NEW TROPICAL CYCLONE WARNING GRAPHICS:

PREFERENCES, COMMENTS AND

FUTURE SUGGESTIONS

by

LAURA M. RADFORD

JASON SENKBEIL, COMMITTEE CHAIR
DAVID M. BROMMER
KATHLEEN SHERMAN-MORRIS

A THESIS

Submitted in partial fulfillment of the requirements
for the degree Master of Science
in the Department of Geography
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2012

ABSTRACT

Hurricane warning communication has become a recent topic of debate among academics, emergency managers, and meteorologists. The current graphic used to portray vital information to people in the path of a hurricane is the “Cone of Uncertainty,” which is produced by the National Hurricane Center (NHC) and modified by local TV stations. Evidence suggests this graphic creates too much ambiguity, which can lead the public to incorrectly interpret its meaning. In order to achieve warning clarity, we must understand the many possible ways people are obtaining information from this graphic. In this research, ArcGis 9.3 and PowerPoint were used to create alternative hurricane-warning graphics. Using these alternative graphics, citizens in Jacksonville, FL and Pensacola, FL were surveyed to ascertain which graphics citizens preferred. Results indicate that the majority of the participants prefer an alternative warning graphic. Furthermore, several additional warning graphics are created based on field results comments, and suggestions.

ACKNOWLEDGEMENTS

I will now to the time to thank all the people who contributed to this thesis, whether it is in advise, in data collection, or simply in encouragement. I could not have conducted this research without them. I would like to start with Dr. Jason Senkbeil, my committee chair. Dr. Senkbeil provided me with the advice and encouragement that was invaluable to the completion of this thesis. I would like to thank Dr. David Brommer and Dr. Kathy Sherman-Morris for their constructive direction and input. Thank you to Barrett Gutter, Hanna Howell, John Mason, Meganne Rockman and Courtney Thompson for their help in conducting surveys and gathering data. Thanks are also deserved to all the faculty and staff in the geography department. Lastly, I would like to my family and friends for all the support throughout the years.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Hurricane warning communication is an interdisciplinary subject, and a topic of concern for government officials, emergency managers, and meteorologists. The recent (1995- present) increase in hurricane landfalls in the United States has intersected with continued coastal development to create billion dollar disasters. In this century, improvements in forecasts and warnings, along with better communication and public awareness have reduced the loss of life; however storm damage costs have increased (Marks and Shay, 1997). The potential for billion dollar disasters will likely persist with projections of continued coastal development (Pielke et al., 2000; Emanuel, 2005). Since hurricane landfalls cannot be prevented, development of ways to improve mitigation must occur. Due to the increase in coastal population, the possibility for a substantial increase in hurricane-related losses in the twenty-first century is heightened (Pielke et al., 2000, 2005; Emanuel, 2005; Schmidt et al., 2008; Senkbeil et al., 2009). If more people are residing on the coast, property losses and fatalities may increase. With higher stakes and greater potential loss, forecasters and emergency managers need to develop improved risk communication strategies. With increased activity probable in the next century, it is important to understand how residents receive and perceive warning information. Such an understanding may reduce economic losses and fatalities. The goal of this thesis is to create several alternative hurricane-warning graphics in order to assess public preference and knowledge. Once public preference and knowledge is determined, it is then possible to develop more informative warning graphics that may improve the communication of hurricane hazards in the future. The hurricane-warning graphic used in the United States, which is produced by the National Hurricane Center (NHC), is the Cone of Uncertainty (COU). The COU represents the forecasted track the center of a tropical storm or hurricane will take and the likely error in the forecast track. It is based on the predictive skill of past years, as well as numerous additional details about the storm (Broad et al., 2007). This graphic is used by the NHC to help the public determine the trajectory of the hurricane as well as to develop evacuation and preparation plans. Currently, several versions of the COU are used to communicate hurricane risk to the public. The National Hurricane Center creates the official COU, and local and cable TV meteorologists modify it slightly for discretionary emphasis.

During or before a natural disaster, the dissemination of information about the nature, extent, and duration of the hazard, as well as official warnings and emergency services, is of critical importance to both local governments and residents (Piotrowski and Armstrong, 1998). From coastal resident surveys, researchers have found that some citizens in these areas misunderstand the meaning of the COU. Research has been conducted to try to understand what the public is grasping from the warning graphic. The results of the research (Broad et al., 2007) show the primary conclusion is that people put too much faith in the forecasted track, negating the uncertainty in the message that the cone is intended to convey. Baker (1991) states that if people are using this medium (hurricane-warning graphics) to make decisions that can save lives and property, we want to be sure that it is providing the public with the best information possible. The current hurricane-warning graphic leaves too much to the public's interpretation causing confusion. Therefore, the study of how the public uses and comprehends the COU can greatly improve our warning systems and the lives of the people relying on this system.

The COU has come under criticism for its ability to be misinterpreted. Many people focus too much on the track line, not understanding that the center of the storm can pass to either side of the line. The cone itself is a source of confusion. Many believe that it depicts the swath of damage from the storm while in reality it is trying to portray the geographic area over which the eye might travel (Broad et al., 2007). Others believe that it shows the growth in size as the tropical cyclone approaches land. Since its implementation, the COU has been a vital tool for the communication of hurricane risk information; however, relatively little is known about how the public interprets, evaluates, or utilizes this important graphic (Broad et al., 2007).

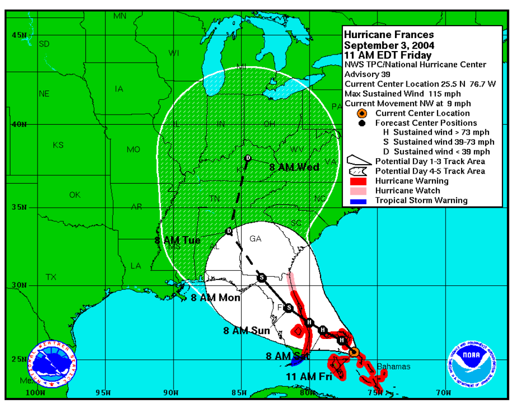


Figure 1: The COU, the current graphic employed by the NHC for disseminating risk information to the public. (Source: NHC)

To assess this issue, Eosco (2008) collected information on how well the public understood the uncertainty in hurricane-warning graphics. Eosco assessed visual validity within the COU. Visual validity refers to the process of correctly transferring the scientific message behind the COU to the public. This is essential to understanding how the public perceives risks. If visual validity were achieved then one would assume that risk perceptions by the public are sound; however, research (Broad et al., 2007; Eosco, 2008) has shown that many residents do not fully comprehend the intentions of the COU. Therefore, it can be assumed that many residents do not have correct perceptions of the risks posed to them by a land-falling hurricane.

Misinterpreted risk information can be costly. Residents that participate in unwarranted evacuations could have unnecessary expenditures from lodging and transportation costs. On the other hand, if residents do not understand that they are in a risk area, they may decide not to evacuate or not to prepare fully for the incoming storm, which could lead to economic losses due to preventable property damage. There are no estimates, to the authors' knowledge, on the costs of misinterpreted risk information, however it is approximated that it costs one million dollars per mile of coastline evacuated (Whitehead, 2003). Future research into this topic could provide insight into the economic and societal impacts of misinterpreted risk information.

Thus, it is pertinent to understand how the public perceives risk, with the goal of designing a graphic that maximizes knowledge and minimizes confusion. The goal of this thesis is to produce a hurricane-warning graphic that maximizes the portrayal of hurricane hazards in the least ambiguous way. This thesis will be organized into the four following chapters: literature review (chapter 2), worldwide tropical cyclone warning scales (chapter 3), methods (chapter 4), results (chapter 5), suggestions (chapter 6), and conclusions (chapter 7). In chapter 2, literature reviewed pertains to physical characteristics of tropical cyclones, perceptions and risk associated with tropical cyclones, evacuation behavior, and the role of media in disseminating risk information. Chapter 3 provides an overview of the four main worldwide tropical cyclone warning systems. Chapter 4 discusses preliminary work required to perform the research, as well as the field and statistical methods employed to gather and analyze data. Chapter 5 summarizes and discusses the results of qualitative and quantitative analysis. Chapter 6 discusses the attempt to make a master graphic- a graphic that includes the projected path of the storm with the addition of the spatial and temporal hazards associated with a land-falling tropical cyclone and the positive and negative issues that arise with creating such a graphic. Lastly, chapter 7 consists of a summary of the results, limitations of the research and concluding comments.

