, or opinions during the NHC's tumultuous time influenced who the administrator chose or perhaps prevented the administrator from choosing them at all because of other institutional constraints, e.g., other superiors not allowing them to participate. Both the administrator's bias as well as the institutional conditions could have biased the interview results.

Although both the key informant and the NHC administrator introduce possible bias into the results, the consistency, and yet diversity, across the interviewees' responses suggest a high level of reliability and validity. Consistency presented itself in areas that seemed appropriate such as the objectives of the cone of uncertainty, or all of the participants' hesitancy to communicate behavioral actions, as discussed in Chapter 6. Diversity presented itself through personal stories, or opinions regarding graphic design. Furthermore, to control for potential biases, interviewees came from a variety of different institutional contexts, i.e., government, private sector weather companies, and broadcast meteorologists. This helped introduce more diversity in interview responses. There are possible biases, but the consistency and diversity of interview responses suggest the reliability and validity of the results.

Potential biases from the researcher.

Prior to graduate studies, I worked professionally for three years full time with the American Meteorological Society (AMS). It was during this time that the United States experienced two of its most active hurricane seasons, 2004 and 2005; the nation witnessed one of the most destructive and costly hurricanes, Hurricane Katrina; and the meteorological community realized that the cone of uncertainty became the focus of a hurricane track mishap with Hurricane Charley. I am passionately involved with hazards from the societal impacts of Katrina to the visual problems of the cone of uncertainty. I admit that there is much passion behind this study to not only further communication research, but also provide insight for the meteorological community as well.

In light of this, it is important to discuss the possible biases that I may bring to this study, and the ways that I controlled for these biases, if possible. According to Weiss, a researcher's bias introduces itself into a study through their presentation, questions, and reactions to questions (1994, 212). Looking at the role of presentation, in order to gain respect from some of the interviewees, I used my insider approach, that is, I explained my work experience with the AMS. When I explained that I am a graduate student at Cornell, I could feel the tension that followed. My interpretation is that they did not want to interview with someone who did not understand meteorology. Knowing this, I always told the interviewees that although I have no formal education in meteorology, my AMS experience provided a considerable overview of the field. Once I mentioned who I worked for, and who I worked with, they immediately perked up. This presentation style made asking follow-up questions rather difficult, as I wanted the participants to state the science for the record. Often times, they assumed I understood the science or the institutional process.

As stated in the section to follow, I had four areas of questions related to the cone of uncertainty, some of which pertained to the technical side of designing the cone. Often times, when interviewees responded, they assumed I knew the entire structure of their institution, or that I understood every technical term they used. Although I have a lot of general knowledge in this area, I simply do not know it all. The integrity of the data depends on gathering full responses without any assumptions of my understanding. As Creswell (2003, 196) suggests, one way to increase the validity of qualitative data is for an author to use rich, thick description. To control for this, then, I asked many follow-up questions to gather a richer description. I soon realized, though, that for some participants, if I said, “I do not understand,” then they became slightly frustrated. On the other hand, many other participants were happy to provide more explanation. In the end, there are parts of a couple of interviews where I do not have full understanding of what they mean. For example, I did not fully understand, even after some explanation, all the different types of track error to design the cone of uncertainty. There are horizontal, vertical and cross track errors. My lack of understanding regarding this type of data, did little to change the integrity of the data.

The third area that Weiss states introduces bias is with the author's response to questions. This was a challenge. Often times, when a participant gave their explanation, I followed up with an unbiased question such as, "Could you tell more?" or "Why is that?" I tried to use very simple follow up questions that would not allow me to introduce my opinion. However, with a topic that I feel so passionately about, I admit that at times follow up questions became more of a discussion with the participant versus an interview. Once I realized that I was in the process of doing this, I would immediately change my language and use words that turned it into a question versus a statement. I would also change my language to reflect, "some people suggest that," versus "I feel that." Having visited New Orleans after Katrina, I feel strongly about societal impacts of hurricanes. Most often, my opinions began to slip out during discussions of Hurricane Charley. As I conducted more interviews, I became much more aware of my biases. I controlled for them as much as I could by changing my language, and writing notes on a pad of paper to remind me to rephrase certain questions.

Reflecting on this, the author of any study bridging two disciplines will come across certain barriers. No one can expect to be an expert in every area. As I conducted more interviews, I learned how to phrase follow-up questions to gather a thicker description, and learned how to rephrase questions to reduce my own bias. Perhaps, if I knew more meteorology, the interview process would be smoother. However, I think there are benefits to being part insider and part outsider to the field. Gathering more data about how the forecasters design the cone is helpful to this study. If I assumed that I knew all about the science, I am certain I would have missed some very informative information. The outsider aspect provided me the opportunity to gather more information, while the insider view granted me more respect from the participants than if I was just a student.

Data analysis

Coding categories.

After transcribing the interviews with the help from an undergraduate student, I initially coded the interviews using Atlas.ti, qualitative coding software. From the beginning of the coding process, I used four specific codes that match the categories used for the interview protocol. The four primary codes include audience analysis, message objectives, behavioral response, and design techniques. From there, the analysis used *in vivo* coding where phrases presented in the sentence became the code (Glaser & Strauss, 1967). Once a number of codes emerged, I grouped or combined the codes, and then used them consistently for the rest of the interviews. In total, there were 52 codes, but only 24 codes had 10 or more quotes associated with them. The other codes were from *in vivo* coding that ended up not being as useful.

After I finished the first round of coding, the second round of coding began, which included recoding the four primary codes from above by hand to develop a better sense of the emergent themes. Once I knew what the emergent themes were, and further developed them with the literature, I started one last round of coding using Atlas.ti. For example, when the coding initially started, coding for message objective was sufficient. After realizing that there were multiple ideas in this one code, I split the code into three parts including uncertainty, impacts/risks, and confidence.

Presentation and Variety of Quotes.

During the writing of the first draft of this thesis, I assigned every interviewee a number. Every time I used a quote in the results section, I also inserted the interviewee's number to ensure a variety of quotes. The reason for this is that inserting the numbers allowed me to ensure that I was including responses from a variety of institutions, as well as from all the interviewees. The numbers are *not* included in the current document. The reason for this is that using the numbers allows the reader to group the quotes and potentially identify who the interviewee is. Where appropriate, the presentation of the quotes includes the interviewee's general institution, that is, government, private sector weather company, or broadcast meteorologist.

This study does not use names, and if possible, does not identify specific institutions. If a quote specifically mentions an institution, I tried to disguise it by inserting "company x." Some quotes, however, were very difficult to disguise the institution, as the wording of the response may give it away. This is why names are also not used. Although many of the participants gave permission to use names, I decided that keeping all sources anonymous increased the integrity of the research. The focus of this research is to further visual communication theory, as well as provide insight into a hazard graphic. The goal is *not* to identify which forecaster likes or dislikes the graphic and why. Additionally, the meteorological community is a tight-knit community. Although I feel that all the quotes used in this study are respectful, it is possible that someone within that community may feel otherwise. To protect my participants, and increase the integrity of this research, I did not use names.

The presentation of the data includes many quote examples as well as supporting evidence and discussion. During the interviews, some participants hinted at other government programs or other news stories that supported their responses. I researched these programs and added this supporting material to the discussion sections of the respective results section. At times, the supporting material is quite extensive, placing the emphasis more on the discussion and less on the quotes. This is not to overshadow the quotes, but to enhance the material presented.

Generalizability

According to Brinberg & McGrath, generalizability is “the degree to which a set of concepts and findings will hold up when extrapolated, or generalized, or extended to materials not yet brought under research inquiry (1982, 12). This study takes a qualitative approach, which only touches the surface of exploring the life of one visual. The data in this study are not generalizable according to the above definition.

There is, however, an alternative description of generalizability known as transferability. This concept applies to the extent to which the results have the ability to ‘transfer’ to different contexts. The difference is the emphasis on the researcher’s opinion of how transferable the results are to other areas of research (Trochim, 2006). Since this is a qualitative study, the results are presented in two parts. First, there are the issues developed from the case study that pertain to the weather community. Secondly, there are theoretical or conceptual questions posed as they emerge from the case study. The questions asked are not presented as facts, but as points for further inquiry. If the results are in the form of questions, then the questions are transferable from the point of view that these questions may have applicability to other visual case studies.

Summary

This chapter provided an overview of the methods used, biases considered, and validity and generalizability of this study. The next four chapters present results and their respective discussions. The first of these, Chapter 4 will discuss the types of communication used in meteorology as well as identify the users of the cone of uncertainty.

CHAPTER 4

TRANSMISSIONS, TRANSACTIONS, AND DEFICITS: THE TYPES OF COMMUNICATION IN METEOROLOGY

Overview

The first step in understanding the life of a visual is to investigate the visual's origins. To do this, this chapter will:

- Explore the institutions that create the cone of uncertainty
- Identify and characterize the receivers of this visual information
- Gain a better understanding of how forecasters communicate with their audience
- Examine if forecasters treat visual messages differently than verbal or written messages

This chapter has three sections that elaborate on the above points. The quotes used to make these points fall under the audience analysis code mentioned in the methods section. Throughout the entire chapter, questions are posed for future research.

Do Meteorologists Follow a Transmission View of Communication with the Public?

Much of the literature on science communication suggests that scientists interact with the public in a transmission view of communication. That is, scientists simply transmit or send their information to the public with limited to no feedback with the public. This chapter shows that the forecasters in this case study follow this same model.

Take for example, a quote from one meteorologist who was answering a question regarding the objective of the cone of uncertainty. This meteorologist gave a non-traditional answer stating, “The whole purpose of a graphic is that you should be able to understand what it is by looking at it.” He continued, “If you’re providing people graphical representations, it should be clear enough that they understand what it means so that they can make a decision about their actions.” The implication is that the forecasters disseminate, or transmit, the information without any mention of interaction with the public.

Another example is more impact focused. A government meteorologist stated, “We produce the meteorology, the impacts, the expected impacts on the infrastructure and on people’s lives. It’s something we can communicate, but they [emergency managers] have the responsibility for protecting when push comes to shove.” Again, there is a message that he will communicate, or transmit, the science, and the associated impacts to the public, but all other decisions and discussions will be made on an individual or a county emergency manager level. Furthermore, if the public has questions regarding evacuations or potential impacts, the meteorologists are sending them to an outside party limiting, severing, or rerouting all feedback from the public.

Yet another example shows how little meteorologists understand their public, despite their outreach efforts and marketing pleas. One broadcast meteorologist stated:

> I never really went out to you know, from the social science perspective, went out to understand my audience because we can broadcast to every single person watching NBC at the same time. If they were all watching Channel 4, my audience is a 9 year old to a 100 year old person, so you know, some are making decisions and some could care less.

It is true that the nature of broadcast meteorology requires communicating to a large and diverse audience, but this suggests that every city, every station audience across the country should be treated equally. It also implies that there is very little audience analysis or interaction further implying a transmission view of communication.

The transmission view of communication is not ideal for many reasons. As stated in the literature view, Gregory and Miller (1998, 104) suggest, "Media audiences have to do work." They must understand, interpret, and retain the information they gather. The problem is that the forecaster has no idea what information that person understood, interpreted or retained. Further, the forecasters are also unaware of whether it is an accurate account of the information, noting that there are a variety of accurate accounts. This leaves the public vulnerable to their potentially inaccurate interpretations, or alternatively, the public will become information seekers in a quest to find answers to their questions or to calm their anxieties. All of this occurs because the current structure does not allow for a feedback loop, which subsequently forces forecasters to follow a transmission view of communication with the viewing audience.

Of potential greater concern is the fact that researchers and public officials know that there are some erroneous interpretations of the cone of uncertainty graphic. Broad et al. (2007) show that news media coverage has a plethora of titles for the graphic. Despite the graphical intent to show the uncertainty of the track of the storm, the graphic has been given names such as the "cone of probability," or "cone of death." These names do not accurately capture the message intent, and potentially may perplex some of the public.

What's more is that not only are media viewers capturing the title wrong, but the USACE's report suggests that the public at large are also misinterpreting the graphical intent, subsequently making poor decisions. The report, completed after the hurricane season of 2004, noted that not only did the public misinterpret the graphic, so too did the emergency managers, those responsible for evacuation orders. This action led to mass evacuation of one community, the Tampa Bay area, and to mass chaos to a community further south, the Port Charlotte area. The USA Today on

August 15, 2004, captured one woman's shock, “"I was surprised it hit here," she sighs, as she pokes through the rubble of her home, salvaging photos of her daughter, son and late husband. "They all said it was going to hit Tampa. Then it turned"” (McCarthy, 2004).

Indeed, this woman is not entirely mistaken. Hurricane forecasters predicted a hit to the Tampa area. Hurricane Charley's eye, or the center of the storm, was projected to hit Tampa, but as the graphic clearly shows in Image 3, the Port Charlotte area was in the cone of uncertainty. Why, then, is there all of this confusion?

Although the answer to that question is beyond the scope of this case study, one potential variable is the fact that forecasters have limited interaction with the public. Following the transmission view of communication may be detrimental to the public's understanding of hurricane uncertainty. There is no one to clear their confusion or answer their questions. Why do forecasters follow this model?

Is There Room for Transactional Communication in Meteorology?

The transmission model is how it appears they communicate, but the more important question is why. To look at this dimension, one must flip the question. Instead of asking how scientists *are* communicating with the public, the focus is now on how scientists *think* they are communicating with their various audiences. Is it simply transmission communication, or does the type of communication depend on the audience?

The interviewees have a diverse audience, but depending on which institution the forecaster belongs to will slightly change the nature of their audience. First, looking at government institutions such as the NWS and the NHC, both of which are under the NOAA, their primary audience is simply everyone. One government interviewee stated, “Any product produced by taxpayer's money goes to everybody all at the same time. I can't just say, "Hey, we have a really good product here, let's just send this to the emergency managers, and military, and not give it to my kids at home and the public.' We can't act like that."

All government products, text or visual, must be available to everyone. With the rise of the Internet, this is now a functional policy, but interestingly enough, prior to the Internet, information was not available to everyone and was transmitted via radio to researchers and broadcast meteorologists. Most people received their weather information from TV broadcast meteorologists. Why, then, does this policy need to be in place now? Is it a flawed policy to treat scientists and the public the same? Can the public understand the same concepts and products that scientists understand? Further, was this a conscience decision to treat everyone the same? Or, could it have been the rise of the Internet that changed how NOAA interacted with all of its taxpaying customers?

What's more, just because information is available on the Internet does not necessarily equate to the "public" receiving the information. With only 68% of Americans with Internet service, this policy still segregates the other 32% of people who do not have access (Central Intelligence Agency, 2008). In fact, one government forecaster recognized this issue by stating, "It is the age of the Internet and the age of technology, but I would survey how many people really have access to these computers." Despite the forecaster's well intentions not to "act like that," NOAA is still in fact weighting their customers differently by those who have the technology, and those who do not.

Further, one government forecaster admitted that not all taxpaying customers receive equal treatment. They claimed:

> No, I would say the audience is what it is. I would say that for this particular graphic, because it's on the web, we know people well beyond the emergency management community will look at it. But, in terms of doing a survey and

> sending it out there, we wanted to make sure the message coming back from the emergency management community wasn't diluted. Look, you can say all of your customers are equal alright, but the emergency manager community is more than a customer to us. They are our partners.

Emergency managers played a large role in all of the interviews, but in particular, emergency managers came out on top of the audience analysis. All of the 19 meteorologists interviewed included emergency managers as a key component of their audience. As the quote states above, the interviewees consider them more than an audience, but a partner. It is this recognition that elevates the level of communication that emergency managers receive. The transmission view of communication no longer applies to this subsection of their audience, as meteorologists determined that feedback is essential for emergency managers to make their critical evacuation decisions.

For example, the FEMA in partnership with the NHC and NWS, created what is called the hurricane liaison team, which is a coordination call for federal, state and local emergency managers and decision makers that will potentially be affected by the pending storm. FEMA created the hurricane liaison team in part because of massive time constraints from the NHC. One government forecaster described the history for its creation and its subsequent utility:

> Now these same people [emergency managers] who have been to the [training] workshops, they know the hurricane forecasters, and they know the NHC director. They would call down, and we would make them *mad.* We couldn't answer the phones. I can't call in from home during a landfall event. We're just so saturated down there. It's not a matter of having more phones. I don't have enough people on the telephones. So FEMA came in on their white horse years ago, and together we partnered to develop this hurricane liaison team. In Katrina, for example, we're talking to FEMA headquarters, the regional FEMA offices from LA westward, Region 4 in Savannah, MS, eastward. And, very importantly the state emergency operation centers are on there. So, we had TX, LA, MS, AL, FL and GA all on the conference call. Our job is to do the meteorology in five minutes or so, and then let them do the emergency management process … [we] make sure that they're talking to us, and that they understand the uncertainty.

This one forecaster sheds light on many issues that came up from other forecasters representing all institutions. First, time is of great importance during a pending storm. Forecasters are working around the clock incorporating the most current data into their models and forecasts. Depending on where the interviewees work, they must update text products, online broadcasts, static TV products (i.e., weather on the 8's on The Weather Channel, NBC Weather Plus, etc.), and of course, their live TV news products, and in the case of the NHC, live media interviews. Organizing this national team of forecasters to predict and communicate severe weather requires structure, standards and time to ensure the continuous timely dissemination of forecasts across the country. This dedicated time ensures that at bare minimum the information regarding the hurricane is transmitted. If the audience is unaware of the storm and its potential track, then they cannot take any precautionary actions. The key component *is* transmission.

Second, the quote highlights two ways transactional communication infiltrates the system, between the meteorology community and the emergency managers as well as within the meteorology community. Taking a closer look at the emergency manager community, it is not difficult to understand why emergency managers are so closely related to the forecast message. Emergency managers make evacuation decisions based on the best available information. The issue is the information is complex, plentiful, and fraught with uncertainty. Despite the forecaster's intent to have a consistent message, inconsistencies can be seen in the design of graphics and message objectives presented, which causes confusion and frustration on the part of emergency managers.