CHAPTER 2: LITERATURE REVIEW

2.1 *Physical Characteristics and Societal Implications of Tropical Cyclones*

2.1.1 Understanding Tropical Cyclones

In order to understand the complexity of hurricane-warning graphics, one must understand the physical characteristics of a tropical cyclone. Hurricanes are the single most costly and destructive of all storms (Elsner and Kara, 1999). There are five stages of North Atlantic tropical cyclones: tropical wave, tropical depression, tropical storm, hurricane and finally major hurricane (Elsner and Kara, 1999). Detailed information on North Atlantic hurricanes only extends back about 120 years (Elsner and Kara, 1999). However, there have been many advances in forecasting technologies since that period. Forecasters now understand many climatological characteristics of hurricanes. It is known that the official hurricane season runs June to November and that the peak occurs during the second week of September. Also adopted is the Saffir-Simpson scale that classifies tropical cyclones, which helps the public understand the storms. This scale will be discussed later in the thesis. Analysis of tropical cyclones show that eighty-five to ninety percent of them originate between 20 degrees north and 20 degrees south (southern hemisphere hurricane are less frequent) and that a minimum latitude of eight degrees away from the equator is required for formation (Elsner and Kara, 1999). As noted previously, hurricane interests have grown recently and this is partly due to the potential relationship with climate change. There is a heated debate over how/if climate change will affect the intensity and frequency of tropical cyclones. Since the Atlantic Ocean is currently in a period of heightened storm activity, this debate becomes of interest to society due to the impacts that might be expected with an increase in intensity and frequency of storms.

The physical explanation for greater hurricane impacts over the past two decades has materialized from the possible relationship with global climate change, and also the phase of the Atlantic Multidecadal Oscillation (AMO, explained in next paragraph). The possible increase in hurricane activity caused by climate change remains uncertain (Knutson and Tuleya, 2004; Emanuel, 2005; Pielke et al., 2005; Webster et al., 2005; Holland and Webster, 2007; Shepherd and Knutson, 2007). Emanuel (2005) suggests that if warming continues, the potential for more destructive tropical cyclones may trend upward. Societal vulnerability to hurricane impacts may also increase (Pielke et al. 2008).

The AMO is a naturally occurring sea surface temperature (SST) oscillation in the Atlantic Ocean that fluctuates between a negative (cool) and positive (warm) phase every twenty to forty years. Positive phases are associated with heightened tropical cyclone activity with warmer SST. This relationship has been established on the basis of the number of tropical cyclones that develop per year in during a positive AMO (Folland et al., 1986; Schlesinger and Ramankutty, 1994; Delworth and Mann, 2000; Knight et al., 2007). During a positive phase, the number of hurricanes that develop into severe hurricanes is at least twice as many when compared to a negative AMO. The number of tropical cyclones does not change much between a negative or positive phase, rather the number of intense hurricanes (NOAA, 2005). When the AMO is negative, the transport of warm equatorial waters does not travel as far north when compared to the positive phase, therefore the likelihood of severe hurricanes forming is low and it has been noted that the likelihood of experiencing a land-falling hurricane is reduced during the negative phase (Farris et al., 2007).

2.1.2 Land-falling Tropical Cyclones and Associated Hazards

Hurricane landfall officially occurs when some part of the eye-wall crosses the coastline. Tropical cyclones usually lose hurricane classification within twelve hours after making landfall with some storms taking up to twenty-four hours. The stronger the circulation, the quicker the storm will weaken over land. (Elsner and Kara, 1999). The friction and loss of the energy source over land facilitates the weakening of the tropical cyclone (Elsner and Kara, 1999). Although storms weaken after landfall, they can still be dangerous. This is especially true in the right-front quadrant.

2.1.2-1 Storm Surge

A large portion of the damage caused by land-falling hurricanes results from storm surge. Storm surge is the rising of wind-driven water defined as the difference between the storm tide and normal tide (Elsner and Kara, 1999). It is caused by the high wind speeds of the storm as well as its forward motion and direction of approach. A secondary agent that also contributes to water rise is lower atmospheric pressure near the eye. The faster and more perpendicular the approach, the greater the peak surge height will be. Another factor influencing the magnitude of storm surge is the shape of the coastline, depth of the continental shelf, and the duration of the strongest winds. A location that has gently sloping bottom topography will see greater surge heights. Storm surge has its greatest destruction potential in the right-front quadrant of the hurricane during an astronomical high tide. The effects from storm surge can last from a period of hours to days (Elsner and Kara, 1999; Irish et al., 2008).

Estuarine storm surge can be just as detrimental as open ocean storm surge. The shape of the shoreline and the intricacies of the man-made or natural system can generate a higher storm surge (Senkbeil and Sheridan, 2006). This is due in part to a large amount of water being forced into a smaller, and more complex area, relative to the open ocean. Furthermore, surge creates a damming mechanism, which exacerbates surge in large estuaries. This prevents river water from draining into the estuary causing excessive flooding in delta regions.

The size of a tropical cyclone can also have an impact on the destructive potential of storm surge. Irish et al. (2008) found that the size of a storm plays a prominent role in the creation of surge and is most prominent in very intense storms that make landfall over gently sloping bathymetries. Surge can vary by as much as 30% for a particular intensity, over a range of storm sizes. For that reason, storm size should be considered when forecasting surge and its impacts (Irish et al., 2008).

2.1.2-2 <u>Tornadoes</u>

As a storm makes landfall, the deceleration of winds due to friction as well as rapidly rising air can generate tornadoes. These tornadoes are usually weaker than classic synoptic supercell tornadoes experienced during the transition of seasons in the southeastern United States. Eighty percent of hurricane-spawned tornadoes develop within 150 km of the hurricane center in the outer spiral bands of the right-front quadrant (Schultz and Cecil, 2009). Tornadoes are most common with tropical cyclones moving northward and are less likely with rapidly moving westward storms (Schultz and Cecil, 2009). This hazard can be responsible for up to ten percent of the total fatalities and up to fifty percent of total damage in a tropical cyclone (Elsner and Kara, 1999; Belanger et al., 2007).

2.1.2-3 <u>Precipitation</u>

Many believe that storm surge is the deadliest hazard associated with hurricanes; however, inland flooding is the leading cause of death associated with hurricanes in the United States (Rappaport, 2000). Hurricane Katrina might complicate the aforementioned statement due to its destructive and deadly surge. Heavy rainfall can cause significant damage to property and threaten lives. Flooding produced by tropical cyclones (TCs) is associated with the storm's maximum wind intensity, its forward speed, and its size (Zhang et al., 2007). Slow moving storms are often heavy precipitation producers (Konrad et al., 2002). After landfall, additional factors that can influence precipitation are the presence of significant topography, and extratropical transition of the cyclone and associated meteorological processes (Carr and Bosart 1978; Atallah and Bosart 2003). TCs undergoing extratropical transition produce more precipitation to the left of the storm track when they interact with a trough, while more precipitation on the right side of the storm track is common when the TC interacts with a ridge (Atallah et al. 2007). Furthermore, studies on tropical cyclone shape reveal relationships with precipitation. Rain shields associated with TCs will morph into different shapes throughout the course of a storm. In turn, different rainfall rates will occur in different places. Understanding these changes can be of assistance to predicting where freshwater flooding will occur (Matyas, 2007, 2008). Tropical storms can sometimes produce devastating floods, but they can also produce very beneficial rains. Much of the rainfall received throughout hurricane season contributes a significant amount to the annual rainfall in the southeastern United States (Knight and Davis, 2007). Because heavy precipitation typically creates more significant problems inland than along the immediate coast, it has the largest spatial extent of all hurricane hazards and represents a significant hazard to the majority of the people experiencing the storm (Senkbeil and Sheridan, 2006).

2.1.2-4 Wind and Falling Trees

On average 132-kt (157 kt) hurricane winds can be expected near the U.S. coast once every 10 (100) years (Jagger and Elsner, 2006). These winds can be responsible for deaths by wind-related tree failures. Hurricane force winds are not necessary to cause tree-related deaths. Heavy or prolonged periods of precipitation can cause trees to fail with only moderate tropical storm winds. In the period of 1995-2007, 57 deaths were reported from fallen trees caused by 15 tropical cyclones. These deaths comprise 31% of all deaths caused by tropical cyclones in the same period. 68% of the deaths were males with a median age of 45 years. There is a nearly equal distribution of tree deaths at home, in vehicles, and outdoors (Schmidlin, 2009). In addition to deaths caused directly by fallen trees, wind-related tree failures can have indirect consequences by causing many nonfatal, but life-changing injuries, many involving chainsaws. Indirect deaths and additional suffering are caused by trees that fall on roadways and impede emergency response to injured persons (Schimidlin, 2009).

Several case studies have looked at the indirect fatalities resulting from land-falling tropical cyclones. Combs et al. (1992) studied direct and indirect deaths from Hurricane Andrew. Results showed a higher number of indirect deaths than direct. These mortality rates were higher with older, white males (Combs et al., 1992). Jani et al. (2006) examined indirect deaths from Hurricane Isabel (2003). The study noted twenty indirect deaths caused by motor vehicle wrecks, clean up operations, power outages and stress. Drug and alcohol presence was recorded in a number of those deaths. Ragan et al. (2008) looked at the 2004-2005 Florida hurricane season and determined that 80% of deaths were accidental with trauma being the main reason for death. Other contributors to this percentage were drowning, carbon monoxide poisoning, usually from generation use, and electrocution. In 2004, out of the 144 hurricane-related deaths, 59% occurred in the post-landfall phase; in 2005, 61% of the 69 hurricane-related deaths occurred in the post-landfall phase. Of all hurricane–related deaths occurring in 2004 and 2005, 79% were people 40 years of age and older (Ragan et al., 2008; McKinney et al., 2011).

These results all found that most hurricane-related deaths are unintentional injuries thus, preventable (Ragan et al., 2008). The authors all conclude that public education messages should be included in hazard and risk information. Safe driving procedures and shelters that are adequately equipped with basic medical needs need to be emphasized during policymaking (Combs et al., 1992). These messages should be aimed at high-risk areas and provide information on how to perform post-impact activities safely (Ragan et al., 2008) to try to reduce the number of indirect hurricane-related deaths.

2.2 *Misinterpretation of the Cone of Uncertainty*

This section of the literature review is based on the article that was the main inspiration for this research-“Misinterpretations of the ‘Cone of Uncertainty’ in Florida during the 2004 Hurricane Season” (Broad et al. 2007). The focus of the article was to determine if the public was misinterpreting the COU. Broad et al. (2007) suggest that many members of the public pay close attention to and use the COU when making evacuation decisions but at times misinterpret it. One of the most concerning findings of the research is that too many people place undue certainty in the forecast track of the storms. The public does not fully understand that there is uncertainty in the graphic and that it is based on probabilities. Communication of the COU to the public happens through different interpretations and strategies of local weather forecasters. This means that there are several different versions of the COU that are disseminated to the public. Stations alter the color and style of the graphic but seldom make fundamental changes such as removing the track line. This could have unwanted effects on the public's interpretation of the graphic's meaning. However, making fundamental changes (removing track lines) could produce some welcomed side effects such as redirecting focus to the main purpose of the graphic.

Broad et al. (2007) interviewed local and national television meteorologists on the response to Hurricane Charley in 2004. Articles discussing the COU, public comments on the COU, and two proposed alternative graphics were posted on the NHC website. Results from the interviews showed that public misinterpretation of the graphic may be a common occurrence and could be an important factor in evacuation decision-making. Some meteorologists expressed concerns about some of the fundamental aspects of the COU, like the track line. Craig Setzer, a south Florida television meteorologist, suggests that the track line conveys more certainty than actually exists. Doswell (2004) concludes that items to incorporate in hurricane-warning graphics should be a function of the intended audience and that audience's ability to comprehend different sorts of information. The warning communication process is flawed if the public is gathering inaccurate information from these graphics. Therefore, studies that address this issue are crucial to improving the warning system.

2.3 *Perceptions and Risk*

Risk can be viewed as a combination of the probability that an adverse event will occur and the consequences of that event (Ebi et al., 2005). Risk and perception of risk are extremely important factors when coastal residents are trying to make evacuation decisions. How these residents perceive the risks associated with hurricanes is critically important to the design of a high-quality warning system. It could be argued that no other factor has done more to reduce loss of life from natural hazards over the past century than the timely dissemination of advance warning to threatened residents through risk communication (Lee et al., 2009). Currently, the most common avenue for risk communication is the media, followed by public officials. Dow and Cutter (2000) found in their study of South Carolina residents that local television and The Weather Channel were perceived the most credible information sources by 70% and 55%, respectively. In this particular study, respondents reported using the Internet to learn more about the storm 30% of the time. Lindell, Lu, and Prater (2005) reported that local and national television broadcasts were the most important source of information based on public responses. Following television broadcasts, in order, are local radio broadcasts, peers, local authorities, local newspaper, and finally the Internet. These groups provide vital risk information to the public when dealing with an impending disaster; however, sometimes there are issues with the continuity and comprehension of the risks associated with the disaster.

Understanding how the broader community perceives risk can assist policy makers in developing better policy and improved means for communicating government policies and programs involving risk management (Botterill and Mazur, 2004). The public's risk perception when dealing with natural hazards is mainly a function of the characteristics of both the hazard and the stakeholder (Ho et al., 2008). It is important to understand how the public perceives these risks. Public perceptions of risks differ from expert perception of risk. Experts have more objective assessments as opposed to the more subjective assessments of the public (Bostrom, 1997). Experts tend to use narrower, technical definitions of risk (Otway, 1992) where the general public relies more on emotions and personal choices and experiences. It's about competing social and subjective rationales that involve values and emotions rather than instrumental, or quantitative, rationality (Horlick-Jones, 2005; Zinn, 2008). Household risk evaluations consider indirect costs of evacuating and are not solely based on direct safety risks posed by a hurricane (Dow and Cutter, 2000). Research shows that individual assessment of risk, increasing awareness of scientific uncertainty, multiple information sources, and past experiences are becoming more significant aspects of household response (Dow and Cutter, 1998) as well as the desire for risk information for independent decision-making (Dow and Cutter, 2000). Fischhoff, (2009) makes a valid statement, in which he asserts,

> "Without listening to people, it is impossible to understand what they know and value, hence impossible to provide them with relevant information in a comprehensible form."

Fischhoff continues to state that the risks associated with the event are aggravated when communications are disseminated without proper evaluations of content, and an audience that fails to understand the message's intent. The majority of citizens rely on intuitive risk judgments or perceptions (Slovic, 1987), and it becomes a problem if the information these citizens are receiving is not completely understood.

2.3.1 Perceived Safety and Complacency

There are many reasons people choose to evacuate or to not evacuate for a land-falling hurricane, but the most cited reason by residents was the perceived safety of their home (Dow and Cutter, 2000). Evacuees felt as if their home was not a safe place to ride-out the storm and non-evacuees felt the opposite. The main reasons why residents chose to evacuate were the risk level of the area, public officials' actions, housing situation, prior perception of risk, and storm-specific threats (Baker, 1991). Senkbeil et al. (2010) found that when asked, evacuating residents generally perceived the storm to be headed closer to their home than it actually did. Not every evacuee experiences the worst of the storm so there are possible differences in perception between actual and expected intensity. There could be a greater chance for evacuation and threat complacency for following hurricanes of similar magnitude. A situation like this could lead the evacuees to feel as if they evacuated unnecessarily (Senkbeil et al., 2010). This is one of many scenarios known as a "Cry Wolf" event, however there is no empirical evidence that suggests that the cry wolf effect is a factor in evacuation decision-making (Dow and Cutter, 1998). Another factor that can cause evacuation complacency is hurricane hypoactivity (Pielke, 1997). The NHC estimates that the lingering effects from a hurricane landfall are around seven years. After those seven years, residents begin to forget the impacts from the last hurricane and become more complacent (Blake et al., 2007).

2.3.2 Warning Systems and Shaping Risk Perceptions

Warning systems inform people at risk of an impending disaster. They enable those in danger to make and implement decisions. Warning systems are very complex in that many organizations are involved in creating them. Parties involved are scientists, engineers, government, media, and the public. These groups together can design an effective warning system that integrates detection of the disasters, management of hazard information, and public response. What makes this the recipe for an effective warning system is the inclusion of planning, exercise, and training (Sorensen, 2000). Lam (2005) believes to achieve the best effect of warning systems, meteorological services should devise strategies in the design, presentation, operation, dissemination and communication of the warning to maximize its relevance and effectiveness. Designers should explore opportunities to improve the processes and presentations of warning information to meet the needs of the public by using advancements in computer and telecommunication techniques (Lam, 2005). Elaborating on Lam's stance, Eosco (2008) brought attention to the effectiveness of the visual graphics employed by the NHC and media outlets. Since most media outlets use a form of the COU, many citizens are using this graphic as part of their evacuation decision-making strategies. However, no previous research has really assessed how well the public understands the graphics being used (visual validity (Eosco 2008)). If the public is misunderstanding or misinterpreting the graphics being used, then graphics lack visual validity (Eosco, 2008). When residents in the path of a hurricane are misinformed on risk information, confusion can transfer to evacuation decision-making.

2.4 *Evacuation and Vulnerability*

2.4.1 Why do People Choose to Stay/Go?

In the previous section, results showed that a major factor in evacuation decision-making was the perceived safety of the home. In this section other aspects influencing evacuation decision-making are discussed. If officials can determine which factors influence decisions to evacuate, warning systems can then be tailored to give the public clear and concise risk information. Officials need to know how these factors vary spatially by location and how these concerns may influence their decisions (Brommer and Senkbeil, 2010). When residents are making their evacuation decisions, they tend to rely on personal risk assessment based on that individual or household’s interpretation of factors directly or indirectly associated with the hurricane (Baker, 1991). Evacuation rates will vary among locations in the same hurricane and among hurricanes in the same location. However, it is known that an unsafe (safe) feeling causes most residents to evacuate (stay). The question then becomes why some residents feel safe and others do not (Baker, 1991). There is an effect known as the conformity effect. An example of this is when a resident chooses to evacuate because most of the neighborhood evacuated. It works the same when most of the neighborhood does not evacuate although the reason why people living in the same neighborhood might evacuate could also be explained by similar risk levels (Baker, 1991). Evacuations are not convenient for coastal residents. These residents have to gather belongings, arrange for places to stay, provide for pets (Dow and Cutter, 2000; Edmonds and Cutter, 2008), fight traffic, and endure the discomfort and environment of public shelters (Baker, 1991). Though many individual demographics are weakly related to evacuation, it has been found that households that include children are more likely to evacuate (Sorensen, 2000). These underlying issues are complex and difficult to recognize which complicates the understanding of evacuation decisions (Dash and Gladwin, 2007).