While this complex situation does exist, meteorologists understand that emergency managers are the link between their forecast message and the public. The decisions made by these emergency managers will affect thousands if not millions of people. Thus, it is in the forecaster's best interest to ensure that these partners understand the forecast. What makes communication easier with this population is that it is a known population. Forecasters, through FEMA, know who the emergency managers are. The coordination calls are setup such that all stakeholders are identified. Additionally, everyone on the call has a similar purpose to make the best decision possible to protect the lives and property of every person in harms way. This makes the interaction among the call participants much more focused allowing the meteorologists to focus on the uncertainty of their forecast, and the emergency managers to focus on any relevant questions regarding the potential risks for their geographic area.

Despite this transaction, forecasters still show signs of frustration with emergency managers. Take for example, the following series of responses regarding Hurricane Charley. The discussion focused on the forecaster's perspective on why emergency manager's decideded not to evacuate even though their location was just south of the "skinny black line":

G	Who do you think the emergency managers are listening to? Are they looking at these graphics?
Interviewee	The emergency managers are coordinating very closely with the National Hurricane Center.
G	Okay so in terms of Port Charlotte and the border area?
Interviewee	Again, what part of hurricane warning don't you [the emergency managers] understand? Yeah. Evacuation levels would have been a little different if the emergency managers, and it would depend on the geography of course, but if you're expecting a high end 1 or a low end 2 [hurricane] versus a low end 4 the evacuation would be a little different. However, in this case it wasn't so much of the storm surge problem because of the track the storm would take. This was a wind event. But, I go back to my original statement: What part of a hurricane warning don't you [they] understand?

The forecaster admits that every situation is different. They acknowledge that category size and the specific threats from each hurricane vary from storm to storm.

Despite the fact that the hurricane liaison calls exist, emergency managers may still have questions unanswered. Although the forecaster just openly discussed the complications of geography, winds, and surge, he ends with a conflicting, “What part of hurricane warning don’t you understand?” If every hurricane warning were the same, emergency managers would not need clarification. Some forecasters still fail to recognize why transactional communication is so important.

Although transactional communication exists with the emergency management community, it is important to note that it takes a third party such as FEMA, to complete the feedback loop between emergency managers and meteorologists. This is not a positive or negative component, but it does raise the question of whether or not a third party, such as FEMA, is required to make transactional communication occur between scientists and their associated partners. Does this theme repeat itself in other governmental contexts or in other institutional settings?

Exploring another institutional setting, there is at least one additional scenario where transactional communication comes into play. By the nature of their business, the private sector has paid customers many of whom are emergency managers, but also include the energy and oil industry, and trucking and aviation companies, just to name a few. In essence, these customers pay for specialized transactional communication. For example, one private sector meteorologist explained:

> So we're not conveying to the general public and therefore, we don't feel compelled or constrained by what the official government line [forecast] is. If we tell Utility A that we think their assets are more at risk, then we're going to say it out loud until they pay us all the money for that service. There's a lot of hand holding that goes into that. That service is really where they're paying money, for that hand holding. They can ask questions or even banter with our meteorologists, and in that discussion process now it's a human discussion process. The uncertainty is conveyed to them and they are presumably making better tactical and strategic decisions because they now understand the certainty better than the line and the red area and the yellow area that you see on TV.

This forecaster clarifies that the paid service includes the right to, “ask questions or even banter with our meteorologists.” Forecasting takes a lot of time and thought, thought that is not always easily explained. The time it takes to offer explanations has a value, a monetary one. Those who value transactional communication will ultimately come forth, if it is in their benefit to do so. For many of the oil companies in the Gulf Coast, they have people and profit at stake, and a service such as the one described above is worth every penny.

Another private sector forecaster explained their interaction with customers:

> Most of them [emergency managers] know who I am and know me. I’ve given them my card. They have my email. I get a lot of them, and we also have conference calls with them at [Company X] so they’re able to talk to me and ask me about what impacts do I expect. Do we think it’s coming my way? And we arrange those. I don’t arrange them, somebody arranges them and I show up and give them my best estimate: I don’t currently think its going to hit you, that’s my opinion, you may have to make your choice based on the official National Hurricane Center forecast…

In this passage, it is unclear whether the emergency managers pay for this service, but it furthers the idea that customers of private sector weather companies have access to specialized communication.

Both government and private sector institutions appear to identify a subset of

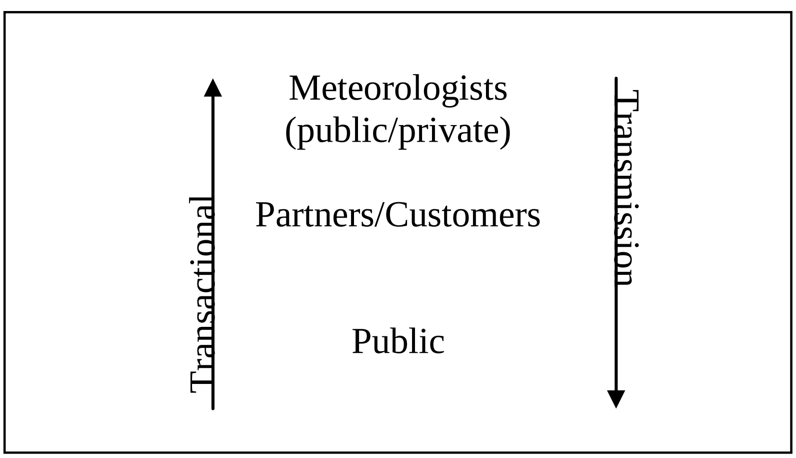

Figure 2. Direction of increased transactional or transmission communication by audience

the public worthy of transactional communication. The institutions under NOAA identify emergency managers for this specialized communication; whereas the private sector companies identify their paying costumers. None of the institutions prioritizes the general public as having a need for transactional communication. Thus, the farther away you travel from the main source, the meteorologists, the less likely one will experience transactional communication. Emergency managers, the partners, and paid customers will receive focused attention as time allows, whereas the public, being the farthest removed from forecasters, will have limited transactions, and is much more likely to experience a transmission view of communication. Figure 2 summarizes this finding.

Although the transmission view of communication characterizes most of science communication, the finding above suggests that there are levels of increased communication within the source's audience. It seems plausible that all scientific contexts have varying levels of communication, noting that the similarity is that the public receives the least attention.

The highest degree of transactional communication should occur within the meteorology community, the main source. Recall one of the forecaster's dismay with emergency managers when he stated, "What part of hurricane warning do they not understand?" What perhaps makes this statement so intriguing is the fact that much coordination, and transactional communication, occurs before implementing such a simple, understandable warning. It is possible that warnings are not so easily to understand after all. One forecaster described this process:

> Right before every forecast is issued by the NHC, we have a hurricane hotline call with all of the potentially impacted local national weather services offices. In Katrina, we were talking to the Houston office, Lake Charles, Slidell, New Orleans, Mobile, and Tallahassee. We hadt the whole gulf covered basically right there. We had the river forecast center online, the guys who do the flood forecast for the rivers. We had HPC, the hydrometeorological prediction center online, the rainfall experts. We had the storm prediction center people

> up there from Norman OK, who help us with tornados. We had all the experts giving us input to come up with the advisory. But then after that, and the dept of defense is online too, maybe Norfolk or Jacksonville for example, somebody at NASA … Anybody can speak up. If they don't understand something, they can speak up and say how come you're doing this or explain that. We'll try to explain why we're doing what we're doing. After that, we finish up all the products and transmit those.

This is probably the most exhaustive explanation of what happens directly before products, such as the cone of uncertainty, are issued as well as an indication that meteorologists of all types are communicating with one another. One distinction must be made clear though. All of the folks mentioned in the above quote are from the government. It is clear that government meteorologists from the NHC to the NWS to the National Severe Storms Lab to the military are communicating with one another, but where is the rest of the field?

Interestingly enough, only the government forecasters in the sample commented about non-governmental meteorologists, while private sector meteorologists did not hint at any interaction with the government. The reason for this might be that the NHC issues the official forecast. Most private sector meteorologists will not deviate from this track, as the meteorological field knows how important it is to have a consistent message to the public. For example, one private sector meteorologists stated:

> Oh, we always verify what's happened. My boss is very big on that and he watches religiously, says, "[Name], you know, are you sure". He plays the devil's advocate and we really, most of the time, are not much different track and turning wise from the Hurricane Center. Most of the time we're the same, and we're evaluating the impacts, which they don't provide directly. It's only in some cases where I'm absolutely confident it's not going there.

Another broadcast meteorologist expressed his sentiment,

> Well, because I knew that people would look at the edge of the cone to determine whether they were in or whether they were out, and I didn't want it to be the in on Channel 4, but out in the NHC or some other thing, I have been espousing for ever that there is no upside to using any other cone other than the NHC cone. There is only a downside.

Although the sample for this study is small, it is safe to say that the field of meteorology resonates with the interviewees' sentiments. This lack of deviation may also explain why a private sector meteorologist may not need to interact with government forecasters.

Government forecasters, on the other hand, did mention interaction or the importance of interaction with private sector meteorologists, though the responses are conflicting. One forecaster said,

> We'll talk to anybody, sure. They can call and some do, they will call or email, and we'll treat them like we would anybody, sure. There is no problem there.

This implies that there is interaction between the government forecasters and private sector forecasters, whereas the quote below suggests limited communication with only a few people.

> No, the [private sector] meteorologists are not talking to us with just a couple of exceptions. The local TV meteorologists here, some of them will talk to us. [The Weather Channel] will call us … Accuweather doesn't talk to us. They just insult us.

The potential difference between the two interviewees might be their placement in the chain of command. The higher your leadership position, the more communication you have with your audience. The interviewee below identified broadcast meteorologists as another partner, similar to the emergency managers.

> I personally don't think the Weather Service sees the media complication. They, [broadcast meteorologists], are critical. They are partners, right. They are qualified. Without the media our message would not get out because this is the thing, the reality is that more people get the message from radio or TV or, the Internet has been increasing. In reality, they still get our information, they get it from us, and they pass it on …

In response to a question about training of broadcast meteorologists, one interviewee said:

> It seems to me that there has been some discussion on whether we need to do that or not, but I don't know whether, I'm pretty sure we haven't moved that forward in any serious way. We're hoping that that they understand.

Yet, another government forecaster suggested that broadcast meteorologists may not understand or, at the very least, may not be framing the message appropriately:

> It's almost one of those things that, maybe I sound like I'm blaming the media, but I think the media needs to, you know, it needs to be, I mean, hopefully the media reads our discussions and can communicate these uncertainties to the public. But, I think that was a big issue in that case was the angle it could have gone anywhere, anywhere down to the west coast of Florida. We were saying that.

It is apparent that although transactional communication takes place within the community, the diverse responses show that there are varying opinions on whether transactional communication is necessary. Although many other interviewees mentioned that they attend conferences such as the AMS's Annual Meeting as well as their Broadcast Meteorology Conference and Tropical Meteorology Conference, National Hurricane Conference, National Weather Association, etc., the focus at these meetings is typically not on the training of new products or how to frame a consistent message, but more on research aspects of tropical meteorology.

Thus far, this case study shows that science communication is not entirely characterized by the transmission model of communication. Although much of the direct communication with the public follows the traditional literature in this area (Dornan, 1999; Lewenstein, 1995), the participants have shown that there are layers of their audience that require more or less communication, such as with emergency managers. Although it is easy to group all scientists into one category, it is also important to recognize the institutional groupings of the scientists, as scientists often do not communicate as one group with one voice, as this thesis shows. As a result, it is important to study how scientists within these different institutional contexts interact with each other, and as a consequence, how this interaction leads to effective or ineffective communication with the audiences to follow.

Applications of the Deficit Model: Are Visuals, Text and Verbal Messages Treated Equally When Communicating to the Public?

Organizing a national team of forecasters to predict and communicate severe weather requires structure and standards to ensure the continuous timely dissemination of forecasts across the country. Although there are structures and standards for the scientific aspects of the process, are there similar standards or structures to communicate with the public? While there are no official policies on this matter, there are many unstated official rules to communicating with the public.

In addition to the unstated rules, the science communication literature also offers ideas as to how scientists will communicate with the public. The deficit model, although widely criticized, suggests that the public lacks the foundational knowledge required to understand science (Miller, 1998). With this interpretation, scientists potentially respond to this by making educational assumptions regarding their audience. As the concept implies, if the audience has a deficit of scientific knowledge, then scientists and media alike have a responsibility to disseminate science information in a simplified form. Society is at an advantage if it has a public that knows *some* science versus no science at all. The belief is that an audience that has a deficit of scientific knowledge is not capable of understanding complicated scientific processes. Scientists and the media must adjust their communication messages accordingly.

Most of the literature in this area focuses on verbal or written messages, that is, messages that are written in some form of plain language. As this case study focuses on visuals, the question focuses on whether visuals follow the same type of deficit model of communication. Do scientists oversimplify visuals the same way they treat text?

The unstated rules.

In journalism, it is common to write articles that target a particular reading grade level. In fact, Meyers (2004) concludes that most major newspapers, such as the New York Times or the Washington Post, target 6th to 8th grade reading levels. In other words, reading levels are rarely higher than today's junior high education. Science communication, a different form of journalism, acts very similarly. Many of the forecasters provided their insights as to a target grade level. For example, one forecaster stated, "For TV, it used to be 5th grade." Yet another example, in response to what grade level the interviewees target suggested even lower.

> Lower. I think it would almost be less, unfortunately. I just feel like you have to keep it as simple as you can, yet convey what we want. And I think it's tough and I do think that makes the graphic, may make it hard to understand for some people.

Not only does this quote convey this forecaster's opinion regarding the education level, they also recognize that because of this level the graphic may be difficult to understand. This begins to unveil evidence that visuals are not included in this deficit model of communication. The forecaster just admitted that the education level is lower than 8th grade. If they believe the public will not understand them, then by deduction, the graphics target a much higher level of education; higher than at least 8th grade.

Another interviewee refused to answer the question in a traditional form.

G	What level do you write it [text products] to? You know how newspapers kind of have a target grade audience.
Interviewee:	This is geared for the public
G	But if you were to, I mean, the public has a range of education and reading levels. Would you say you have a grade level that you would, I mean, are you shooting for 8th grade science level? A 10th grade science level?
Interviewee:	No, there's no science on this. Just plain language.

Although this series of responses is concerning a text product, the response almost implies that there is no science education required. They simply state that it is just plain language.

All of these responses indicate that the target science education level is depressingly low signifying that forecasters appear to follow the deficit model of science communication. These examples are also beginning to show signs of unequal applications of the deficit model to different modes of communication. The data are beginning to suggest that forecasters apply their ‘simple communication’ to text and audio, while they may exclude visuals from this policy.

Understanding probabilities.

Knowing that meteorologists have such low scientific standards for the public, it is ironic that this section is on the use of probabilities, which are quite common in meteorology. On the one hand, probabilities play a very important scientific role. On the other hand, the use of probabilities seems to be in direct conflict with the determination that the public has little to no scientific literacy. The use of probabilities works against the deficit model approach to communicating science.

Prior to the last few years, much of the weather communication with the public used deterministic forecasts such as assigning one number to the predicted temperature (ex. It will be 62 degrees.) The alternative is not only to move toward ranges (ex. The high temperature will be between 62 and 70), but to also give probabilities. This is much more common for precipitation amounts, i.e., 40% chance of rain, or 60% chance of a thunderstorm, etc. From a scientific point of view, probabilities are a more accurate account of the state of the science. Probabilities are explaining the reality they know right now for the future. Deterministic forecasts are only useful for one point in time, i.e. the temperature right now is 62 degrees, etc., but when giving a forecast, that is, the state of the weather sometime in the near future, the truth is the science cannot provide the exact future account. Probabilities are the most honest, objective approach to communicating the uncertainty of weather.

The issue at hand, then, is how do meteorologists reconcile their use of probabilities with the fact that they have determined that their audience's scientific literacy is dismally low? Further, there are many examples in the literature that support the idea that the public as well as educated professionals, misunderstand the use of probabilities (See Gordon-Lubitz, 2003; Lipkus, Samsa, & Rimer, 2001; Schwartz, Woloshin, Black, & Welch, 1997). How, then, do scientists conclude that probabilities are the way to communicate with the public? The interviews show that there are diverse opinions on this matter.

One of the alternative graphical products to the cone of uncertainty is a graphic called the tropical storm force wind probabilities graphic. It shows the wind field for a hurricane assigning probabilities to spatial areas for their chance to feel tropical storm force winds or above. To show the complexity of this graphic, this meteorologist described:

> We're showing these wind products in 12 hr increments out to five days. So that's, ya know, 12, 24, 10 graphics with in five days, 8 products time three, 24 products. Most people I would envision this working out to five day probability. We also have a text product that goes with that, and this, if you know how to use it, is extremely useful... But, you can go in there and see the cumulative probability for each time period, and then the individual probability, so it kind of gives you the probability of getting impacted and then it, depending on the highest probability, it also gives you the most likely time it will impact you. So there are ways to use this that have much more meaning than this simple cone and skinny black line.
>
> G: Do you think, though, that the public has time to process all of that information?
>
> Interviewee: No.

First, this is an example of how complex these graphics are to design as well as implement in real time. As the forecaster states, within 5 days he is producing 10 graphics on this one product alone, not to mention all of the other visual and written products he must update during a storm. It helps to show the complexity of communicating hurricane information, which is not something to belittle, and further is something that forecasters struggle with every day. In fact, a recent National Academy report titled, “Completing the Forecast,” summarizes the difficulties of communicating weather information and identifies areas that are in need of more research. Communicating uncertainty and using probabilistic products are a large focus of this study (Ban, Andrew, Brown, & Changnon, 2006).

Second, the quote shows their recognition that the public will not be able to process all of the individual and cumulative probabilities that are shown in the wind graphic. Despite this recognition, the forecaster later followed up with,

> It seems to me that this is where we want to go to let people know number one, that we can’t give a perfect forecast, and that there is uncertainty involved, and two, we really want them to have a feel for where the storm winds are going to be or most likely going to be. Now, having said that, we’ve got these products out there, is that the absolute only way to do it, well of course not. There are multiple ways to do this. I just feel strongly that we want to convey that uncertainty. Everybody in meteorology is grappling with trying to find out the best way to deal with uncertainty.

Although they admit this graphic may not be the only way to do it, they are suggesting, by the combination of these two quotes, that the wind graphic, which uses probabilities, will be employed, and the public will not understand it. This is an interesting combination not only because the two statements are in conflict with each other, but also because the forecaster is choosing not to apply the deficit model to the visual. This is the second piece of evidence to suggest the exclusion of visuals under the deficit model of communication.

Further, another forecaster also suggested that the public has difficulties understanding probabilities. A private sector meteorologist expressed,

> Most of the public, the vast majority of the public, doesn't know how to calibrate scientific statistical statements, i.e., 80% probability, 70% probability into action and there is a challenge there to figure out what's the right way to convey the uncertainty, … and get people to translate those uncertainties into actions that affect their world.

Conversely, another government forecaster who uses probabilities suggested that the public *is* capable of understanding, but admits that it is an educational process. He further stated, "Media is extremely critical in doing that, exactly, and the same thing would happen with any of the products here."

The use of the words 'challenge' and 'educational process' indicates a difficult, learning curve toward understanding the use of probabilities both in visuals, such as the wind graphic, or in text, such as descriptions of a 70% chance of rain. The emphasis on education takes this concept once step further. It implies that the use of probabilities requires an explanation, a verbal explanation. In the media context, as suggested above, when broadcasters explain a graphic using probability, they must explain what the graphic means. One forecaster remarked on how to do so stating,

> Oh yeah, the TV consultants says, 'talking the weather, don't talk down to them, but don't throw all the scientific jargon – there's vorticity next blah, blah, blah.' No, you speak to them in every day plain language.

This is yet another example of the possible exclusion of visuals and inclusion of audio/text as it pertains to the deficit model.

Forecasters, through their own personal opinions or through TV consultants, determined that their audience has a low scientific literacy, and in response to this, the public must hear simple, plain language explanations. Yet, the graphic presented still uses difficult, probabilistic scientific concepts that forecasters openly admit are difficult for the public to understand. What characteristic of visuals potentially excludes them from this simple communication process? Are visuals more useful in capturing and communicating intricate scientific phenomena such as uncertainty?

Summary

The analysis of the transmissions, transactions, and deficits of how communication functions in meteorology begins to shed light on a visual's life, in particular, on a science visual's life. Although it would be easy to think of a visual as having a linear life juxtaposed between two worlds, those of the creator, the scientists, and those of the reader, the many levels of the audience, this case study shows that it is not that simple. The cone of uncertainty sits in a complex web of many creators and users (See Figure 3). This chapter identified the creators of the visual, the audience for the visual, and the many types of communication that infiltrate the visual

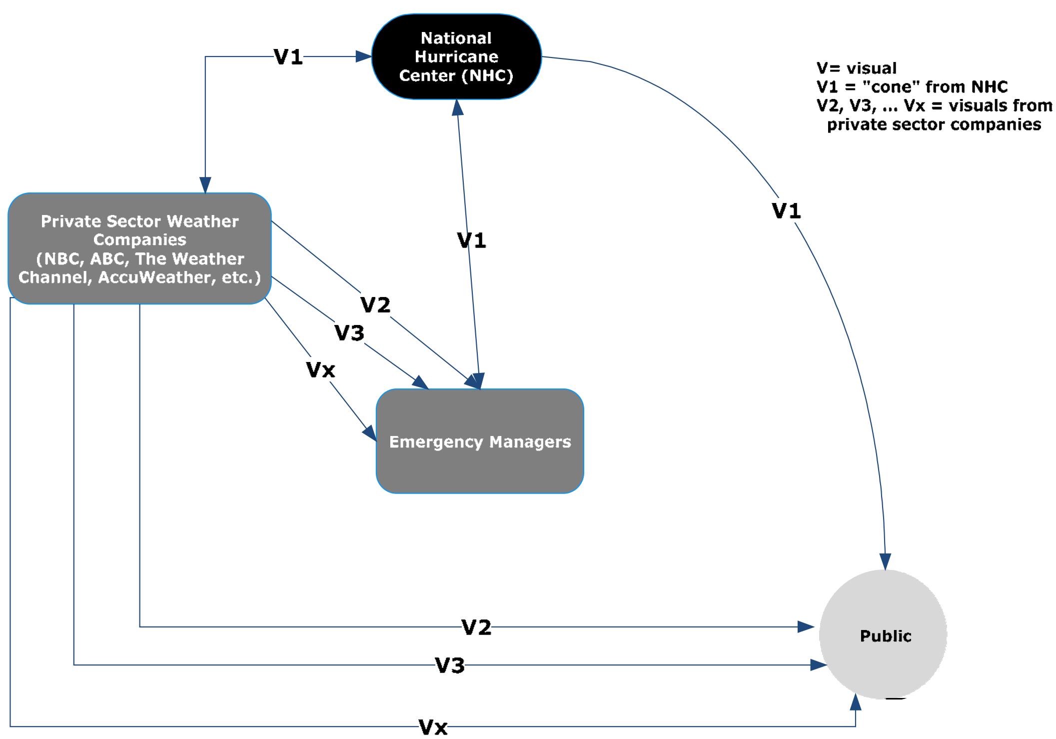

Figure 3. The visual process of the cone of uncertainty

communication process. The next chapter will explore the value of written or verbal explanation to achieve visual validity.

CHAPTER 5

VISUAL VALIDITY: THE VALUE OF EXPLANATION

Overview

Up until now, this thesis has primarily focused on the forecasters that creates the visual, who these forecasters communicate it to, and how. This chapter focuses its attention on potential characteristics of science visuals, specifically trying to explore if science visuals always need explanation, or alternatively, if they can stand-alone. To do this, this chapter will:

- Develop and define visual validity,
- Explore whether the cone of uncertainty can act as a stand alone graphic,
- Determine what the cone of uncertainty needs to ensure high visual validity.

This chapter brings together examples from both science, the cone of uncertainty, as well as an example from art to strengthen the definition of visual validity. The quotes used in this chapter fall under the value of explanation code, which I developed during the second phase of coding.

The Value of Explanation

Much of the controversy regarding the cone of uncertainty indicates that people direct more of their attention to the visual rather than listening to associated explanations. One forecaster stressed the importance of explanation,

> I don't have a problem with that at all [putting the skinny black line on the cone], but you've got to make sure you've got the cone up there and emphasize that this is our margin of error, and notice it expands the farther we go out in time … They've [broadcasters] got to beat that into the ground of the viewers. You've got to harp on it.

The forecaster was passionately expressing the need to emphasize what the visual means to the viewers. If broadcasters are "beating that into the ground of the viewers," and if they are listening to it, then one would surmise that the public would interpret the graphic correctly. Yet, as the literature has pointed out, there is some evidence to suggest that this is not the case. This leads to three questions: (1) what is preventing the public from focusing on the verbal message, (2) what is potentially wrong with the graphic that it is leading to costly misinterpretations, and (3) can a science visual *without* an explanation prompt one of the many correct interpretations?

The first two questions are beyond the scope of this study, but warrant further attention. A combination of the visual literature as well as the forecasters' comments, can offer some insight into the latter question. First, what does it mean to stand alone, and what are the implications of a science visual standing alone, if any? To find the answer to this, science must find a comparison with art. Art often finds its way to a prestigious spot in a museum, a historical building, or maybe even the wall of a home. It proudly sits still awaiting the moment when a viewer stops to take a glance. The viewer, or visual reader, begins the process of mentally digesting their meaning of the piece of work.

Meaning is a complicated word, especially when associated with all types of visuals. Whether the object under consideration is art, science, or both, visuals might have an intended meaning from the creator. Regardless of this, the responsibility of creating that meaning lies with the reader. As Daston and Galison (1992) explain, history shows the transfer of objectivity from the creators of the object to the reader. Although scientists attempt to have objective visuals, the determination of how objective they are lies within the hands of the user, the individual. The irony is the determination of objectivity is a subjective process, as each individual brings their own experience and knowledge to create their own personal meaning.

The responsibility to create personal meaning is a powerful trait that all humans possess; a responsibility that some argue is one of many defining characteristics of art. As Ede states, "Although artists may make ironic play with many images or ideas, I believe they too wish to stimulate audiences to think freely for themselves" (Ede, 2002, 67). Whether artists intended for this independent thinking or not is almost irrelevant, as the individual has sole custody over their thoughts, or do they?

In reality, individuals do have control over their constructed meaning, but as stated earlier, this meaning includes their own personal experience and knowledge. If the visual has a description written by the creator, and this description is read during the viewing process, then the creator has an opportunity to influence the viewer's lasting impression. Moreover, text or verbal explanations associated with a visual enhances a person's individual knowledge, knowledge that is used for information processing.

Both art and science may have such a description associated with them. In this way, the creator is trying to steer the process of constructing meaning. The intent of the visual must come from the creator, not a secondary source. Many descriptions of historic pieces of art, for example, are written from a second hand account, an expert in that particular period of art. Many creators are no longer alive making it impossible to have a first hand account of the intent. There are many artists today, however, that are alive and capable of giving such a description.

Take for example, Laurie Simmons and her piece of art titled, Purple Woman/Kitchen/Second View (Image 4). A description of the photo on the Metropolitan Museum of Art states,

> During the heyday of the feminist movement, however, such toys for girls were viewed suspiciously as agents of persuasive indoctrination. Simmons nevertheless also understood their complex allure. Located at the intersection

> between personal and collective memory, these dollhouses represented for an entire generation a set of untenable illusions that, while fading, nonetheless stubbornly clung to the unconscious.

Notice that the writing of the description is from a third person point of view, not the actual artist's point of view. Further, in an interview with Paul Laster from the Sperone Westwater museum (2007) in New York City, Simmons states, "Despite the kinds of issues — political, feminist, psychological — that have been associated with my work, I'd say that light and shadow are the most important things to me. In the end, I'm a picture maker, and if the light isn't there, I can't make the picture." The focus of her work is on light, yet many art critics or historians associate words such as political, feminist, and psychological, none of which she endorses in her comments.

The point is that the description of Laurie Simmons' piece of work is not entirely representative of the intended meaning, or there may very well be multiple acceptable interpretations. Many, not all, science visuals, such as the cone of uncertainty, also have written descriptions, which are produced by the source, the creators. Similarly, as has been noted throughout this thesis, there are also multiple acceptable interpretations of the cone depending on the individual reader's characteristics, such as their geographic location and their shelter's condition. The main difference between these two examples is the consequence of a wrong interpretation. I argue that there is no physical consequence to interpreting art (scientific, contemporary, cubism or any other) in an incorrect fashion. If a reader looks at Simmons' piece of art and does not see varying shades of light, then they simply create a different meaning. If someone looks at a satellite picture of a hurricane, and does not see a category 3 storm, then they create a different meaning. Art, in a traditional sense as well as in a scientific sense, allows for a liberal ontological point of view.

The cone of uncertainty, on the other hand, raises questions about varying interpretations, especially those interpretations that are incorrect. The reason for this is that the cone of uncertainty is more than a visual of art, but is also a graphic representing risk. Risk might be the defining feature that makes this graphic so different from art, and further distinguishes itself from the rest of science visuals. Risk has varying definitions but may include words such as hazard, danger, consequence or threat. When a science visual contains a risk component, the reader's interpretation becomes critically important. From the creator's point of view, in this case the scientist, they feel an ethical obligation to ensure that the reader understands the meaning of the graphic as well as makes an appropriate risk assessment, as the extreme consequence of being unable to do both may include death or destruction. It is in this light that risk visuals may revoke their ability to stand alone and subsequently, require an explanation.

The goal of written description or intent is to steer a viewer's visual interpretation. Many scientists, like the forecasters in this study, have a specific intent in mind, which this thesis will explore in the next section. Visuals have their limitations, as Paul Messaris outlines in his book titled, *Visual Persuasion.* Messaris states, "What visual syntax lacks, especially in comparison to verbal language, is a set of explicit devices for indicating causality, analogy, or any relationships other than those of space or time" (1997, xvii). He calls this characteristic of visuals syntactic indeterminacy. Knowing that visuals have limitations to their persuasive character, written descriptions must make up for this missing characteristic.

In a way, the cone of uncertainty is trying to persuade people in the impact area that there is a pending risk in the immediate future. Knowing this, and combining the concept of syntactic indeterminacy, expands the argument that visuals containing risks require explanation. This argument also matches the forecasters' sentiments. One broadcaster said:

> The graphic by itself doesn't do much of anything… So what I have done for years and years, and I think it's the only way to do it, is that you have to *talk about scenarios* in the cone, and say lets lay out the possibilities, because all the cone is telling us here is that its likely that the center of the storm will stay within this boundary.

The opening line describes the theoretical issues with risk visuals, what do risk visuals do by themselves? Unless the reader has enough prior experience or knowledge with the graphic to know what it means, the description is vital. Even more, hurricanes are like fingerprints; no two hurricanes are the same. Thus, every cone of uncertainty expresses a unique, independent risk.

Another government forecaster expressed, "You need the [skinny, black] line … to convey with the uncertainty on either side and the cone is the best way of representing that …. So we need to do a *better job of communicating* that during the event." This forecaster emphasizes the importance of the visual conveying something as abstract as scientific uncertainty, but recognizes that such abstraction needs explanation.

The forecasters show the need for visuals, but also the value of explanation. The requirement of explanation is not present to create jobs for broadcast meteorologists. On the contrary, explanation is present to ensure that people understand what the visual is conveying and providing them with the tools to make an accurate risk assessment. The necessity of the reader understanding the creator's intent is what I call high visual validity.

Defining Visual Validity

Visual validity is an analytical construct to describe how accurately a reader's meaning of a visual matches that of the creator's intent. In other words, it is the process of visual meaning or intent translating into an individual's meaning. In the case of the cone of uncertainty, high visual validity is necessary to prevent costly and potentially deadly misinterpretations for those in the likely impacted area. The reader must understand the creator's intent if the reader plans to use the graphic to make an evacuation or other storm related decision. On the other hand, for Laurie Simmons, low visual validity is necessary, as the creator does not have one, specific intent for the audience to comprehend.

As the forecasters demonstrate through their comments, not all visuals are capable of communicating a message without a verbal or written description. Even more, when there is a risk or consequence involved in a misinterpretation, it is imperative that the reader take away the essence of the message, requiring both visual and verbal explanations. Therein lies another potential characteristic of risk visuals; risk visuals require high visual validity. This appears to be the case not only because the creator wants the public to take away the intent, but also because there is a consequence involved if they do not.

Summary

This chapter makes one small step to define and explore visual validity. It is a concept worthy of more research, especially as it pertains to risk visuals. The cone of uncertainty indicates that risk visuals may require verbal or written explanation to attain high visual validity. What also needs more attention is what this verbal or written explanation entails. The next chapter will take a closer look at the written and verbal messages associated with the cone of uncertainty.

CHAPTER 6

EXPLORING RELATIONSHIPS BETWEEN A VISUAL AND ITS OBJECTIVES

Overview

To begin to unravel the relationships between visual and verbal messages, it is important to assess each individual piece. The first question focuses on how many different verbal or written messages exist. Based on the meteorologists emphasizing the need for a consistent message, one would imagine that the verbal message is the same, but as this thesis has already shown, visuals, in contrast, move through many institutional design changes. Do verbal or written messages have different objectives as well? If so, how do people interpret these objectives? How does this affect their risk assessment? Does the public actually hear multiple messages? Or, do they trust one media source over the other? This chapter will begin to answer whether the verbal or written messages have different objectives among the varying institutions.

Second, because the cone of uncertainty as well as other potential risk visuals, focuses on an impact, there is often a desire to prompt a behavioral response to the message. Do meteorologists have a specific behavioral message? If so, how does this behavioral message relate to the visual? Is the behavioral message the same as the verbal or written messages from the previous paragraph? Protection motivation theory suggests that when people perceive a threat, they are more likely to protect themselves if they are aware of the steps they can take. Further, they will feel a higher level of self-efficacy if they believe they have the ability to take these steps (Rogers, 1975). Protection motivation theory suggests, then, that one of the messages discussed above will be a behavioral response. To look at this, this chapter will concentrate on forecasters' opinions of the potential behavioral responses from the cone of uncertainty and explore the potential relationship between these responses and the graphic.

Overall, this chapter will:

- Identify the message intent of the cone of uncertainty, and
- Identify the intended behavioral responses to the cone of uncertainty.

The relationship between a visual and its associated message or behavioral objective will be explored in the discussion section in Chapter 8. The quotes used in this chapter fall under the code ‘message objective’ and ‘behavioral response to the graphic.’ This message objective code, however, became too larger and was broken down into emphasis on uncertainty, confidence/certainty, and risk/impacts.

Multiple Meanings and Messages: The Objective of the Cone of Uncertainty

Although meteorologists emphasize the need for a consistent message, it appears that implementing consistency is much more difficult. Just as there are many variations on the cone of uncertainty, there are also many verbal or written messages associated with this graphic. There are also three distinct categories of looking at message objectives: (1) what does the graphic mean; (2) what are the specific objectives of looking at the graphic; and (3) what is the objective of those objectives, i.e., to understand or to take action, etc. Simply from the varying levels of what an objective is sheds light on the question about verbal or written messages having multiple meanings.

The first objective that appeared in the data was a clear definition of what the graphic means. Not surprisingly, the responses relate to the specific design of the graphic not in an artistic sense, but in a scientific one. One forecaster explained,

> The cone as you know is made up by connecting a series of circles drawn around the forecast points at various time periods and for many years the size of the circles had been determined by looking at average errors of a previous

> ten year period. Beginning this year we've changed the way the size of the circles is computed and it's no longer the mean of the ten year error, but it is the 67th percentile of the five year error.

If the cone of uncertainty appeared in the AMS's Glossary of Meteorology, which it does not, this is the type of definition that would appear. This response fits as a dictionary definition of the cone of uncertainty. To further define it, another forecaster stated, "So in other words, if you take say the 72-hour point and you draw the circle and it comes out to the width of the cone, by taking the 67th percentile of the area that means that 2/3 of the time the actual position [of the hurricane] would be within that circle." Even further, another forecaster finished the definition by adding, "But, the bad news is that means like 1/3 of the time it's going to be outside of the cone."