The local variations in evacuation rates reflect a range of experiences with a hurricane from those that are personal to those that are empathetic. Personal experiences greatly alter the salience of a hazard and the sense of uncertainty and vulnerability (Dow and Cutter, 1998). Experience heightens the awareness of the hazards, leading to an appreciation of the potential danger of it (Baker, 1991). It is logical to believe that residents of communities which have recently experienced a major hurricane will evacuate in larger numbers than those who have not experienced one recently (Baker, 1991). Following that same logic, one would believe that newcomers to a coastal area would be more likely to evacuate than long term residents who have not dealt with a "false-experience." This theory is called the "experience-adjustment paradox" (Windham et al., 1977). Evidence to this paradox was found in Dow and Cutter (1998) that showed that longer-term residents are more likely to remain because they invest a great deal of time being well-informed of the status of the hurricane. Some research demonstrates that perceived vulnerability to hazards can be influenced by how recently the citizen experienced these hazards (Lee, Meyer, and Bradlow, 2009). Because of the large number of evacuees from a single hurricane event, the majority of evacuees reside outside of the area that experienced the worst of the storm (Baker, 1991). This leads to people incorrectly believing that they have been through major hurricane conditions (Leik, 1981). Having residents that do not fully comprehend their experiences with hurricanes can lead to potentially fatal future evacuation decisions due to complacency. Complacency may also worsen by indirect issues such as traffic congestion and pet ownership; however, traffic congestion has been found to be only a minor issue when assessing evacuation complacency (Baker, 1991; Dow and Cutter, 1998, 2000).

Higher evacuation rates result from residents living in high-risk areas and in response to stronger storms (Dow and Cutter, 1998). Evacuations from more inland areas adjacent to high-risk and moderate-risk areas can cause a phenomenon known as evacuation "shadow" to occur. This happens when evacuations from high and moderate-risk areas trigger evacuations in low-risk areas that do not necessarily need to evacuate (Baker, 1991). Evacuation "shadow" can cause greater traffic congestion and leave at risk residents with an even more chaotic evacuation. This experience may lead to future evacuation complacency, but research has shown no empirical evidence to conclusively support this (Baker, 1991; Dow and Cutter, 2000; Zhang et al., 2007). This becomes an unfortunate scenario for officials giving evacuation notices and orders. These officials put themselves in a legally risky position if they advise low-risk residents to stay (Baker, 1991). Notices from public officials and the way they are worded have a great effect on evacuation rates. Residents are more likely to leave when they have a solid understanding that an evacuation notice apples to them; more personalized and urgent messages result in higher evacuation rates (Baker, 1991). What makes these notices so important is the fact that watches and warnings alone do not prompt the majority of the public to evacuate. If officials wish for maximum response, they must work with the media to communicate official advisories in a spatially specific fashion (Baker, 1991).

2.5 *The Role of Media in Disseminating Risk Information*

During a natural disaster, the media are crucial to disseminating information to the public, however, the way in which the information is delivered changes. In times of disaster, the media activate a ritual that presents an "interactional approach" that depends on the media working in concert with political and social institutions (Durham, 2008). Understanding the strategies used to disseminate risk information is critical to improving communication in the event of a disaster. The strategies employed by the media help contribute to the large role they play in communication between government agencies and the public, which has an effect on how the public perceives the risk of a disaster (Choi and Lin, 2008). The relationship between risk communicators and the media can lead to a reduction of uncertainty among the public (Choi and Lin, 2008).

The media have considerable responsibility and influence on how a community experiences and responds to a disaster (Piotrowski and Armstrong, 1998). Mass media are a central force behind the social construction of risk because of its utility and the power of media hype (Miles and Morse, 2007). This fact can help shape how a disaster plays out and is perceived by the locals affected and the rest of the world (Choi and Lin,

2008) because the information is addressed to audiences that range from young children to practicing meteorologists (Dow and Cutter, 2000).

Mainstream media have many different roles that range from public health and safety advocates to raising awareness, but the most important is the role of disseminating risk information to the public. This role is crucial to understanding hurricane-warning graphics because it is the source in which most people get their information (Choi and Lin, 2008). Therefore, the sustainability of our society depends on better knowledge of the risks associated with where we live (Miles and Morse, 2007) and the media can become a powerful conduit to inform the public on these risks.

2.5.1 Media Dissemination and Public Perception of Risk Information

Understanding how individuals use different types of communication media in natural disaster events is crucial to making improvements in emergency preparedness (Lee, Meyer, and Bradlow, 2009). From studies of media coverage during disaster events, results show that most people rely on television to gain information about the event (Altheide, 1985; Dow and Cutter, 2002; Hammer and Schmidlin, 2002; Lindell, Lu, and Prater, 2005). Citizens rely mostly on television viewing to gather information during a natural disaster because most people prefer the visual imagery and dramatic impact that television provides (Piotrowski and Armstrong, 1998). Most people choose to use television as their primary source over newspapers because of faster information delivery. Other studies have shown that the public perceives television to be more accurate than newspapers (Piotrowski and Armstrong, 1998). Local television is the most cited source for finding news on disasters, most also report using the Internet to gain information (Tanner et al., 2009). Due to the public's reliance on television, it is impetrative to strengthen effective communications between risk communicators and the media.

Television news helps define public attitudes toward events and issues associated with a disaster (Walters and Hornig, 1993). Mass media defining how the public perceives the disaster can be achieved through media frames and media agenda setting. Media agenda setting refers to the deliberate coverage of topics with the intent to influence public opinion or policy. Framing can be a positive process if it is in concert with government officials and experts however, it can have negative impacts if it takes away the focus from the important information that needs to be disseminated to the impacted public (Barnes et al., 2008). For instance, if the media focuses too much on certain issues, that can lead the public to perceive those issues to be the most important. Media coverage should equally emphasize disaster mitigation and preparation as well as response and recovery that could reduce economic and life loss (Barnes et al., 2008). Barnes suggest that public health practitioners should communicate with the media before, during, and after a disaster event to make sure that they are on the same page with respect to what information needs to be disseminated.

Disasters open the information gates and allow average citizens to pass through in large numbers and for a variety of crises (Walters and Hornig 1993). The greatest number of news sources during a disaster are citizens and public officials (Nimmo and Combs 1985). When citizens, not experts, become the main source for journalists, public confusion about the disaster can occur due to the fact that these citizens are asked to comment on issues that are beyond their typical level of knowledge on the subject (Walters and Hornig 1993).

2.6 *Visual Communication of Risk*

Risk can be communicated through many ways. It is usually determined numerically, however when trying to communicate risk to the public by numerical means, the information trying to be disseminated can be lost in translation. The use of graphics can have desirable properties that can improve understanding of numerical risk and when transferring numerical risk into visuals, the likelihood of holding the audience's attention increases (Lipkus and Hollands, 1999). One of the advantages of graphics is their ability to summarize large amounts of complex data and transform that data into something more simplistic (Lipkus, 2007). Research on visuals has found that display design is one of the more important aspects of communicating risk in graphical forms (Simkin and Hastie, 1986; Shah et al., 1999; Peebles and Change, 2003). Oftentimes, graphics with less detail are more effective than graphics that provide more detail and more information (Dwyer, 1978). The United States' Homeland Security Department has a database of symbols they use to communicate risk. This is one approach that could be helpful for those who cannot comprehend written text (Mayhorn et al., 2004). They claim that the use of pictorial safety symbols can cross cultural boundaries and become "culturally neutral" (Mayhorn et al., 2004). In order for the graphics to work correctly, the audience must have the capacity to extract the appropriate information from the display (Lowe, 1999). Allen et al. (2006) proposed a way to assist in user understanding by including supporting geographic information such as city locations and landmarks with respect to weather maps. When dealing with the communication of meteorological hazards, users tended to better infer the task-relevant information from the graphics after given instruction (Canham and Hegarty, 2009). When graphics are used for weather events, broadcast meteorologists are usually the source where most of the public gets their information. Therefore, instruction from these meteorologists is crucial and they should highlight the task-relevant information based on what the audience should take away from the graphics (Sherman-Morris, 2005). The findings on the effects of instruction are positive, however the user will not always be given instruction on what the task-relevant information is and what they should take away from a graphic. Because of this, graphics should not display more information than is needed for the task at hand (Canham and Hegarty, 2009). Therefore, visual communications of risk must be carefully designed and as unambiguous as possible.

The main assumption about graphics is that they can facilitate comprehension, communication and inference by transforming abstract data into concrete data (Tversky et al., 2002). However, this assumption can only be held true if the graphic is carefully designed and with advances in technology creating aesthetically pleasing visuals, research on how effective these graphics are is lacking. Graphics will not always be effective in all situations (Tversky et al., 2002). Graphics will not always address every aspect of the risk, and can sometimes be misinterpreted (Mayhorn et al., 2004). Understanding the graphic's audience is critical to the success of a risk communication visual (Lipkus and Hollands, 1999). Some graphics can actually draw attention away from the main message, therefore an effective graphic would allow the user to simply and clearly draw specific and desired conclusions (Lipkus, 2007). Because graphics can shape the user's perception of the risk (Sherman-Morris, 2005), comprehension testing should be in place to determine the effectiveness of risk graphics before they are implemented (Mayhorn et al., 2004).