It is not surprising that meteorologists give an initial scientific description of the cone of uncertainty. Research shows, for example, that there are differences between expert and lay judgments regarding risk. Some researchers suggest that scientists think about risk quantitatively whereas laypeople think about risks more qualitatively. Scientists tend to associate risk with probability, whereas the public tends to think more about previous experiences, or past impacts (Tversky & Kahneman, 1974; Slovic, 1999). As the graphic expresses a risk or hazard, it is fitting that scientists would follow this suggested model. It took more probing to gather a deeper response from the interviewees as to what the public's objective or take away message should be. One interviewee, however, refused to give a deeper response suggesting that the graphic has a title in policy, meaning that any NHC or NWS graphic has a policy, a documented description, of what the graphic means. The title, or meaning, for the cone of uncertainty is the "Tropical cyclone Track and Watch Warning Graphic." Indeed, the graphic does show the track of the cyclone and its associated hurricane watch and warnings, but to quote one interviewee, "But, again, I would say, what does that cone mean? So what? How is that going to impact me or you?" That question is what the next subsection of message objectives will explore.

The interviewees' comments converged into three main categories for the specific message objective, uncertainty, impacts (risks), and confidence. It is worth stating that all three of these message objectives have a relationship with the track, or path, of the hurricane. Many interviewees when prompted for an objective mentioned things like, "Where it's going to go," or "the area of possible impact." Both of these responses have associations with the track of the hurricane, but the real message objective is in the details of the responses focusing on whether the interviewees emphasize, scientific uncertainty, impacts (risks), or confidence.

A closer look at the responses shows that emphasizing uncertainty of the storm track is one of the most important factors to communicate. In response to the question, "what is the objective of the graphic," here are some of the answers:

> Example 1: Bottom line the answer to your question is whether we'll be able to give the public an idea of the *uncertainty* to provide the real detailed information, well how to use it to decision makers at the local and state level to help them with their tough calls.
>
> Example 2: We have to convey that there's a level of *uncertainty* with this track prediction
>
> Example 3: We will never be able to predict a perfect forecast, so somehow we have to convey that *uncertainty* in the forecast.
>
> Example 4: I try to convey the *uncertainty* and the possible areas of risk.

It is quite apparent that uncertainty is a key objective of the visual message. The visual, through the white cone surrounding the black line, tries to convey the uncertainty that these meteorologists are referring to, but even more, they suggest that the verbal message must emphasize this message as well.

The concept of uncertainty is related to a previous section on using probabilities when communicating a weather forecast. In the case of hurricane tracks, numbers or probabilities are not associated with specific locations in the cone, but the white cone is still suggesting that there is uncertainty, or variability as to where that track might travel. The center of the hurricane will eventually only hit one area of the coastline. The problem, however, is that when the hurricane is 3-7 days offshore, there is no way to predict exactly where that hurricane will hit. As one forecaster stated,

> We're working to get more certainty in there [in the forecast], but we still have to convey the level of uncertainty we have today when we make a forecast, and if that covers too large of an area for people's liking, then, you know, we [the weather community] will just keep on supporting our research.

The amount of uncertainty in hurricane forecasting is indeed a reason to fund future hurricane research, but potentially of more interest is how to communicate the current day uncertainty. Mistaking the "skinny black line" as the exact hit location could result in an unprepared community, such as the Port Charlotte, FL area during Hurricane Charley. If this community understood the uncertainty of the track, it is possible they would have made better decisions. From this, it is easy to understand why uncertainty is highly emphasized as an objective of the cone of uncertainty.

The second most emphasized objective includes the impacts or risks of the hurricane as related to the track of the hurricane. The difficulty in communicating impacts is that there are many types, and their start time, and even forecast ability time, differs. For example, when the hurricane is out in the ocean, well beyond the shore, the only impact information that forecasters feel comfortable discussing is wind intensity. One government forecaster stated, "We forecast track. We forecast intensity and we forecast size." As soon as the hurricane path is closer to the shore, forecasters feel more comfortable talking about a wider array of impacts, but that responsibility also shifts from the NHC to the NWS local offices. For example,

> Okay, so how we interpret those threats, those hazards? How do we incorporate uncertainty? That's where the cone of uncertainty doesn't have

> much anymore. It's not good enough, okay. In a sense, what we try to do is take the forecast they provide for us, which is the, the larger forecast and we sort of try to downscale it for the local user. We pay special attention to every one of those hazards.

The hazards that they are referring to include coastal flooding, or storm surge, inland flooding, wave height, tornadoes, etc. Even further, one private sector forecaster stated that hazards also include,

> Rainfall impacts, power outage graphics. The rainfall graphics show likelihood of flooding: low, medium, extremely high, catastrophic flooding possible. Then we have power outage impact: possible, likely, certain, guaranteed, you're going to get power outages here, be prepared for it within the next 24 hours. So those other graphics have developed and they run through my numerical models and then I draw the pictures from them.

But, one might be asking, what do these impacts have to do with the message associated with the cone of uncertainty? If everyone is making different graphics for impacts, then how are these impacts included in the message?

The cone of uncertainty shows the potential track and uncertainty of the hurricane, which plays a vital role in communicating where the impacts of a hurricane are heading. One forecaster explained, "You want to convey some type of impact, and the center is, I mean, for maybe a hurricane it is certainly good to know where the center is going to be and where it is most likely going to be." Specifically, one forecaster suggested, "If you were close enough to that track … then know you should expect damage within 50 miles of landfall." Thus, the location of the center and the potential track of the hurricane are not communicating a specific risk or impact, but rather the interviewees are suggesting specific locations that are most likely to feel the worst impacts of the storm. The potential impacts, then, are the reason why an audience pays attention to the uncertainty of the track.

In many ways, then, forecasters need to combine the objectives of uncertainty of the track with its associated impacts. Indeed, some meteorologists did identify both as objectives. Reviewing example 1 and 4 from above, both of these quotes imply that uncertainty and impacts are important objectives. Take example 1,

> Bottom line the answer to your question is whether we'll be able to give the public an idea of the *uncertainty* to provide the real *detailed information*, well how to use it to decision makers at the local and state level to help them with their tough calls.

The forecaster is implying that he wants their detailed information used in tough calls referencing more than simply the track. Just the track is not enough to make evacuation decisions for decision makers. It is the associated risks, the "detailed information," of this track that leads to behavioral actions. Further, the forecaster's statement in example four specifically mentions both objectives stating, "I try to convey the *uncertainty* and the possible areas of *risk*." This association may lead meteorologists to make sure that NWS issued watches and warnings are on the cone of uncertainty. Looking closely at Images 1 and 3, one can see that the watches and warnings are color coded on the NHC graphic. Private sector companies respond similarly showing the NWS watches and warnings on their graphics as well.[4]

At this point, the cone of uncertainty has two message objectives that of scientific uncertainty and potential impacts. Additionally, the relationship between these two objectives is clear, the uncertainty of the track relates to the uncertainty of where the potential impacts are heading. The third objective, though not as prominent as the first two, indicates a desire to differentiate each storm. The third objective is characterized best by one forecaster's response to what is the most popular question that emergency managers ask. His response was, "the most common question is how confident are you in the forecast."

Confidence, not to be confused with certainty, characterizes the meteorologists desire to show their "sureness" about their forecast. For example, one meteorologist

[4] I do not have examples of private sector graphics showing the watches and warnings. Private sector graphics are not archived on the web, which makes accessing such graphics very difficult.

stated, “So you need to know, figure out how to forecast the uncertainty to sort of calibrate it so we can be statistically sure that when we say something is high *certainty*, that we are right.” First, the use of the word “certainty” does not mean the opposite of uncertainty, but rather it means how confident they are in a forecast. A forecaster may have a higher confidence in the track for a specific hurricane, but the uncertainty of the track, the cone, remains a prominent part of the discussion. They could also be more confident about the intensity of the storm, but still be uncertain about the track. For example,

> If they decide to ignore the forecast, they're saying there's too much uncertainty. ‘Look, these guys got a big cone out there or they're flipping around. I ain't making a decision today’, but if we come back at day three and four and say hey, this thing is a Cat 5. We think it's going to be a Cat 3 or 4 when it makes landfall. We're pretty *certain* about that. It's going to be anywhere between New Orleans and northeastern Florida. We're pretty *certain*.

Here, the forecaster provided an example of when he feels more confident regarding the wind intensity calling it a category 3 or 4. Their landfall location, however, still includes a wide geographic area concluding that the track is still uncertain.

Having high confidence of a storm’s forecast is a desired characteristic, as it allows forecasters to start discussing the potential impacts. One private sector forecaster stated, “When it gets closer in, where you’re thoroughly *confident* where it’s going, that’s when you can start talking about the impacts.” Further, a broadcast meteorologist stated, “As the hurricane is coming toward the coast, a risk area goes up on the coast, and if it’s especially *certain* things at some point a high risk area goes up on the coast, prior to a warning or a watch.” Confidence is a tool, or even a desired state of knowledge, to indicate when it is appropriate to communicate particular impacts.

Even more, confidence is so highly valued that some forecasters would like to see it incorporated into the graphic. A couple forecasters suggested that the addition of a confidence scale to the cone of uncertainty could potentially be helpful in communicating risks. One interviewee suggested using the Hydrological Prediction Center's process for incorporating confidence, which includes writing in their advisory whether their confidence is below average, average, above average, or well above average. Additionally, one forecaster asked about changing the size of the cone based on confidence:

> There is a lot of confusion about what the air cone truly means. I know because I used the information, .. the cone itself, the size is independent of current environmental conditions and I remember a long time ago asking if a weighting factor could be applied to the cone such that based on the confidence level that the forecaster had, that the cone could either be increased in size or decreased.

Currently, the science is not there yet, but one forecaster leads us to believe that it is not that far away. In response to changing the size of the cone, he said,

> We don't, because A, we're not confident in it and B, because we haven't gotten to the point of doing scenario specific cones. We're working that way, but I would doubt that we would always…well we certainly might change the size depending on the confidence. There are other situations where we feel confident about something and we would narrow [the cone] if we could.

Nevertheless, the cone has a standard definition of which confidence is not included. As some forecasters suggest, confidence is most appropriately included in a written or verbal message, but it is not entirely appropriate for the graphic.

Uncertainty, impacts and confidence emerged as the three most pressing message objectives regarding the cone of uncertainty. Figure 4 on the following page summarizes how these objectives add to the cone of uncertainty's complicated life. Despite knowing this, what is the greater objective to people knowing this information? This thesis identifies the cone of uncertainty as both a science and risk visual implying the need for an audience to understand the science, assess their risk, and take some action. Although these implications seem clear, the forecasters stress

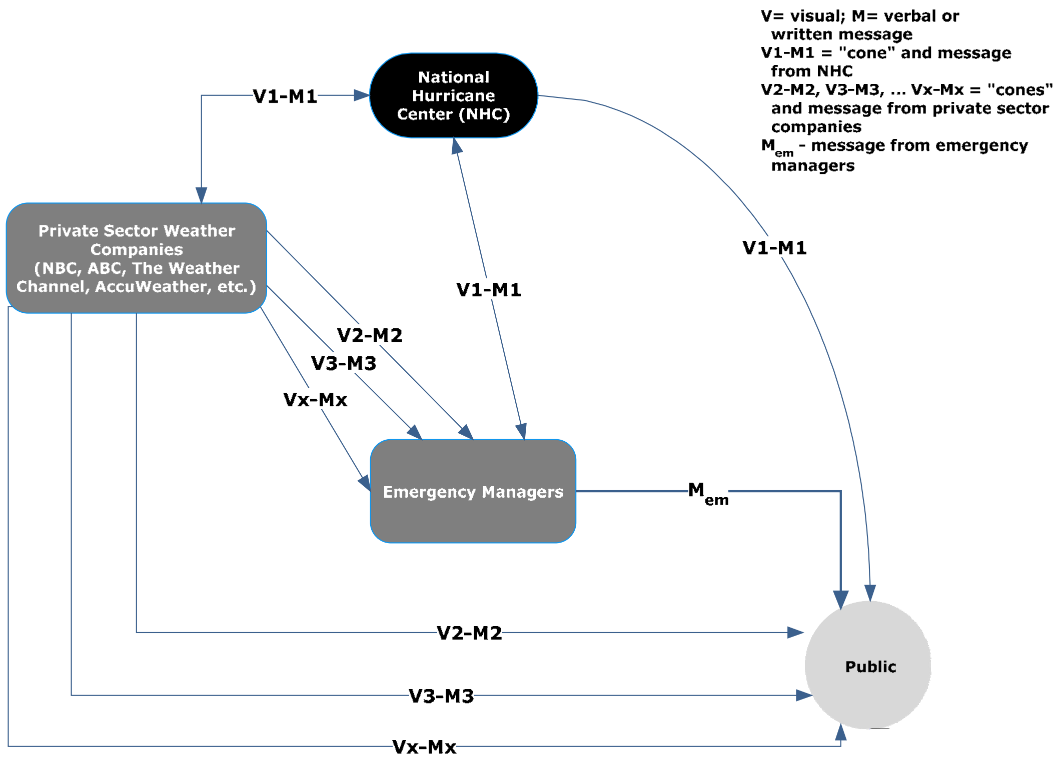

Figure 4. The visual process of the cone of uncertainty with its associated verbal or written description.

understanding of the science and general awareness of the risks before taking any action from their message.

For example, a government meteorologist in response to what is the message objective stated, "Realize that anywhere in that cone of uncertainty you can have a hurricane breathing down your neck." The forecaster does not suggest any action, but emphasizes being aware that there is a hurricane coming.

Another example emphasizes the understanding of what the graphic is showing, the forecaster stated, "Take away message? Well, the first thing I think I would want them to know is if they're in a watch or warning. The second thing I would like them to know is, are they in the area of possible impact." Again, this statement emphasizes having the person be aware of their risks, but does not suggest any action.

Furthermore, another meteorologist wanted people to take away that:

> This is where we strongly feel in this area, that this is where the hurricane is going to go. In the article, we would write the factors, high pressure here, upper low here. It's driving it in this general direction you know. Here's where we think it's going to go at what particular time. And of course you know that, you obviously know the farther out you go the wider the uncertainty gets.

This response emphasizes the state of the science and understanding the uncertainties involved. Unlike the other two examples, this objective does not stress the importance of assessing risk.

Although the implications of behavior seem inherent in the graphic, some forecasters deem it otherwise. In fact, one government meteorologist stated, "There's very little actionable information that someone can and should be taking away from this graphic." It is important to note that this section focuses on forecasters' responses to the cone of uncertainty's *message* objective. The next section will concentrate on the responses given regarding the potential behavioral response to the graphic in hopes to examine the above statement's inaccuracy.

Do Visuals and Their Verbal or Written Messages Have a Behavioral Response?

As stated in the previous section, the meteorologists included in this study do not identify prompting behavior as a main message objective. There are four potential explanations for this: (1) the need for scientific objectivity, (2) liability concerns, (3) complacency, and (4) the role of emergency managers. First, scientists like to maintain objectivity when giving a forecast. Introducing a behavioral concept may show signs of subjectivity violating their scientific standards. When dealing with a large audience, it is difficult to associate one behavioral response for the entire viewing audience. A private sector forecaster stated, "We never tell somebody to evacuate. 'Hey, you in New Orleans?! Get out of there! You need to evacuate!' What I say is this, 'this is going to be a close call. You're going to be missed by the worst part of it.'" Focusing their statement to suggest that the public will miss the worst part of it leaves the decision to evacuate in the viewer's hands. It allows the scientist to remain objective and transfers any subjective response to the individual.

Second, there is a liability factor in providing a behavioral response. A private sector forecaster confirmed this concern:

> The tropical storm force winds are going to overtake you by 6 o'clock. This is the latest information that we have, and the storm surge is going to start to cut off the bridge by midnight tonight. You have to be careful as a broadcaster by telling people what to do because there are liability issues and stuff like that.

This forecaster indicates that fine line between giving potential real-time impacts with associated behavior. Informing the public that the storm surge will "cut off the bridge by midnight" is a clear indication that one should not travel on that bridge. There is an implication of a behavioral message, but the forecaster never states it due to liability concerns.

Third, meteorologists feel that there is a high level of public complacency concerning hurricane threats. As one government meteorologist suggested:

> I think we're doing just about everything we can. I know the emergency managers up in the Northeast and in NY are beating the drums constantly, but I fear that it's falling on deaf ears up there. We haven't had one since 1938. That's 60 years ago, 50, 60 years ago, what's the problem? 70 years now, so, there's a lot of complacency in there, and unfortunately sometimes it takes a hurricane to wake them up.

This apparent complacency with the public is also influencing how the forecasters feel about communicating behavioral actions. For example, in the case of Hurricane Charley, one meteorologist questioned "whether [an] evacuation would have made any difference [for the Port Charlotte area], because there's a lot of people who won't leave their homes no matter what you tell them." The influence of the public's complacency on forecasters may preclude them from thinking about communicating behavioral actions.

Lastly, and more importantly, meteorologists believe that the responsibility of communicating actions lies with the emergency managers. Recall a quote used in a previous section that shows this distinction in responsibilities. It stated, “We produce the meteorology, the impacts, you know, expected impacts on the infrastructure and on people's lives. It's something we can communicate, but they have responsibility for protecting, okay, when push comes to shove.” This government meteorologist divides the responsibilities into two categories: (1) communicating the impacts, which is the responsibility of the weather community, and (2) communicating how to protect the people, which is the responsibility of the emergency management community.

Further, when asked if people should take specific action when looking at the graphic, another government meteorologist responded with, “*Absolutely not*. I want them to listen to their local decision makers.” Again, the forecaster presents what looks like a clear division between communicating impacts compared to communicating actions. What is perhaps more interesting, however, is that prompting someone to “listen to their emergency managers” is an action. It requires a person to continue watching the TV, to look up their emergency manager’s website, or perhaps to read evacuation orders in a newspaper, all of which require action. The meteorologists in this study appear to have a limited view of what action or behavioral messages entail.

In fact, as the rest of this section will show, there are a myriad of behavioral actions that meteorologists want to prompt.   The major difference among these actions is when to communicate them. Hurricanes are a moving risk. Unlike cancer, vague terrorism threats, or soil contaminants, forecasters and the public alike have the ability to watch the risk, the hurricane, move closer to or away from the United States. Because it is a traveling risk, there are unique actions associated with the amount of time (t), that the risk is away from landfall. For example, emergency managers on average issue evacuation orders 48 hours before landfall, perhaps as early as 72 hours for extremely vulnerable cities such as New Orleans. The strongly suggested behavioral action at time equals 48 hours before landfall (B_t=B_{48}) is to act on the evacuation orders. The concern is meteorologists are communicating the threat and potential impacts as soon as the hurricane forms, which could be more than a week a way from landfall, if it *ever* makes landfall. If meteorologists are truly transferring all behavioral responsibility to the emergency managers, as they state they are, then how do meteorologists explain, if at all, the actionable responses that people may take at these different times?

After coding the interviews, there are five distinct time frames that have actions associated with them. In sequential order, they are the beginning of hurricane season (June 1st), the formation of a hurricane, the 5-day cone, the 3-day cone, and the 48 hours before landfall. As the beginning of hurricane season approaches, public officials, emergency managers, and meteorologists stress the importance of preparedness. As one forecaster outlined, "You have to get down to the individual level. Absolutely. And that's why I always like to say that every individual, every family, every person in the community should have a hurricane plan in place before the hurricane season even starts." Another forecaster resonated with these sentiments and further explained,

> For any given point from the Yukatan to the Carolinas, the chances that they're going to get hit is very small. So what sort of thing should you make to sort of … the only thing you should make sure, which is what I think is the most obvious course of action for anybody, is to say, well, I have to make sure I have all the cards in place, that I know where I live, that I know when something is a watch or warning. Do I live in an operation zone? Is my home properly prepared? If I have all the instruments, all the tools to prepare my home come the time that I need to take action. Life goes on, you know.

The main message as June 1st nears is to prepare the individual, their family and their belongings for the chance of a land falling hurricane in their area. This is the actionable item communicated at the beginning of hurricane season.

Disappointedly true, though, most people are not prepared as hurricane season begins. The Hurricane Survival Initiative, a public private partnership that surveys the public regarding hurricane preparedness, states that for the hurricane season of 2007, 52% did not have a family plan, and 61% did not have a hurricane survival kit, which includes items such as, first aid materials, flashlights and batteries, and most importantly, enough food and water per person for at least 3 days (National Hurricane Survival Initiative, 2007). It is not surprising, then, that meteorologists include preparing hurricane kits in their message once it is known that a hurricane is going to threaten land.

Before a hurricane hits land, however, the hurricane must form in the Gulf of Mexico or somewhere in the Atlantic Ocean. This is not necessarily the time to induce fear as the hurricane may or may not become a threat to the United States. As one private sector forecaster remarked:

> If it's out in the Atlantic Ocean, the first thing we try to do is tell people "is this going to be a threat to the United States or not?" or, "we can't tell yet". So the first thing is, we need to stand by if it's a long way out, we can't tell yet, or just from what it's not a guarantee yet. But it looks like this is going to turn to the North and not become a threat to the US, but keep watching just in case. Don't turn your back on it yet. We never tell them to turn their back completely 'cause if you're wrong and they turn off the TV for 5 days they're doomed.

As this forecaster outlines, this is not the time to frighten people about the threat, but it is the time to increase awareness that there is a risk out there. Furthermore, the actionable item at the hurricane formation stage is to "keep watching." As the forecaster observes, there is another risk to turning off your TV for the next few days.

Being unaware about a potential risk does not allow you to take *any* preparedness actions.

Once the hurricane reaches a distance comparable to five days away, this is where most meteorologists have a distinct message. As one meteorologist stated:

> If you didn't do the preparations at the beginning of the hurricane season like you were encouraged to do, which most people unfortunately don't, then that's your opportunity to reevaluate the stock of your own personal preparedness and take advantage of that as being your 5 day window to take care of those things you should've already done.

The 5-day window is denoted by an extended cone with dashed lines, as used by the NHC, or by different color shadings, as with the private sector. The forecast uncertainty for day 4 and 5 is much higher than that of days 1-3. Thus, the action to take and to communicate at this moment is to start or finish making your hurricane preparedness kit.

Furthermore, many meteorologists emphasized the action of listening to emergency managers stating, "They better listen to their emergency managers," "I want them to listen to their emergency managers," or, "Take actions according to what the emergency managers tell them to do or recommend them to do." This was a major theme from most of the interviews. Emergency managers typically issue evacuation orders 48 hours before an area begins to feel hurricane impacts. Decision makers do not want individuals driving through evacuation routes while beginning to feel the impacts from a hurricane. Because of this, meteorologists identify the 5-day cone as a good indicator to start listening to emergency manager orders.

Once an individual is in the 3-day cone, the threat of feeling impacts from a hurricane drastically increases. As one forecaster explained, "If I'm in that [5-day] cone, I've got to keep monitoring the situation and see where it is [heading]. If I'm in that 3-day area, heck, I need to try and make my hurricane plans." This forecaster, again, stresses the importance of monitoring the storm, but even further, when an individual is in that 3-day cone, one should begin to implement their plan in accordance with the emergency management message.

The 3-day cone shows that the *center* of the hurricane is three days away. Depending on which variation of the cone one looks at, it may or may not be clear that the individual my feel the impacts from the hurricane, due to its size, earlier than those three days. To help communicate this threat, the NHC in coordination with the NWS, issues tropical storm and hurricane watches and warnings. The NHC issues a tropical storm watch when, “tropical storm conditions, including winds from 39 to 73 miles per hour (mph), pose a possible threat to a specified coastal area within 36 hours.” They issue a tropical storm warning when “tropical storm conditions, including winds from 39 to 73 mph, are expected in a specified coastal area within 24 hours or less.”

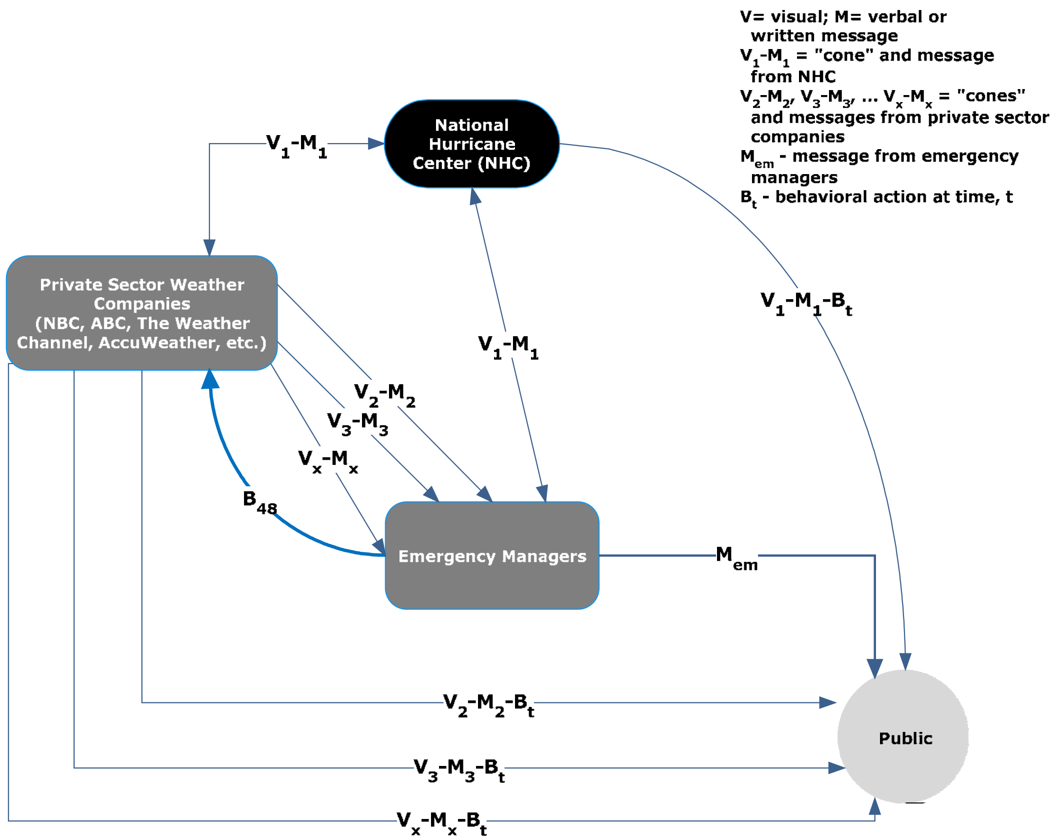

Figure 5. The visual process of the cone of uncertainty with its associated verbal or written description as well as its associated behavioral actions at time, t.

The same time frames apply to hurricane watches and warnings, but the winds must reach a sustained level of over 74 mph (NOAA, 2008). Meteorologists also identified the watches and warnings of the 3-day cone, as action inducing characteristics.

For example, one forecaster explained:

> Once the watch goes up, then you're going to have to start putting that plan into action. And especially true is that when that warning is issued then that's it. You either stay or you go depending on what your plan is, and then you do it. Simple as that. Get that hurricane plan in place.

Another forecaster described the meaning of a warning explaining, "When you see 'hurricane warning,' that's not a forecast. That's a headline. That's there to invoke an action." Bottom line, meteorologists use tropical storm and hurricane watches and warnings to evoke action, whether its stay tuned, listen to emergency managers, or get "out of Dodge."

Despite many of the meteorologists suggesting that the cone of uncertainty does not have behavioral actions associated with it, this section shows that their statements could not be farther from the truth. Although meteorologists do not give individual orders to evacuate, they do promote numerous behavioral actions such as listening to emergency managers, developing hurricane preparedness plans, and staying tuned to hazard updates. Figure 5 on the previous page summarizes the addition of the behavioral message to the life of the cone of uncertainty. Meteorologists need to be more aware of the role they play in communicating these behavioral messages, as it is these messages that may increase an individual's self-efficacy, that is, their willingness to believe they have the ability to respond to the threat.

Are Both the Message Objectives and Behavioral Actions Objectives, and If So, How Do They Relate To the Visual?

The initial response to the question, “Do you want people to take any action from this graphic,” sparked a flurry of reactions from “absolutely not” to “there’s very little actionable information that someone can and should be taking away from this graphic.” As the previous section shows, though, behavioral actions typically follow from these sharp reactions. One private sector forecaster demonstrated this dissonance. First, in response to action from the graphic, this meteorologist stated, “Based solely on the graphic, I would say no.” He followed with this:

> I would say you definitely need to start doing your own research, read the article [written forecast], because the graphic is just a supplement to the article. We emphasize that you go back and read the warnings. You go to a separate link on the application that has where we display the hurricane warnings and hurricane local statements.

By the use of phrases such as, “start doing,” “read,” or “go to,” the forecaster implies that there are behavioral responses to the graphic. What is possibly more important is what this forecaster offered just moments after:

> People are going to take action. It’s a perfectly human natural reaction to see that your area is in this cone and you know, or is highlighted based off the cone. Being targeted by a hurricane you feel that you need to do something. There’s no doubt about it that that’s a perfectly natural thing. Then comes along educating what to do when you reach that point of, I need to do something, you know, and that’s where the article comes in. Go to your weather link and read the local hurricane statement. Then basically educate them that there is now a decision making process that they have to make and making sure that they are referred to the right direction and the right group of people and help them make the right decisions they need to make in order to save their property, their lives and so on.

This particular statement is the closest assessment to the truth. People will take action.

Despite the fact that meteorologists do not identify a behavioral response as a message objective, it appears that through all of their responses, behavior does play a crucial role. Further, as protection motivation theory describes, people’s initial reaction to the graphic will include assessing their risk or perceiving a threat and wanting to take some action to alleviate this threat (Neuwirth, Dunwoody & Griffin, 2000). The combination of these two statements suggests that the behavioral message might potentially be more important than any other message objective initially identified by the meteorologists, which leads me to ask, what is the desired impact of the graphic and its associated message? Is it more important for individuals to understand the science of the cone of uncertainty, or, is it more vital for individuals to respond appropriately? What *is* the ultimate goal?

After reviewing all the interviews, it appears that meteorologists want both. One government meteorologist explained, "Ultimately, we want people to take action." This is true, but in order for people to take that action they must first accurately understand the general science and assess their risk. There is a relationship from the forecaster point of view, then, between the visual and its associated written or verbal message as well as with its associated behavioral message. First, the written or verbal message may help the individual focus on specific aspects of the graphic in turn helping them assess their risk. Second, depending on where the individual's location falls on the cone of uncertainty, that location at time, t, has a specific behavioral message associated with it. Figure 6 (See Appendix C) tries to outline all the potential message and behavioral components of the cone of uncertainty, as stated by the meteorologists in this study.

Summary

This chapter identified three main message objectives for the cone of uncertainty including scientific uncertainty, risks or impacts, and confidence. Furthermore, this chapter showed how there are distinct behavioral intents at different times associated with the graphic. Although meteorologists are hesitant to communicate behavioral actions, their responses show that behavioral messages are just as important as communicating scientific uncertainty and impacts. The next chapter will define visual framing, and compare some of these objectives to the design of the cone of uncertainty.

CHAPTER 7

VISUAL FRAMING

Overview

Now that the messages of the cone of uncertainty are clear, the last step is to compare the relationship between these message and behavioral objectives and the design of the visual. Much of visual literacy is a subjective process, as outlined in Chapter 5. There is, however, an entire body of literature that suggests, for example, that the design of visuals should follow a certain process (Tufte, 1986), and that there is a relationship between visuals and their associated message (Braden, 1994; Lang, 1995; Mayer, 2001). How well or not well does the cone of uncertainty match its messages? How does this (mis)matching impact the public's understanding or perception of the risk? What does this mean for other risk visuals with associated messages? The chapter will explore whether the messages and behavioral intent of the cone of uncertainty do indeed match their associated visuals. This chapter will also define visual framing.

It is worth noting that this chapter will not make a theoretical comparison between framing of verbal or written messages as compared to visual framing. The meaning of framing has a long and debated history in communication that goes beyond the scope of this thesis (Scheufele, 2000). This thesis will only develop the idea of visual framing, but future research should focus on the direct comparison between both types of framing.

The quotes used in this chapter fall under the visual framing code, which I developed during the second phase of coding.

Defining Visual Framing

Visual framing, although a new concept for scientific or risk visual design, stems from many developed areas of literature. From visual displays (Tufte, 1986) to cognitive theories of multimedia learning (Mayer, 2001) to the effectiveness of visuals on TV (Lang, 1995; Zhou, 2005), the foundation for visual framing exists. This new concept, however, must pull together all of these literatures to become a viable concept that will potentially influence the creation of risk visuals, such as the cone of uncertainty.

Researchers studying the effects of visuals in TV news use the term "channel semantic relatedness" or redundancy. These terms capture the idea that both visual and verbal channels presented in TV news need to have a certain level of relatedness. Summarizing the works of Lang (1995) and Reese (1984), Zhou states, "Most researchers defined redundancy as shared information between the audio and visual channels, such that they are facilitative and not contradictory relationships between words and pictures" (2005, 25). For example, if the audio refers to science budget cuts, a picture of lawmakers is more effective than a picture of scientists in the lab, as the emphasis is on lawmakers cutting the science budget not on laboratory scientists.

Mayer's work may explain why that is and offer the foundation for visual framing. First, when using both verbal and visual information to communicate a message, a person must process both types of information simultaneously, but as researchers show there are separate channels for verbal versus visual processing (Paivio,1986) . Further, there is a limit to how much information each channel can process simultaneously (Baddeley, 1992; Chandler & Sweller, 1991). Lastly, as suggested earlier, individuals will use their prior knowledge and combine it with the newly processed visual and verbal data (Mayer, 1999).

Using this information, Mayer suggests that there is a process of integration between the separately processed visual and verbal information. He states,

> It involves building connections between corresponding portions of the pictorial and verbal models as well as relevant existing knowledge from long-term memory. This process occurs in visual and verbal working memory and involves the coordination between them.

Thus, for the cone of uncertainty, individuals must first separately process the visual and the verbal or written message, and then integrate that information to form an understanding of the material. Mayer continues to look at this phenomenon by focusing his attention on presentation space between visuals and written messages or the timing of presentation. Although Mayer does suggest that extraneous words on visual drawings may inhibit learning, to date, Mayer has not looked at visual design features such as how well the visual design corresponds to the verbal message to increase learning.

Mayer's work provides the foundational literature to suggest that maximum learning occurs when visuals and verbal messages correspond, so as to make the 'integration process' as effortless as possible. Tufte's (1986) work, on the other hand, focuses on the details of graphical data such as, how to present the data, the use of colors to express quantitative information, or the idea of erasing unnecessary ink. Although Tufte's work has direct applications and suggestions for the visual in this case study, his work does not consider nor does it experimentally test the direct implications of these suggestions on the public's understanding of the visual, their risk perception, nor their potential behavioral response to a graphic. What he does offer are a number of potential visual design techniques that forecasters could incorporate into a new design for the cone of uncertainty.

Combining these literatures, then, it follows that specific design techniques may help a visual and verbal model correspond more appropriately, subsequently maximizing multimedia learning even further. As Mayer explains, integration requires an individual to associate corresponding parts of both the visual and verbal message. Perhaps for the cone of uncertainty, the visual and verbal message does not have adequate correspondence to maximize learning. Instead, the divergence between the visual and verbal integration may influence the individual to focus solely on either type of message. In fact, Drew & Grimes (1987) suggest that when a visual and verbal message does not have high correspondence, it forces the individual to focus more on one channel, in essence, creating a competition for attention between the visual and verbal message. If the creator uses purposeful design, that is, if they visually frame their graphic to match their verbal objective, then it is conceivable that a person may integrate the information more accurately. Visual framing is a technique to help increase the correspondence between a visual and verbal message whereby the creator purposefully designs the visual to match the verbal message.

To look at this potential phenomenon, three examples will be discussed. Example 1 will focus on when a visual does not match its message. To do this, the NHC's version of the cone of uncertainty will be used to show how the visual framing, the skinny black line, does not match one of the message objectives to emphasize the importance of the track uncertainty. Example 2 will focus on when a visual does not match its behavioral action. To show this, all the variations of the cone will be compared to the behavioral action at the 5-day cone at potential landfall, which is primarily to listen to emergency managers. Lastly, example 3 will show a case where the visual is in agreement with one of the verbal messages. This case will focus on the use of visual watches and warnings on graphics as compared to the message objective to explain the impacts and potential risks to an area. This example will look at positive visual framing, but then suggest other potential variables that may cause misinterpretations.

Example 1 – What If the Visual Does Not Match Its Message Objective?