CHAPTER 3: WORLDWIDE TROPICAL CYCLONE WARNING SCALES

3.1 *Atlantic and Eastern Pacific Basin*

The creation of a hurricane warning service in 1898 by President William McKinley transformed our forecasting abilities and therefore our preparation for these storms but most importantly, the introduction of weather satellites in 1960 has had the greatest impact (Elsner and Kara, 1999). Other countries have tropical cyclone warning systems that perform in the same or similar ways as the NHC. The four major tropical cyclone warning scales will be discussed throughout the section.

North Atlantic tropical cyclones are classified as a hurricane when their winds have a one-minute maximum-sustained near-surface speed of 33.1m/s^{-1} (74 mph, 64 kts). Wind speed and minimum sea level pressure (SLP) are used to measure the intensity of a hurricane. The Saffir-Simpson (SS) scale is currently used by the NHC and the NWS to classify the destructive potential of an approaching hurricane in the United States. This scale is based on one minute averaged maximum- sustained near surface winds and is considered an extension of the various stages of tropical cyclone development (Elsner and Kara, 1999). Storm surge was an original criterion for SS category, however, in 2009 storm surge was removed from the scale due to its complexity and poor correlation with wind speed. The SS scale classifies hurricanes in five different categories ranging from a category one storm, the weakest, up to a category five storm, the strongest. This scale also denotes differences between destructive potential of hurricane with a title of a major hurricane-category three or greater.

One issue with the Saffir-Simpson scale is that it can lead some to believe that there is a linear relationship between category and damages. For instance, many would believe that a category one storm is only slightly less threatening than a category two storm. This is not the case. The intensity of a storm increases exponentially. Stewart (2011) surveyed Gulf of Mexico residents to assess how many people understood this concept. Results showed that 77 % of the participants thought that hurricane damages increased linearly with an increase in category. Stewart suggests that the SS scale does not do a sufficient job explaining this to the public and believes that if officials would frame the nonlinear relationship between damages and category, hurricane evacuation rates will likely be greater.

As a tropical cyclone threatens the United States, the NHC will issue a watch or warning. A watch means that hurricane conditions are possible in a specific geographical area within thirty-six to forty-eight hours. A warning means that hurricane conditions are expected within twenty-four hours. Watches and warnings are intended to alert the public about the potential for evacuation or other emergency preparations and prompt people to act quickly to protect life and property (Elsner and Kara, 1999). When there is a tropical cyclone in the North Atlantic that has the potential to impact the US coastline, the NHC creates the COU graphic that is based on ensemble forecasts. Where watches and warnings are issued is based on where the COU intersects with the coastline.

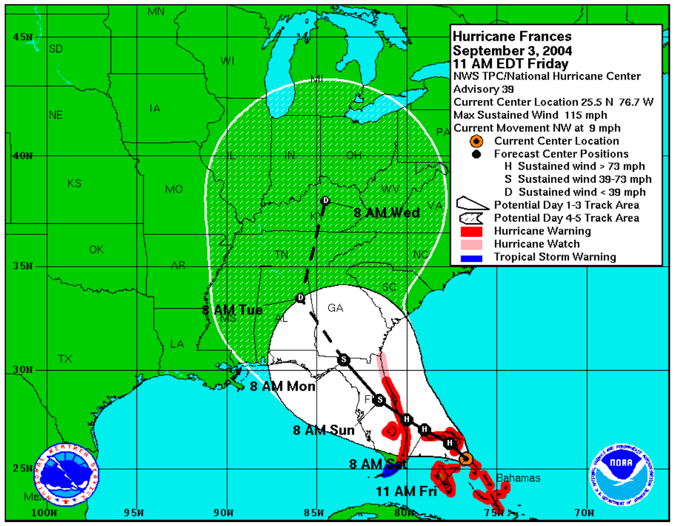


Figure 2: The COU, the current graphic employed by the NHC for disseminating risk information to the public. (Source: http://www.nhc.noaa.gov/sshws.shtml)

3.2 *Australian Region*

The Bureau of Meteorology in Australia (ABM) is the tropical cyclone forecasting agency for the Australian region. The ABM uses a 1-5 categorical scale for estimating strength of a cyclone based on maximum mean (sustained) wind speed averaged over a ten-minute period. The Australian scale ranges from a category one (weakest) to a category five (strongest) (See table 1). Category one and two storms are considered tropical cyclones whereas categories three to five are considered severe tropical storms. This is similar to the NHC denoting the difference between hurricanes and major hurricanes. An additional classification is a tropical low, being a step below a category one storm. The ABM issues a tropical cyclone watch for coastal areas when cyclone-force winds are expected within forty-eight hours. A tropical cyclone warning is issued when cyclone-force winds are expected within twenty-four hours. The graphic used to display risk information to the public is called the Tropical Cyclone Forecast

Track Map. It provides the track of the cyclone, recent movements, and forecast movements out to forty-eight hours. In addition, it shows the extent of damaging winds and areas currently under cyclone watches and warnings. A sample forecast graphic is shown in Figure 3.

There are some differences between the ABM classification and the Saffir-Simpson scale. First, the maximum mean sustained winds are averaged over a ten-minute period relative to the one-minute time period for the SS. This creates about a ten percent difference in wind thresholds between the two systems. For example, the ABM category three storm wind threshold begins at 119 km/h (74 mph) whereas the NHC category three begins at 178 km/h (111 mph). Second, the ABM uses gust to categorize cyclones instead of sustained winds. The ABM reports categorical damages based on the effects of the wind gusts associated with the category of the storm. Structural damages are based off the winds at their highest, not the prolonged period of strong winds.

(Source: http://www.bom.gov.au/cyclone/about/warnings/)

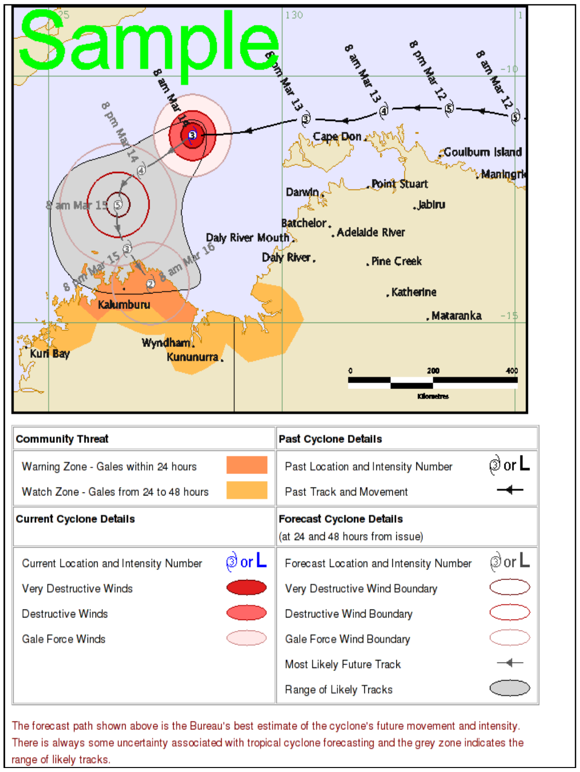


Figure 3: Sample Tropical Cyclone Forecast Track Map. This is the current graphic the ABM provides to the public to disseminate risk information.

3.3 *Western Pacific Basin*

The Japanese Meteorological Agency (JMA) is the tropical cyclone forecasting agency in the western Pacific basin. The JMA monitors tropical cyclone activity in the North Pacific and South China Sea. Issuance of five-day track forecasts, based on the Typhoon Ensemble Prediction System, by the JMA began in 2009. The JMA uses four classification types in their forecasting. A tropical depression is the weakest and a typhoon is the strongest. Three sub types are used in the typhoon category: strong typhoon, very strong typhoon, and violent typhoon. These classifications, like the ABM, are based on maximum sustained winds averaged over a ten-minute period. The wind thresholds compared to the SS scale are similar. Thresholds are virtually alike for tropical depressions and tropical storms. The JMA has two distinctions for tropical storms (tropical storm and severe tropical storm) but when combined, the thresholds are the same as the lone tropical storm classification at the NHC (33-63 kts/38-72 mph). Strong typhoons line up with NHC category one storms (64-84 kts/73-98 mph). Very strong typhoons have thresholds that range from a NHC category two to a lower end category three (85-104 kts/97-119 mph). Violent typhoon wind thresholds begin at the NHC low/mid category three and extend throughout the major hurricane wind speeds (>105 kts/ >120 mph).

(Source: http://www.jma.go.jp/jma/en/Activities/forecast.html)

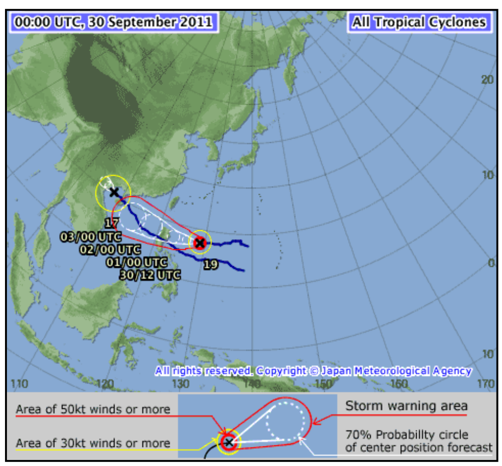


Figure 4: Five-day track forecast map. This is the current graphic used by the JMA to disseminate risk information to the public.