Most of the behavioral actions from the cone of uncertainty discussed in this thesis stem from the cone at 5-days, 3-days, or 48 hours prior to landfall. Meteorologists identify the cone as an important design feature not only for communicating track uncertainty, but also to emphasize when to take action. The last aspect of the 3-day cone that evokes action is the most controversial. It is best described as the "skinny black line," although it, too, undergoes design facelifts (See Image 4 and 8, for examples). According to the meteorologists in this study, the "skinny black line" is often mistaken as the action indicator, instead of the cone. One government forecaster explained:

> You have the problem that people will only react if they're near the track itself. In fact, you saw this with Charley. We had a very good forecast for Charley, as far as I'm concerned. I mean, we had it moving right up the west coast of Florida, up towards Tampa, and then within 50 miles of landfall where it was actually predicted, it made a sudden turn to the right. It made landfall 50 miles further south. The people react you know. 'I'm following the track, following the line.'

As stated previously, the people of the Port Charlotte/Punta Gorda community did follow the line, not the cone, and this had its repercussions. Further, another private sector forecaster described people's reactions to the line stating, "They were watching the line and saw, 'the lines going up there. We're fine.'" The message coming from the forecasters, though, is that if you are in the cone, you are not fine. In other words, stop focusing on the line.

As previously stated, meteorologists identify the cone as the action indicator, not the line. Yet, the public, it appears, focuses more attention, or perhaps processing time, on the "skinny black line." Although this study cannot prove that the "skinny black line" is causing misinterpretations, it does suggest that it is, at the very least, one main concern. Recall that the top two emphasized message objectives include scientific uncertainty and impacts, while the number one behavioral action message is to listen to emergency managers. The proposed problem is that the design of the "skinny black line" represents poor visual framing compared to its associated verbal message to focus on the white cone, the uncertainty of the track.

Meteorologists in this study emphasize that the cone is of vital importance. The 'skinny black line' is present on the visual to show the most likely track of the center of the hurricane. The relationship between the black line and the cone is that the black line could potentially move anywhere within that geographic boundaries of the cone. There is not a stark difference between the two. The line shows the most confident forecast, whereas the cone shows the uncertainty. The area of concern is that for the NHC's cone of uncertainty, they chose colors that show a stark difference, almost an opporsite relationship between one another. According to Krygier & Wood (2005), choosing black for the line generates words such as mystery, strength, or heaviness. Alternatively, for the white cone, the white color generates the words purity, clean, faith, and illness. Thus, the 'skinny black line' indicates strength and heaviness compared to the white cone, which indicates purity and faith. The public may focus on the black line due to the saturation of the color black compared to the white cone. The white cone, representing uncertainty, appears less important using a "pure", light color.

Combining these color features with the message objective to focus on scientific uncertainty creates a conundrum. It is possible that the colors will attract the viewer to focus on the 'skinny black line,' while listening to the broadcast meteorologist emphasize the scientific uncertainty of the storm path. In this scenario, the person may experience confusion as they begin to integrate a visually, 'strong and heavy' black line with a verbal message to concentrate on uncertainty.

Visual framing, in this example, is not saying that colors are not effective, but it is suggesting that the use of colors, or hues and saturations of colors, should more accurately represent the message objective. A potential example of visual framing is to emphasize the relationship between the cone and line by reducing the color contrast to shades of gray. In doing so, it may create the connection necessary to relate the cone and line, while allowing the individual to relate the verbal uncertainty message to the graphic.

Alternatively, if the line is not the focus of the message objective, then simply take the line off the graphic. Image 5 is an example of a variation of the cone of uncertainty without the line.

Visual framing in this example shows how a creator of a visual can purposefully design their graphic with their message objective in mind. This study does not prove that these changes in visual framing lead to increased understanding or more accurate risk perception. Nevertheless, it does offer potential ideas to link the visual design with the message objective with the hope to provide easier integration for the person processing the information.

Example 2 – What If the Visual, Does Not Match Its Behavioral Message?

Although understanding the science and taking appropriate behavioral action are both important, ultimately, forecasters and emergency managers want individuals to focus on implementing actions that will protect their lives. After all, the NWS's mission is to "provide weather, hydrologic, and climate forecasts and warnings for the United States,… for the protection of life and property and the enhancement of the national economy" "(NOAAb, 2007) Knowing this, the importance of understanding that the cone of uncertainty is the 66th percentile of the mean average track error over the last five years begins to dwindle. As the previous example shows, it is not the exact size of the cone that matters, but how an individual reacts to the cone.

Even if both the message objectives as well as the behavioral actions are important, meteorologists still tend to emphasize the scientific side of their work more when designing visuals. Looking at image 1, the cone of uncertainty as well as Image 9, the newer NHC wind probability graphic, the first reaction is that it is a science tool to help decision makers, but not a tool to indicate what decisions to make. The visual framing, the design of the graphic, suggests that the focus is on the message objectives of scientific uncertainty or potential impacts. Despite the fact that there is a lot of text on the graphic, none of the text indicates what to do, who to call, and where to find out.

Currently, the design of most hazard graphics occurs from a top down approach. As noted earlier, meteorologists do not have unlimited time to have transactional communication with the public to gather their feedback. Instead, most, if not all, graphics show the scientific perspective. This perspective, however, does not match the verbal message to "get out of Dodge," or to listen to your emergency managers. An alternative design approach could visually frame the graphic from a bottom up perspective.

This unconventional approach includes designing the graphic from the behavioral perspective. Much of the cone of uncertainty may remain intact, but with a change in approach. For example, one meteorologist explained, "If you were close enough to that track … then know you should expect damage within 50 miles of landfall." First, the track is referring to the contentious black line, but the forecaster provides one more characteristic. If an individual is within 50 miles of either side of the black line, then that person should expect damage, and subsequently take some action. Combining this with liability concerns, the 'black line' should first be drawn to scale to represent the 100 miles of expected damage, and second, the area covered by the 'black line' should represent the order to "listen to your emergency manager."

The rest of the cone represents a forceful, yet slightly less powerful message of "Stay tuned to your emergency managers." Image 10 is a mock up of such a graphic. Though this graphic is far from perfect, it helps to incorporate the behavioral message while still showing the size and track of the cone. As a forecaster stated, "People are going to take action. It's a perfectly human natural reaction to see that your area is in this cone … Being targeted by a hurricane you feel that you need to do something. There's no doubt about it that that's a perfectly natural thing." Indeed, it is, but when looking at the cone is it more important to understand what the cone means, or to prompt that individual to look up local official's evacuation orders as their next step?

Visual framing in this example shows how a creator of a visual can purposefully design their graphic with the behavioral action in mind. Again, this example does not prove that these changes in visual framing lead to increased positive behavioral responses such as increased evacuation numbers. Even so, it does offer potential ideas to link the visual design with the behavioral intent with the hope to provide easier integration for the person processing the information.

Example 3 – What If the Visual Does Agree With the Verbal or Written Message?

The first two examples of visual framing show how to redesign the graphic to more accurately express the message objective or behavioral action in a visual. Example 3 focuses on an aspect of the visual that does match the message objective. In other words, this visual and objective are already highly visually framed. Visual framing is a potential tool to increase the proper integration of visual and verbal or written information. It, however, is not the only variable or relationship of concern.

Earlier in this thesis, it found that there is a link between two message objectives, the storm track and the impacts. It showed that the uncertainty of the track relates to the uncertainty of where the potential impacts are heading. It also explained that the NHC in coordination with the NWS issues hurricane and tropical storm watches and warnings to alert people about these potential impacts. These watches and warnings are quite visible on NHC's cone of uncertainty. The visible watches and warnings on the graphic correspond well with the verbal message to focus on impacts. This is an example of positive visual framing.

Despite the positive visual framing from the meteorologist perspective, one question still emerges. Does the public understand the link between the visual watches and warnings and their relation to verbal impacts? The visual shows that there are clear warnings, and the message objective is stressing the impacts, then what is wrong?

As stated previously, there is a variety of impacts related to each storm, and even further, every storm has varying levels of intensity. The combination of this fact reveals what the public and forecasters alike already know: no two storms are alike. Yet, every storm has the same 'warning' associated with it. Once a storm reaches hurricane strength and it potentially threatens U.S. land, the NHC in coordination with the NWS issue a hurricane warning. It is possible that this visual use of color-coded warnings as well as its associated message, "it *is* a hurricane warning," is not sufficient, and at least a few meteorologists agree. One said, "The Weather Service has a very convoluted, complicated way of communicating watches and warnings and advisories. Extremely, extremely complicated." Another stated, "I hate the watch and warning too, they're warped, but that's another … ." Further, one private sector meteorologist explained, "I'm not going to deal with the cone, the watches and warnings. I almost never show those. Only if, if there's something unique and interesting I can say about it other than just showing that watch warning graphic. I won't even show it." It is apparent that there is disagreement as to the success of communicating risks through watches and warnings suggesting that the message must include a more detailed description of *this* hurricane's potential impacts. Even further, this evidence suggests that not all design frames will highly correspond, despite the intent to match the visual and verbal message.

Meteorologists would argue that extended detailed information exists through the NWS public advisories, private sector descriptions of impacts on their websites, or through additional impact graphics. If the visual shows the warning, and the message is providing the additional information regarding impacts, then what *is* wrong with this Vx-Mx relationship? Perhaps, it is the medium. This study cannot clearly state whether this is a problem or not, but if the hypothesis holds that visual framing and message framing must correspond to one another, then the next variable of interest is the medium. How easily accessible are the written descriptions? What medium, i.e., newspaper, Internet, etc., are they printed in? What percentage of the population has access to this medium?

Further, if the Vx-Mx relationship is on TV, are they presented in a timely manner such that a person can process both messages simultaneously? If the processing of one message, either visual or verbal, happens prior to the other, then how does this affect the person's understanding? Then again, does the presentation of the Vx-Mx relationship have to happen simultaneously to ensure ultimate understanding? If not, is there a difference in understanding if one is presented before the other?

This example shows how visual framing can appear to exist between the visual and verbal or written message, but as further analysis showed, not all visual frames correspond well with the message. Again, this example does not prove that changes in visual framing of watches and warnings will lead to improved risk assessment. Even more, this example proposes that visual framing may not always be the variable of interest, showing that how these messages travel, through what medium, and when is also of interest.

Summary

This chapter provided examples of where the cone of uncertainty does not correspond to its message or behavioral intents. As the literature states, to maximize learning it is best for the verbal messages to correspond with its visual. The idea behind visual framing is that it forces the creator of a visual to purposefully design the graphic to match its verbal message. The next chapter will discuss the implications of all the results on the life of a visual.

CHAPTER 8

SUMMARY & CONCLUSIONS

Overview

As this thesis shows, the life of a visual is a complex process. Chapter 4 explored the creators of the cone of uncertainty showing how government and private sector institutions added to the designs of the graphic. In addition, this chapter identified the types of communication that occurs within this visual communication process. Chapter 5 began to explore the concept of visual validity assessing the cone of uncertainty's ability to stand alone. As this graphic is a visual communicating risk and complex science, this chapter suggests that the cone of uncertainty must have an associated explanation. Chapter 6 reviewed the explanations and objectives for the cone of uncertainty. It found that the top four objectives for the cone of uncertainty are the following: (1) scientific uncertainty, (2) risks (or impacts), (3) confidence, and (4) listening to emergency managers. Chapter 7 examined the relationship between these objectives and the design of the visual. In doing so, the concept of visual framing was developed.

The rest of this chapter will explore the implications of these findings, pose future research questions, and conclude with the overarching themes of this thesis.

Types of Communication and Audience Analysis

The analysis of the transmissions, transactions, and deficits of how communication functions in meteorology begins to shed light on a visual's life, in particular, on a science visual's life. Although it would be easy to think of a visual as having a linear life juxtaposed between two worlds, those of the creator (the scientists) and those of the reader (the levels of the audience), this case study shows that it is not that simple. As Lewenstein (1995) has shown, science communication does not sit within a neat and simple framework, but rather it sits in a web of complex institutions, disciplines and mediums. This complex web, then, entangles the life of a visual as it springs among the multiple nodes (See Figure 3 on page 58).

The analysis of this case study introduced many nodes in which the cone of uncertainty must travel. First, the interviewees from most institutions have stressed the need for a consistent message allowing the NHC to devise their official hurricane track forecast. The NHC acts as an opinion leader setting the stage for the scientific part of the forecast and allowing others to disperse this message. Second, the message, that is, the forecast, is distributed to their partners, and then the official NHC graphic is circulated to the public through the Internet or potentially other media outlets. Government forecasters in this case identified two groups as their key partners, broadcast meteorologists and emergency managers. This is where the life of a science visual begins to weave its intricate web.

First, broadcast meteorologists take the official forecast and repackage it, sometimes tweaking the science, and always giving it a facelift. The cone of uncertainty is the queen of design facelifts as companies like The Weather Channel, NBC, ABC, CBS, AccuWeather, or the WeatherBug place their own graphical touch to the original design. In fact, companies like WSI, Inc, or Weather Central provide graphical software designed to allow each user to have their own unique look. Because the cone of uncertainty is a visual that receives a lot of media attention, it is influenced not only by scientific accuracy by the meteorologists but also by the pressures that go along with media marketing. These pressures create variations of a cone (Images 5-8). This variety in design raises a very important question. If all institutions use the same forecast, but entirely different visual designs, then does this change the consistency of the message? In other words, can different visual designs change the scientific message associated with the visual?

Although that question is beyond the scope of this particular case study, it raises concerns for the next partner, the emergency managers. While the broadcast meteorologists are repackaging their visuals, the emergency managers are now receiving the forecast, and graphic, from the NHC. Soon after, they could also be gathering the variations of the cone from private sector institutions. This information gathering eventually leads to evacuation decisions, which are then distributed to the public. The question is, how do these multiple images with multiple objectives change the emergency managers risk perspective, if at all?

The public has now received visuals from a plethora of places from the NHC to ABC, from the Internet to the newspaper, and everywhere in between. One more question must be raised. To counter the question above, is visual variety of a consistent scientific message a negative part of this process? Although this thesis does not focus on the public, literature shows that people respond differently to varying designs of visuals such as risk ladders (Lipskus & Hollands, 1999), attractiveness of colors (Garcia & Fry, 1986; Wells, Burnett & Moriarity, 2000), emotional response to and past experience with colors (Detenber, Simons, and Reiss, 2000; Kaya & Epps, 2004), reactions to symbols (Tversky, Zacks, & Lee, 2000; Monmonier, 1993), and map projections (Mijksenaar, 1999), etc. With this knowledge, citizens have the freedom to find a station or source that has a visual design, which may be more understandable for them.

The process of mapping out the life of the cone of uncertainty showed the complex nature that visuals must travel through. This case study identifies many characteristics for the cone, such as facelifts, multiple sources and several mediums. Are these characteristics systematic of all science visuals? Do all science visuals travel through such a complex web, or is there something unique about this case study? The answer cannot be found in this study alone. What this study has shown so far is that there are many nodes, or variables, that visuals may travel through during their existence. This journey may subsequently affect the message, positively or negatively, once it arrives with the reader. As Chapter 5 showed though, a risk visual rarely travels by itself but rather requires an explanation to achieve visual validity.

Visual Validity in Relation to Message Objectives

The concept of visual validity places weight on both the design of the visual as well as the verbal or written message associated with it. As Chapter 5 indicated, the cone of uncertainty is not a visual that can stand alone but one that must have a written or verbal message to achieve high visual validity. Recall that visual validity is an analytical construct to describe how accurately a reader's meaning of a visual matches that of the creator's intent. Although *this* risk visual requires high visual validity, it remains unexplored as to what other types of risk visuals may also fall into this category. The idea that risk visuals may require additional written or verbal description is potentially critical to ensuring that people understand the communicated risk message. More risk visuals need assessment to determine if high visual validity is a feature of all risk visuals.

If it is a feature of all risk visuals, as it is for the cone of uncertainty, then the life of these visuals just became more multifaceted. As stated previously, visuals do not sit within a simple framework but rather function in a complex web of science communication. Many research questions follow from this intricate web. For example, imagine how visuals change their design through the institutional dimensions of this web. Now, introduce the idea that there is a relationship between a visual and its associated written or verbal message. Imagine how these visuals and their associated written or verbal message change throughout the complex institutional dimensions. How does institutional flexibility and constraints alter the visual design process? The focus shifts from not only the effects on the visual in the complex web of science communication, but also between the visual and its associated verbal or written description (See Figure 4 on page 76). Recall that Chapter 6 unveiled four main objectives for the cone of uncertainty: (1) scientific uncertainty, (2) risks (or impacts), (3) confidence, and (4) listening to emergency managers. The question is how do these different objectives relate to the visual, and how does this affect visual validity, if at all? What this does suggest, however, is that visual validity may be dependent upon the design of the visual as well as the objective attached to the visual.

Further, depending on the medium, a visual and its associated message may not always travel in tandem. TV, for example, strives for no silence, which would require talking while looking at a graphic. The Internet, on the other hand, allows for more flexibility. There could be a video clip with the graphic with audio, or alternatively, there could be a picture of the graphic alone or perhaps with a written message. The variable of interest is now on the relationship between the visual and its associated message. How do these two messages, visual and verbal, relate? How does the placement or timing of these associated variables change the communicated outcome? Are people more likely to process the visual or the verbal or written message objective if they do not travel in tandem? How do the answers to all of these questions relate back to visual validity? What are the requirements to ensure high visual validity for those graphics that require it?

Exploring Relationships Between Visuals and Their Objectives

The relationship between a visual and its message objectives plays an important role not only for the cone of uncertainty but also for other risks. As described earlier, hurricanes are a moving risk, which requires different behavioral actions at particular times. Time is associated with the risk's sense of urgency. As the hurricane approaches landfall, the 5-day cone, the urgency increases, and even further increases in a 3-day cone. Other risks have a sense of urgency as well. Cancer diagnoses typically include what stage an individual is in indicating the level of urgency and its associated medical actions. Even a child's risk of failing a class has a number of signs such as, performing poorly on home works or in class exams, easily distracted in the classroom setting, or perhaps struggling with a personal issue such as a death in the family, or a separation of their parents. Depending on which sign is present, and the urgency of the situation, the teacher and parents may decide to hire a tutor, see a counselor, or simply spend more time with the child. All risks have stages of urgency that help determine which behavioral action an individual should take. Although not all of these examples have corresponding visuals, these examples do show the importance of associating the message, either visual or verbal, with its associated behavioral actions.