3.4 *North Indian Basin*

The Indian Meteorological Department (IMD) is the tropical cyclone forecasting agency in the Northern Indian basin since 1865. The IMD uses six different names in classifying different tropical systems ranging from depression (weakest) to super cyclonic storm (strongest). These categories are based on maximum sustained winds averaged over a ten-minute period. The IMD issues a pre-cyclone watch seventy-two hours before adverse weather conditions, a cyclone alert forty-eight hours in advance of cyclone-force winds and a cyclone warning twenty-four hours in advance of cyclone-force winds. The Cyclone Track Prediction Map is the graphic disseminated to the public to provide risk information. In comparison to the SS scale, the IMD classifies the cyclones based on wind speeds but also uses cloud configuration and surge heights to estimate intensity. The IMD also begins classifying earlier in development than the NHC (Depression forms at 31-49 km/h (19-30 mph). There are four classifications in the IMD system that occur before reaching the threshold for a category one storm in SS scale: depression, deep depression, cyclonic storm, and severe cyclonic storm. The IMD uses two subcategories for the very severe cyclonic storm. The first subcategory has wind speeds of 118-167 km/h (73-103 mph), the second subcategory has wind speeds of 168-221 km/h (104-137 mph). These encompass the NHC's category one through lower category four hurricane, a 103 km/h (64 mph) range. The super cyclonic storm has a lower threshold than its NHC counterpart in that a cyclone is classified to the highest intensity at a threshold of winds greater than 222 km/h (> 138 mph) whereas a NHC category five has wind speeds of greater than 155 mph.

(Source: http://www.imd.gov.in/section/nhac/dynamic/cyclone.htm)

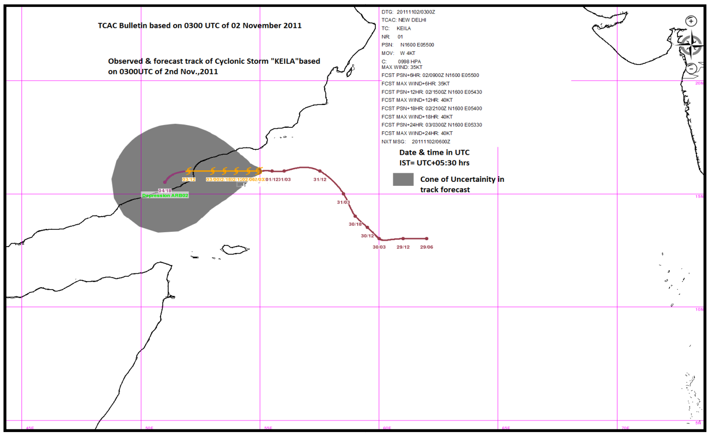


Figure 5: Cyclone Track Prediction Map. This is the current graphic used by the IMD to disseminate risk information to the public.

Table 1: Worldwide tropical cyclone classification system comparison table. The systems are compared based on sustained winds thresholds and nomenclature of storms.

<table>
<tr><th colspan="7">Tropical Cyclone Classifications Worldwide</th></tr>
<tr><th colspan="3">Sustained Winds</th><th rowspan="2">Atlantic/Eastern Pacific Basin
(NHC)</th><th rowspan="2">Australian Basin
(ABM)</th><th rowspan="2">Western Pacific Basin
(JMA)</th><th rowspan="2">North Indian Basin
(IMD)</th></tr>
<tr><td>kts</td><td>km/h</td><td>mph</td></tr>
<tr><td>< 27</td><td>< 51</td><td><31</td><td rowspan="2">Tropical Depression</td><td rowspan="2">Tropical Low</td><td rowspan="2">Tropical Depression</td><td>Depression</td></tr>
<tr><td>28-33</td><td>52-61</td><td>32-38</td><td>Deep Depression</td></tr>
<tr><td>34-47</td><td>62-87</td><td>39-54</td><td rowspan="2">Tropical Storm</td><td>One</td><td>Tropical Storm</td><td>Cyclonic Storm</td></tr>
<tr><td>48-63</td><td>88-117</td><td>55-72</td><td>Two</td><td>Severe Tropical Storm</td><td>Severe Cyclonic Storm</td></tr>
<tr><td>64-82</td><td>119-153</td><td>74-95</td><td>One</td><td rowspan="2">Three</td><td rowspan="8">Typhoon</td><td rowspan="5">Very Severe Cyclonic Storm</td></tr>
<tr><td>83-85</td><td>154-157</td><td>96-98</td><td rowspan="2">Two</td></tr>
<tr><td>86-95</td><td>158-176</td><td>99-109</td><td rowspan="2">Four</td></tr>
<tr><td>96-107</td><td>177-198</td><td>110-123</td><td rowspan="2">Three</td></tr>
<tr><td>108-113</td><td>199-209</td><td>124-130</td><td rowspan="4">Five</td></tr>
<tr><td>114-119</td><td>210-220</td><td>131-137</td><td rowspan="2">Four</td><td rowspan="3">Super Cyclonic Storm</td></tr>
<tr><td>120-135</td><td>222-250</td><td>138-155</td></tr>
<tr><td>>135</td><td>>251</td><td>> 156</td><td>Five</td></tr>
</table>

3.5 *Worldwide Tropical Cyclone Characteristics*

All of the different regions use similar colors to denote certain aspects of the warning graphic. The common colors are warm colors such as: red, orange, yellow, and pink with the only cool colors used are grey and blue. Purple is also used in the IMD's graphic however, because purple is a combination of blue and red; it cannot be classified as warm or cool.   The ABM and the IMD use a grey cone like structure to denote uncertainty by encompassing all the areas where the center of the tropical cyclone could possibly be. The JMA uses a mixture of a cone and circles to represent uncertainty. In each circle, based upon calculations, there is a70 % chance of the center of the storm to be in the center of each circle. As the forecast get farther out, the circles get larger to show the greater uncertainty in the forecast. In the Atlantic and Eastern Pacific basins, uncertainty is shown with a white cone. The track line in the center of the cone is utilized like circles from Japan in that that is where the center of the storm is forecasted to be. When discussing track lines, all basins use a track line expect for Japan. The JMA uses circles encompassed by a larger cone. Outside the white uncertainty cone, there is a larger red cone that represents warned areas. The only track line on the JMA forecast map is a blue solid line that shows the past track of the storm. The Atlantic and Eastern Pacific basins use a black line with black dots to show forecasted center locations. In the Australian region, the track line is a grey line with arrows pointing in the direction of motion and past and forecasted centers as the hurricane/typhoon symbol with the intensity inside the symbols. The IMD graphic uses a solid purple line with dots to represent past track and past center locations. The track color changes to show the storm's changes in intensity from purple to orange to black. When representing wind, only the JMA and the ABM use symbols to show the extent of certain wind speeds. The ABM uses two variations of three shades of red to warn the public about the winds associated with the storm. When portraying the current extent of winds, the ABM uses filled circles ranging in colors from dark red, red, and pink. They use the same colors to show forecasted winds, however the circles are only outlined in these colors. The JMA does not show forecasted winds but they do show the extent of 50 kts winds (red outlined circle) and 30 kts winds (yellow outlined circle) of the current location. Since all of these agencies use similar colors and many agencies use the same shapes to portray warnings to the public, the graphics created for this study will encompass many of the aspects already in place by these agencies to determine which aspects of these graphics the residents of Pensacola, FL and Jacksonville, FL prefer.

CHAPTER 4: METHODS

4.1 *Preliminary Graphics and Survey*

In this research, five hurricane-warning graphics were created in addition to a re-creation of the COU. Initial polling with all six graphics was performed on a sample of 140 Geography (GY) 101 students.

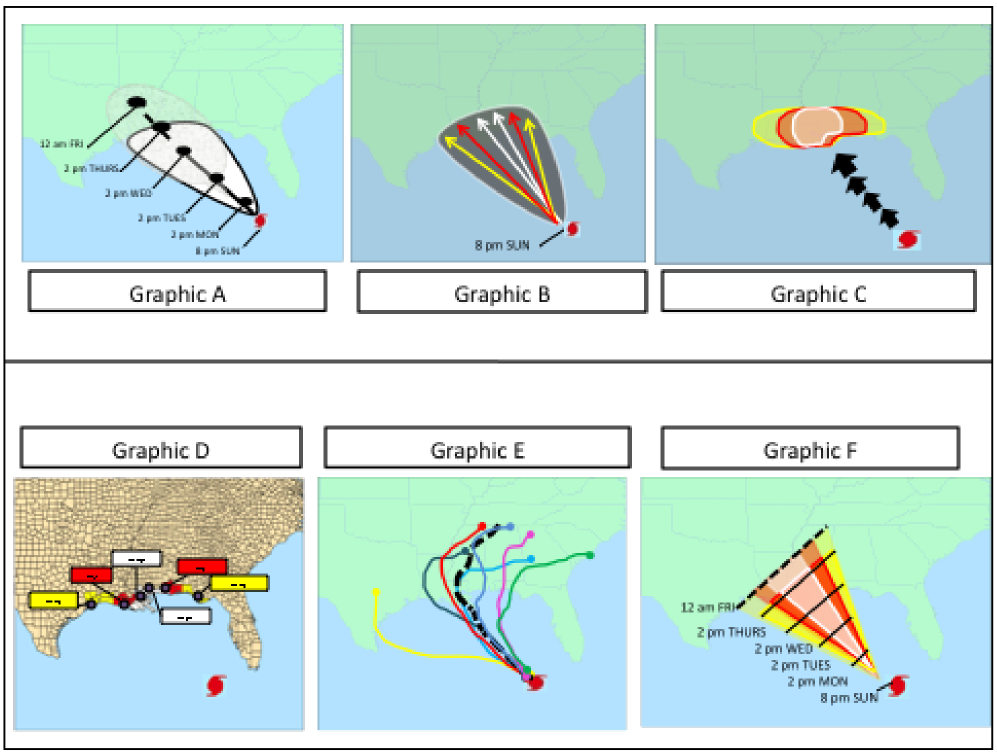


Figure 6: Six original graphics from the preliminary survey. Graphic B was discarded after the preliminary survey and graphic C, D and F were modified to present form before use in the primary survey.

Based on the responses of GY 101 students, the least popular graphic (graphic B) was eliminated because it received so few votes in the pilot survey; it was decided to remove it from the primary study. Therefore, only five graphics were retained for field research in Pensacola, FL and Jacksonville, FL. These two locations were chosen to represent two demographically similar locations with two different recent hurricane histories; Pensacola, FL with a relatively active recent hurricane history and Jacksonville, FL with a relatively inactive recent hurricane history (See table 2 below). Based on these characteristics, two hypotheses were developed: (1) graphic preference will be different between the two locations and (2) the use of graphics will be greater in the less hurricane savvy location of Jacksonville, FL. The reasoning behind the first hypothesis is when dealing with a hurricane savvy population; one would believe that they would prefer a graphic that provides more information. Hurricane savvy populations usually will gather information from the media as well as gathering information on their own from other outlets (Dow and Cutter, 2000). Therefore, it is believed that a simpler or less complex graphic would be preferred by a population that does not have as much experience with hurricanes and hurricane preparedness. Reasoning for the second hypothesis is similar to the first hypothesis. Residents in Jacksonville, FL (less savvy) might not be as familiar or have the desire to search other information outlets therefore, their reliance is solely or majorly on hurricane-warning graphics as opposed to hurricane savvy residents that read forecast discussions and scan numerical models. Using surveys and optional interview questions, it was determined which graphic the residents prefer and if their locations play a role in their perception of the graphics. This study signifies a step in the direction that Baker (1979) thought should be taken: a more critical examination of the role of social scientific research into hurricane-warning-response systems.

Table 2: Demographic and hurricane history characteristics for Pensacola and Jacksonville, FL.

Population and Hurricane History Characteristics for Participating Locations		
Location	**Pensacola, Florida**	**Jacksonville, Florida**
Metro Population	Approx. 400, 000	Approx. 750,000
Last Impact by a Hurricane	2004-Hurricane Ivan	1964-Hurricane Dora
Recurrence Interval for CAT 3 Winds	26 Years	53 Years
Number of Impacts by a Major Hurricane in the Past 109 Years	8	0

4.2 *Institutional Review Board Certification*

University of Alabama Institutional Review Board (IRB) approval protocol 1616 for this research was granted in August 2010. This certification requires everyone involved in the study to complete the NIH Human Participant Protections Education for Research Teams. IRB requires the researcher to submit a protocol that provides all details, including the consent/contact information form and recruitment script, of the study to make sure that the study is in compliance with IRB rules and regulations. During the process, the questionnaire must be submitted to the board.

4.2.1 *Questionnaire Design*

The nine-page questionnaire consists of: recruitment script (1), consent and information form (2), demographic information and past tropical storm experiences (3), five different hurricane-warning graphics (4-8), and with a page asking participants to rank the graphic and add comments (9) (see appendix A (page 90)). The demographic and tropical systems history page asks the participants to provide their age, gender, and zip code of their residence. It then asks the participants if they have ever been in a tropical storm or hurricane; if yes, participants are asked which ones and the Saffir-Simpson category at landfall of the storms participants experienced. Following that, the participants are asked to describe how often hurricane-warning graphics play a role in their decision to evacuate or not evacuate before a storm makes landfall. They were given four choices and were asked to circle the most fitting answer: none, occasionally, most of the time, or always (see appendix A (page 92)).

The next five pages were hurricane-warning graphics, one per page, created using a combination of ArcGIS 9.3 and Microsoft PowerPoint. These graphics consisted of different visual ways of representing the same information. Graphic A is a re-creation of the current COU used by the National Hurricane Center. Graphic B has three circular color-coded warning areas. Graphic C uses three color-coded warning levels denoted by counties, and does not include a projected path or track line. Graphic D is the spaghetti graphic that shows the projected paths of different numerical models. Graphic E uses a triangular forecasted path with three color-coded warning levels and no track line. All five graphics were developed for land-falling scenarios targeting Pensacola, FL and Jacksonville, FL. Examples of all five types of graphics, with the addition of the sixth graphic used in the pilot study, are found in figures 7 through 12 below.

4.3 _Description of Graphics_

Graphic A: Pensacola

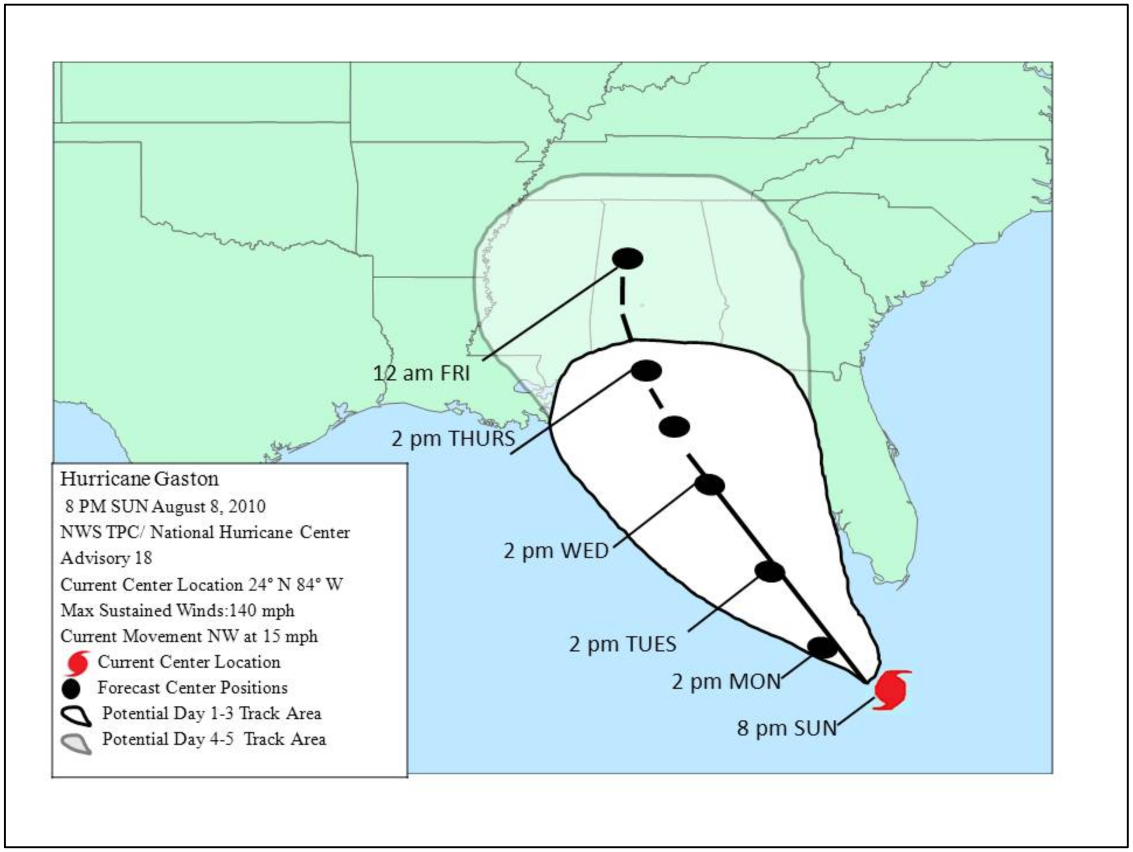


Figure 7a: The "Cone of Uncertainty." Currently used by the NHC, NWS, and media outlets. It portrays the center of circulation, the forecast center position, 1-3 day cone in white and a 4-5 days cone in grey. This graphic was used in the Pensacola survey.