Knowing the relationship between a visual and its counterparts are critically important. The life of a visual is not as simple as just designing it but may require systematic thought about what the message objective and behavioral message is and how this relates to the design of the visual. Looking at Figure 5 on page 83, one can see how complex the relationships may become between a visual and its associated intents. If a visual has too many verbal or written message objectives, then one visual may not be adequate in communicating all the ideas. Indeed, many forecasters in this study alluded to the fact that many graphics exist, as they believe that one graphic cannot tell the entire story. This may be true. When communicating risks, however, it may also be important to emphasize or prioritize the order of communicating these objectives, as individuals at risk may not have long periods of time to listen to *all* the information. This point resonated with broadcast meteorologists who are under pressure to keep their forecasts under a specific time limit.

From a practical point of view then, before designing a risk visual, and even before communicating it, the creator should consider all possible message objectives. For the forecasters in this study, the objectives initially identified are scientific uncertainty, impacts, and confidence, and with further analysis behavioral components, such as listening to emergency managers, were also identified. Depending on the audience, different objectives may need emphasis over others. Since emergency managers are deciding when to issue mandatory evacuation orders, emphasizing the uncertainty and impacts may be more appropriate. If the audience is the public, then forecasters may want to emphasize the behavioral component of the graphic. Just as meteorologists suggest that one graphic does not tell the whole story, one objective does not adequately fit the whole audience.

After considering all the potential message objectives, the focus shifts to their relationship with the visual. Can all four objectives from above fit the design of each variation of the cone of uncertainty? Further, how do the different objectives when paired with the NHC cone of uncertainty, for example, change how people perceive their threat, their understanding of the science, or their potential behavioral actions? Is it possible that different message frames paired with the same graphic changes how a person processes that information?

Even more, recall an earlier discussion on how broadcast meteorologists *do* explain their message objectives while showing the cone of uncertainty. I stated, "If broadcasters are [explaining their message objective,] and if [the public] are listening to it, then one would surmise that the public would interpret the graphic correctly. Yet, as the literature has pointed out, there is some evidence to suggest that this is not the case." With Broad et al (2007) indicating public and media confusion regarding the graphic, as well as anecdotal evidence from media coverage of Hurricane Charley, the evidence indicates that people may potentially be focusing on the graphic more than the potential message frames. This raises a question concerning the relationship between a visual and its message frames. If the focus is more on the visual than the message, then perhaps creators of visuals must design their graphic with a purpose in mind. That is, creators must visually frame their graphics to correspond to their message objectives. The next section will discuss the implications of visual framing.

Visual Framing

Although not conclusive from this data, visual framing is a viable concept that may help explain why multimedia messages become confusing providing the grounds for misinterpretation. The cone of uncertainty is at least one example of how a visual has many potential relationships with its associated verbal or written messages. It is easy to see how the integration of all of these relationships might create difficulty for an individual. Visual framing is a worthy area of research that may offer insight into how multimedia messages can create effortless integration for the readers of such information. For the field of risk communication, and especially for hazards such as hurricanes, visual framing may hold the key to effective multimedia communication with the hope that readers may successfully understand the science, perceive their individual risk, and take appropriate action. In essence, if visual framing is an effective tool for communicating science, risk, and action, then visual framing facilitates the visual validity process. That is, visual framing might be the tool that prompts individuals to take away one of the several valid responses, and even more importantly, not prompt the individual to respond inadequately.

The difficulty with visual framing for science and risk visuals is that specific design techniques do not exist. As this study shows though, knowing the objectives of your message is the first step to visual framing. The steps to follow need more research. Although Tufte (1986) offers many rules for design techniques, his work does not tell us how people respond to those techniques. What type of design helps the public understand science or make better risk assessments? How do these techniques relate to the many message objectives that can exist? Or, maybe developing techniques is too specific. Perhaps, the designer of a visual knows best how to emphasize their message objectives into the design of the graphic. As this study shows though, this is not the case for the cone of uncertainty. Visual communication is still rich with research questions, especially as it relates to complex science and risk visuals.

Visual Validity: How Does Scientific Intent Translate Through a Visual to Evoke Public Understanding of Science and Risk Assessment?

This thesis focused on one piece of the visual process, the forecaster's perspective. Although none of the data can prove exactly how scientific intent translates into understanding, there are a few points worth emphasizing as potential solutions. First, in Chapter 4, the forecasters pointed out that transactional communication is a vital component in how they interact with emergency managers. This interaction may take place because of emergency manager's increased responsibility during a hurricane, or alternatively, this interaction may occur because transactional communication is necessary for emergency managers to understand the visual. Transactional communication may be necessary for people to become visually literate.

Further, the use of transmission communication with the public might be one explanation for their confusion. Trumbo (2006) suggests that the transmission view of science communication is detrimental to the visual learning process. She states, “Without some understanding of how visual representation functions, we are left out of an important part of discourse” (Trumbo, 2006, p. 278). She argues that scientific discourse, or transactional communication, is a key component for one’s visual literacy ability. Transactional communication, then, may be one component to ensure high visual validity.

Second, and building off of transactional communication, Chapter 5 showed how risk or complex science visuals may need a written or verbal explanation to ensure high visual validity. The symbols used, and the science represented may be too complex. Providing supplementary explanation may be another component to achieving high visual validity.

Further, providing explanation and transactional communication may occur in tandem or separately. Having both components may increase the possibility of achieving visual validity. An individual can read an explanation, but also ask questions if something is still unclear. It is possible though, that only one component is necessary for an individual to achieve a fuller understanding of the visual.

The question remaining is what if transactional communication and an explanation still does not attain an accurate understanding or risk assessment? Is there another component to achieving high visual validity? Does an individual need a higher education or analytical ability to understand such graphics? My future research will continue to explore the answers to these questions.

Future Research

This thesis outlined many research questions. First, to explore the concept of visual validity further, I need to see this case study through by asking the following two questions: (1) how does the public interpret the cone of uncertainty, and (2) how does the public’s interpretation of the graphic match that of the scientific intent outlined in this thesis? If the public's interpretation does not match the scientific intent, then this may provide further questioning for the concept of visual framing. Does visual framing increase the visual validity process?

Further, it is important to not only understand the public's interpretation but also try to understand what behavioral action they took based on that interpretation. It is possible that individuals may take away a wrong interpretation, but perhaps through other social influences (family members, neighbors, faith-based organization, etc.) they still made a positive behavioral choice. The question here is what role, if any, the visual played in this process.

As stated earlier, visual framing also needs further research. From a design perspective, how does one visually frame an image? Can guidelines be developed for science and risk visual framing? Alternatively, does each case study need specific analysis to determine how verbal or written objectives visually correspond to the visual?

Further, another question worthy of future research focuses on the variety of graphics that exist on the same topic. The interviewees in this study emphasized the important of consistent messages when it comes to hazards. This raises the question whether different visuals make a consistent forecast seem inconsistent. If forecasters use the same science, but represent it differently, then how does this affect public understanding of science and their risk assessments?

These questions only begin to scratch the surface of future research in this area. The research questions focused on visual validity take precedence in the short term.

Conclusion

This thesis started with an applied problem: The public and emergency managers were misinterpreting the cone of uncertainty, an important hurricane communication tool. At the time, I simply wanted to know why and how to fix it. What grew out of this case study over the last two years was a deeper conceptual question regarding visual validity: How do complex science and risk messages translate through visuals to evoke public understanding of science and risk assessment? This question has been the impetus for this thesis and will be the motivation for many research questions in the future.

This thesis begins to make a mark on the visual communication literature. I feel, though, that its reach goes beyond just visual communication. Recently, a colleague asked me why I needed to develop visual validity. "What makes visual validity different from verisimilitude," she asked. Verisimilitude, according to the Merriam-Webster dictionary (2008), is the quality or state of accurately representing something. How does one accurately represent complex science or risk? The difficulty with this area is that no photograph, image, graphic, or map will ever accurately capture scientific uncertainty or risk from a "truth" point of view. The mere fact that scientific uncertainty *is* uncertain makes it difficult to capture the truth. For complex science and risk visuals, it is not necessarily about capturing the truth but about being objective and in that process ensuring that readers of that objective visual understand the scientific or risk intent, especially where consequences of misinterpretation may be involved.

This thesis and the idea of visual validity not only add to the visual communication literature but also expand its reach to the risk and science communication area. The intersection of visuals, science, and risk is a rich area full of research questions, as this case study has shown. It is my hope that the questions that emerged out of this thesis will not only add to the visual, risk, and science communication literature but also improve the visuals used for complex science and risk to ensure that the public will understand these messages and be prepared for the risks of the future.

APPENDIX A

HUMAN SUBJECTS APPROVAL INFORMATION

CONSENT FORM

INFORMED CONSENT FORM

Visual Perception and Its Influence on Decision-making

You are invited to participate in a research study on risk perceptions associated with visual graphics, specifically the cone of uncertainty. You were selected as a possible participant because of your expertise in this field. I ask that you read this form and ask any questions you may have before agreeing to be in the study.

Background Information: This research will interview hurricane forecasters and national hurricane experts to understand the objectives of the cone of uncertainty.

Procedures: If you agree to be in this study, I will ask you to participate in an interview, envisioned to last between 30 minutes to one hour. During this interview, I will ask what you think the objectives are for the cone of uncertainty, the scientific uncertainty behind the graphic as well as your opinion on public perception of the graphic.

Risks and Benefits of Being in the Study: I do not anticipate any risks for you participating in this study, other than those encountered in day-to-day life. If we correspond via email, there is a chance that a third-party could read our correspondence. Indirect benefits of participation include a greater understanding of how visuals affect risk perception as well as specifically understanding how the public interprets the cone of uncertainty.

Voluntary Nature of Participation: Your decision whether or not to participate will not affect your current or future relations with Cornell University. Your participation is voluntary, and you may refuse to participate before the interview begins, withdraw or ask questions at any time, and/or skip any questions with no effect.

Confidentiality: The records of this study will be kept private. In light of your potentially publicly visible position, you have the option to remain confidential or not. If you decide to remain confidential, in any sort of report I might publish, I will not include any information that will make it possible to identify you. All data will be securely stored in my office on my computer, several hard disks, and audiotapes. Hard copies of data will remain in my office. All data will be destroyed (i.e., shredded or erased) when their use is no longer needed but not before a minimum of five years after data collection.

If you choose not to be confidential, articles for publishing may include your comments that will make it possible to identify you.

I choose to be confidential in this study (circle one): Yes or No

Permission to Use Recording Device: Please sign below if you are willing to have this interview audio-taped. You may still participate in this study if you are not willing to have the interview recorded.

Signature ____________________________________ Date

____

Contacts and Questions: The researcher conducting this study is:

Gina M. Eosco, Department of Communication, 336 Kennedy Hall, Cornell University, Ithaca, New York 14853. Phone: 781-704-4458; Fax: 607-254-1322; Email: gme7@cornell.edu

If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, or access their website at http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm.

You will be given a copy of this form to keep for your records.

Statement of Consent: I have read the above information and have received answers to any questions I asked. I consent to participate in the study.

Signature ___________________________________ Date ________________________

This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the UCHS on February 2, 2007.

Interview Guide for Hurricane Forecasters

History of Cone

1.) I was wondering if you could tell me about the history of the cone of uncertainty during your tenure at the NHC.

   a. Why did they shift to a new cone in 2002? (show example if needed)

   b. What was ineffective about the graphic prior to 2002? (show example if needed)

   c. What do you think improved from the first graphic to the second graphic?

   d. Do you recall how the public perceived the first graphic?

Science of Cone

1.) When designing the new cone of uncertainty for the 2002 season, what scientific aspects played a role in the design?

2.) What aspects of the science are most critical to communicate? Why?

3.) How does each hurricane's "cone" vary?

   a. Hopefully he will say something about uncertainty of models, models not converging, etc

   b. Follow up – why are the cones symmetrical if the uncertainty is not symmetrical?

Objective of the Cone and Public (mis)perceptions (his views, his stories, his suggestions)

1.) In designing the 2002 cone, how did you envision the public's perception of their risk?

2.) Who came up with the new design? Did they test public perception?

3.) What part of the graphic do people find the most confusing?

    a. Can you share some stories of people misunderstanding?

    b. Can you share some storied of people understanding?

4.) In designing the graphic, what decisions do you feel people can make from this graphic?

    a. Hopefully he will say evacuations

    b. Follow up – something about large geographic area/not everyone will make the same decisions

    c. From your experience, what other factors play into people's decision to evacuate?

APPENDIX B

IMAGES

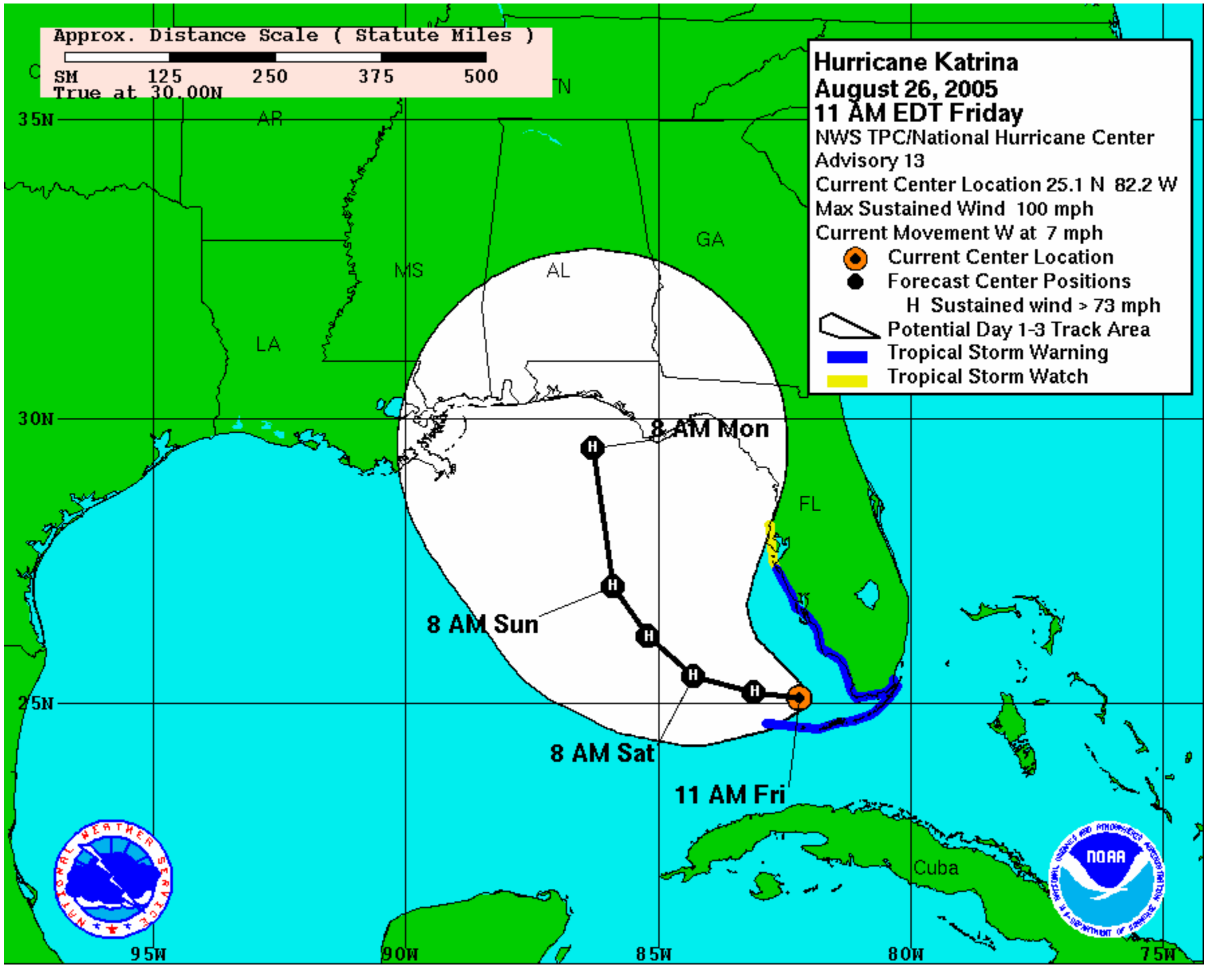

Image 1. Hurricane Katrina cone of uncertainty track graphic for August 26, 2005 (NOAAc, 2007)

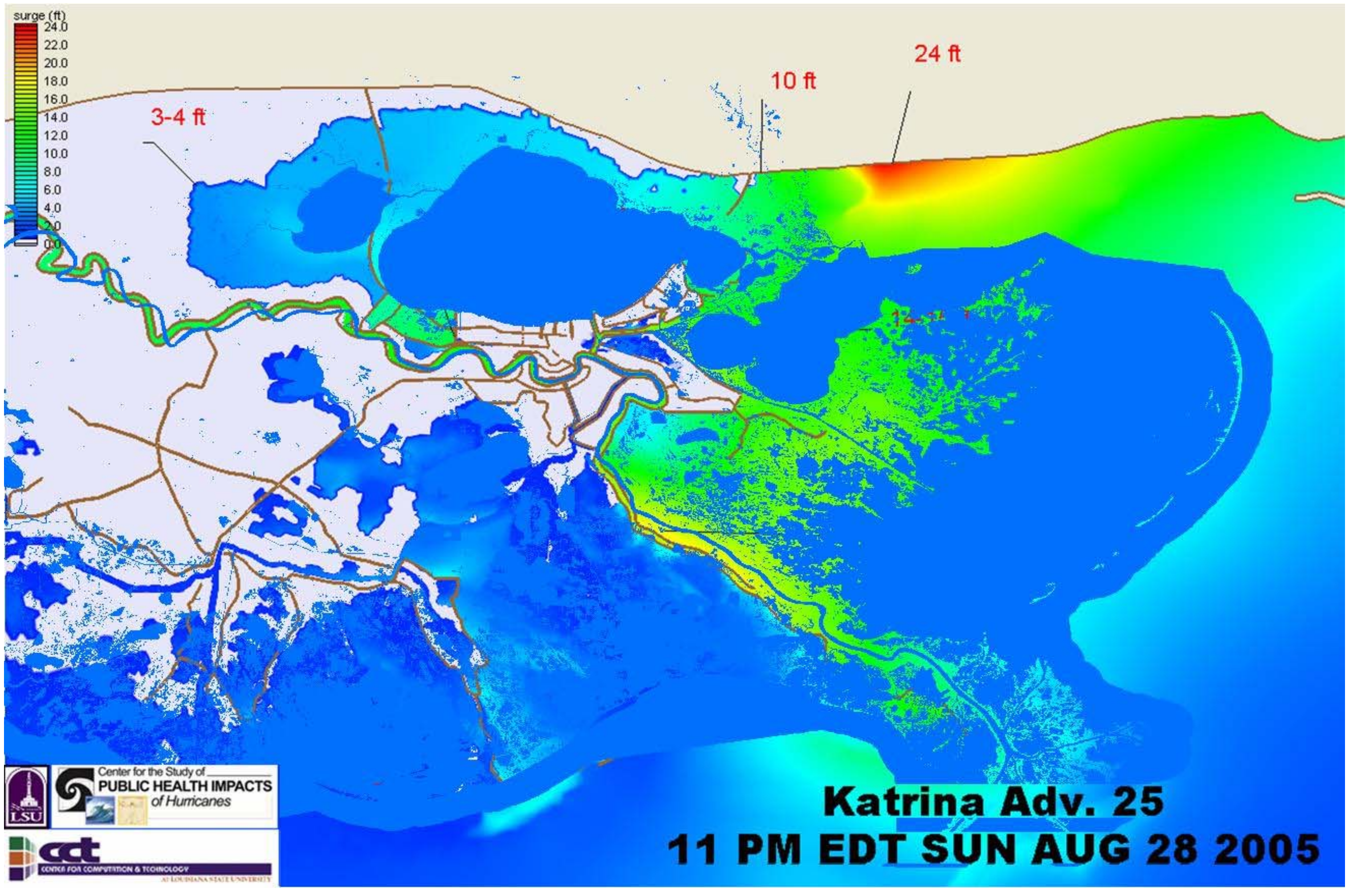

Image 2. Hurricane Katrina, Advisory #25 (http://hurricane.lsu.edu/floodprediction/katrina25/)

(http://hurricane.lsu.edu/floodprediction/)

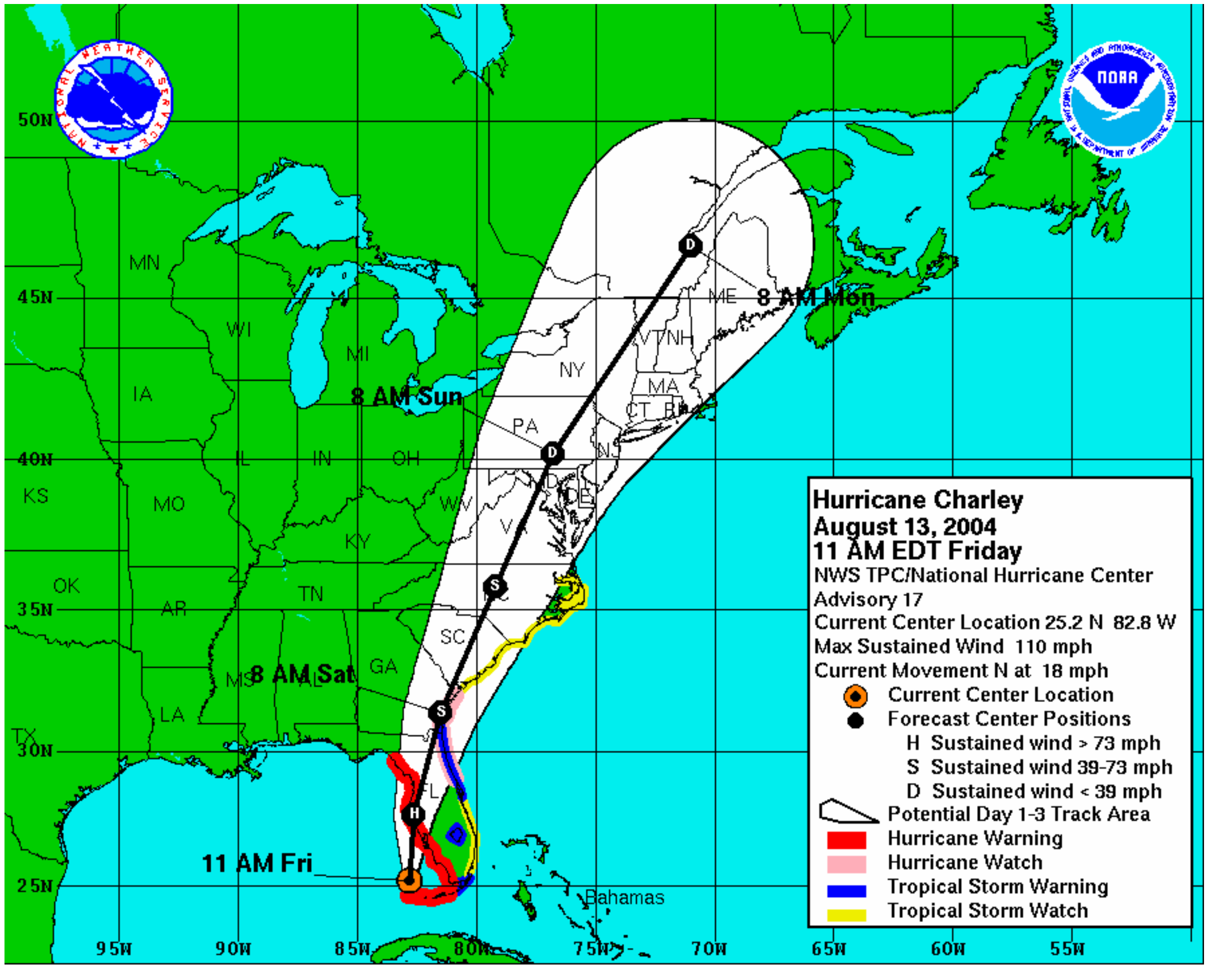

Image 3. The cone of uncertainty graphic for Hurricane Charley. Both Tampa and Port Charlotte are in the white area of the cone of uncertainty.' This means that both communities have the potential for a direct hit from the center of the storm.

Image 4. A Photo in the Metropolitan Museum of Art by Laurie Simmons titled, Purple Woman/Kitchen/Second View, 1978.

Image 5. A variation of the cone of uncertainty from The Weather Channel.

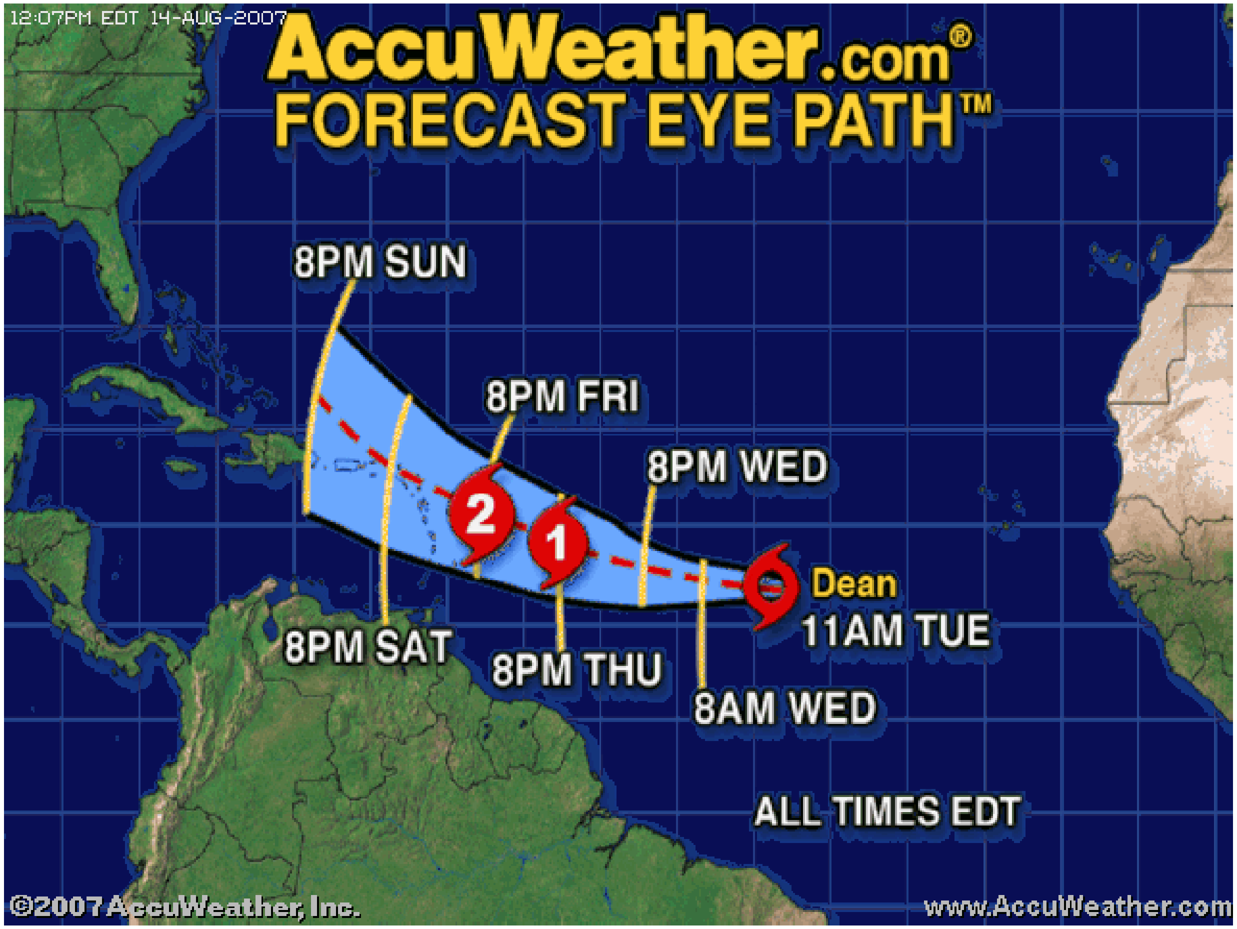

Image 6. A variation of the cone of uncertainty from AccuWeather

Image 7. A variation of the cone of uncertainty from WeatherBug.

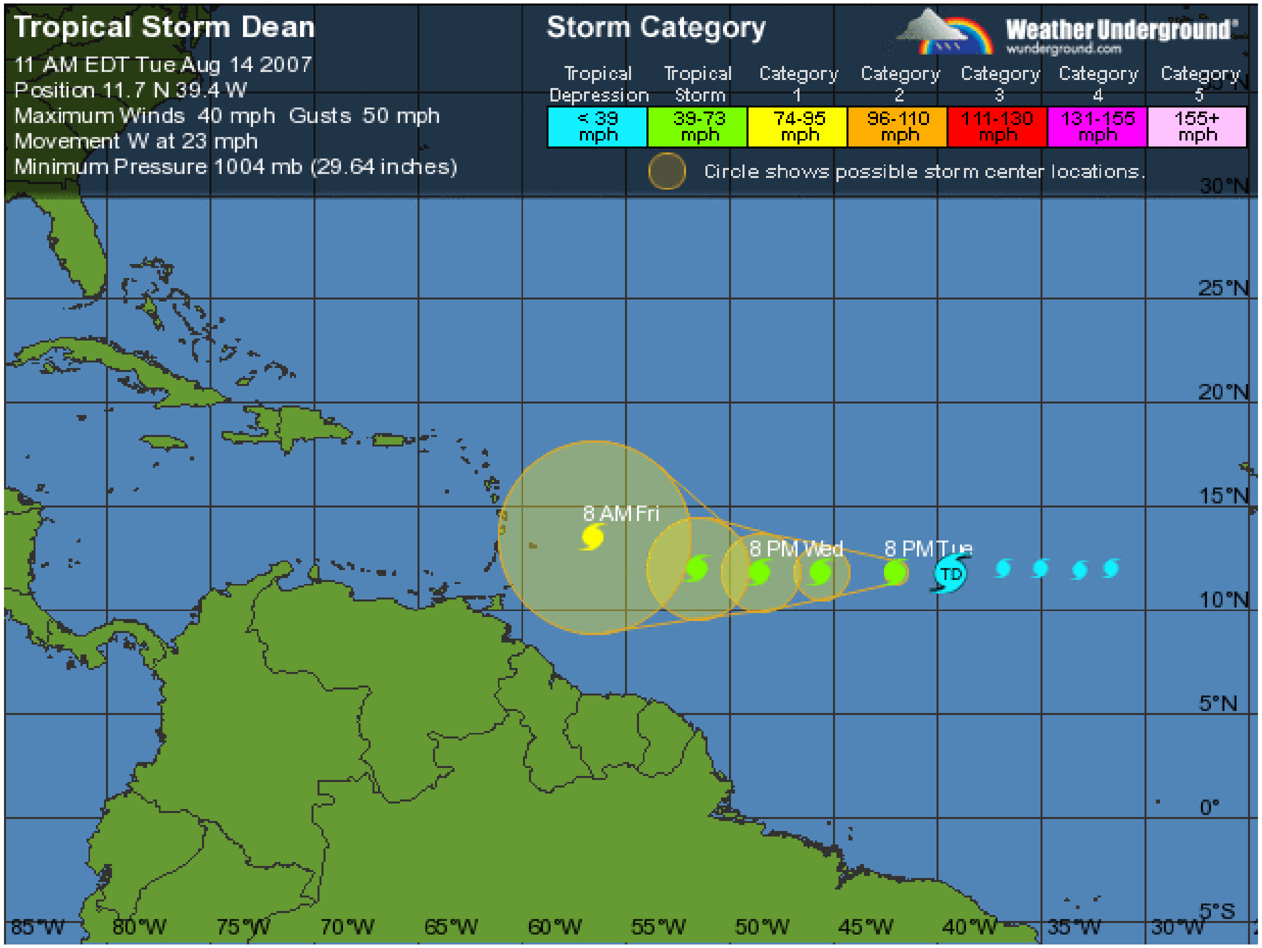

Image 8. A variation of the cone of uncertainty from Weather Underground.

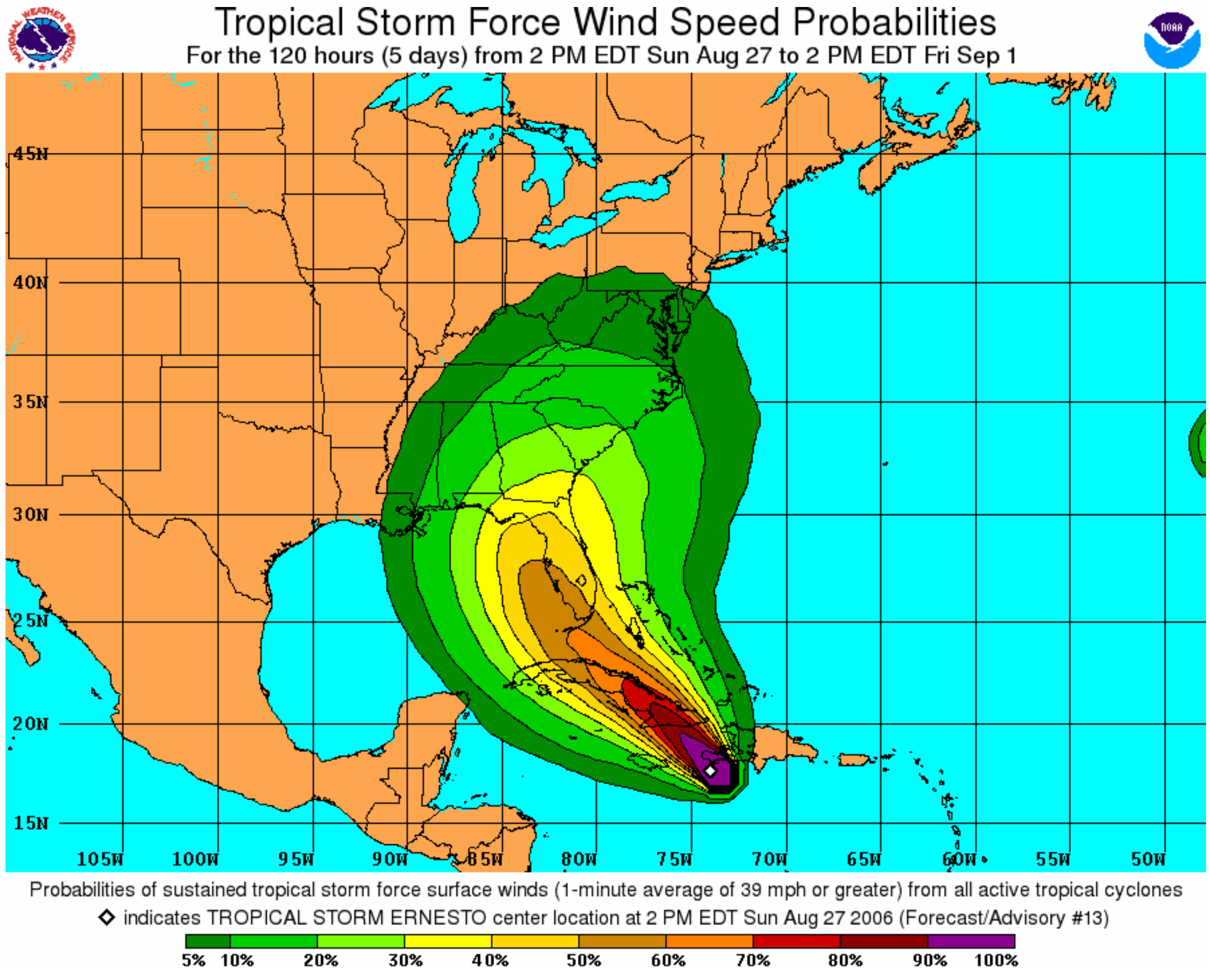

Image 9. National Hurricane Center graphic showing probabilities of tropical storm force winds for Tropical Storm Ernesto on August 27, 2006 (NOAA, 2006).

Image 10. A mock cone of uncertainty to show how the graphic can *potentially* show the behavioral actions while still maintaining scientific integrity.

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