Graphic A- Jacksonville

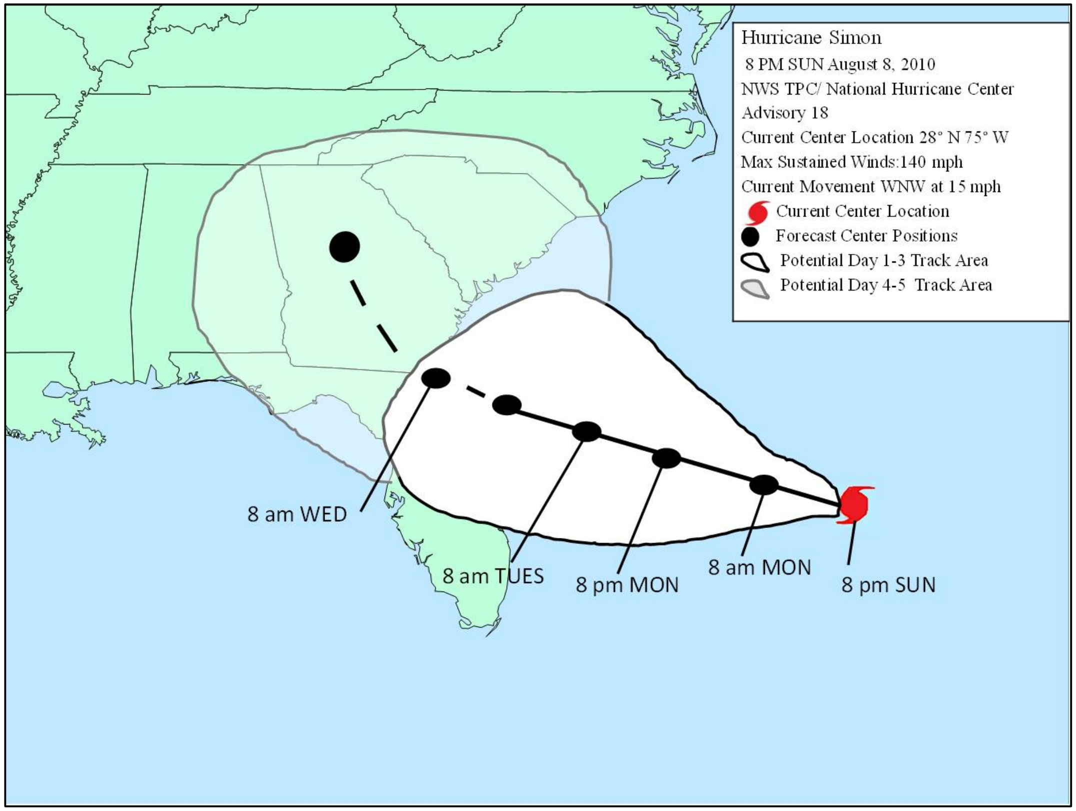


Figure 7b: Jacksonville survey version of figure 7a.

Graphic A Inspiration

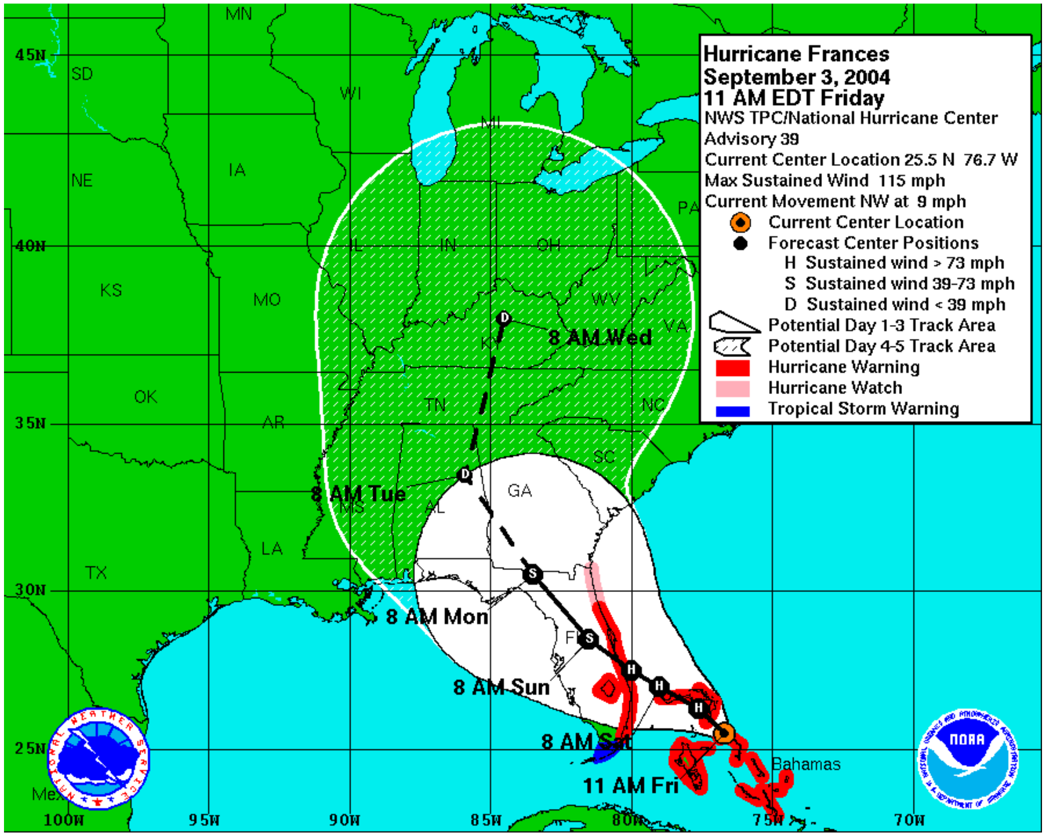


Figure 7c: This is the COU produced by the NHC. This graphic was the inspiration for graphic A. It is currently used by the NHC and many other media outlets and is the graphic upon which this research is based. (Source: NHC)

Graphic B: Pensacola

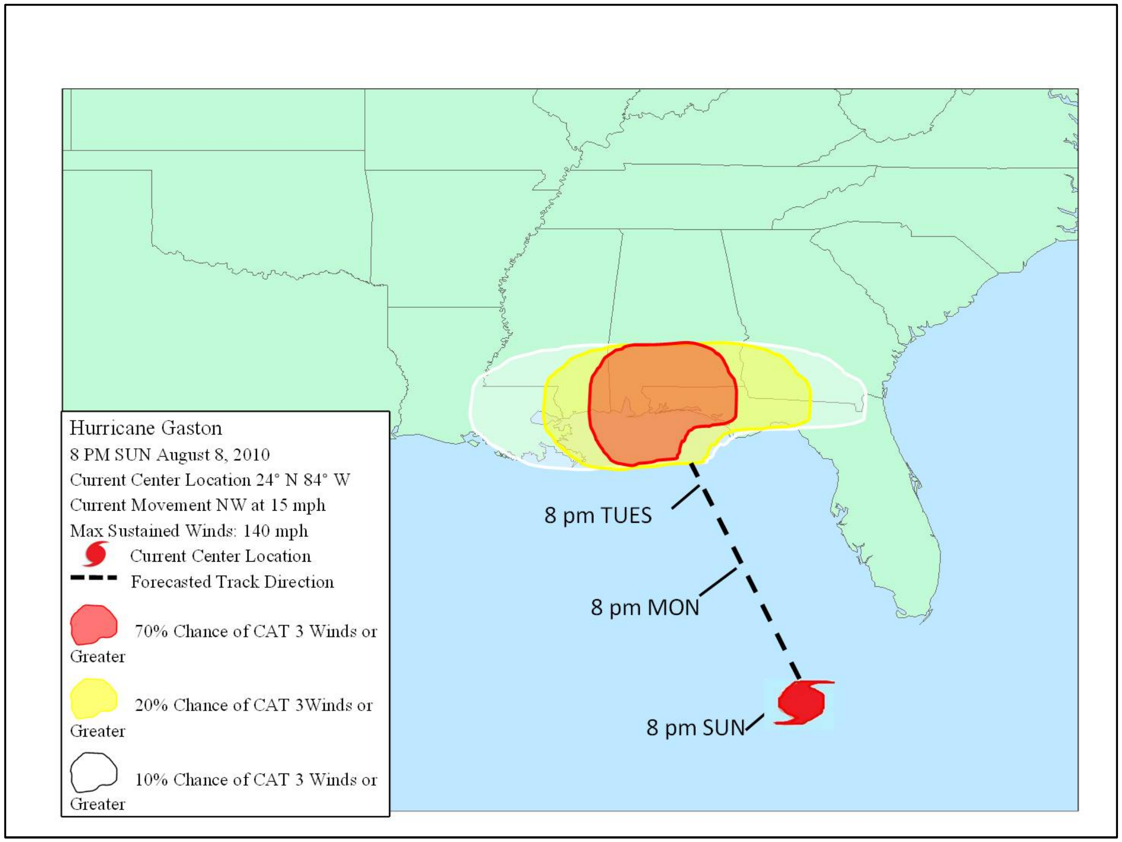


Figure 8a: Color-coded impact zones with track line. Three levels of warning denoted by percentages of impact. Red represents a 70% chance of experiencing category three winds or greater, yellow represents a 30% chance, and white represents a 10% chance.

Graphic B: Jacksonville

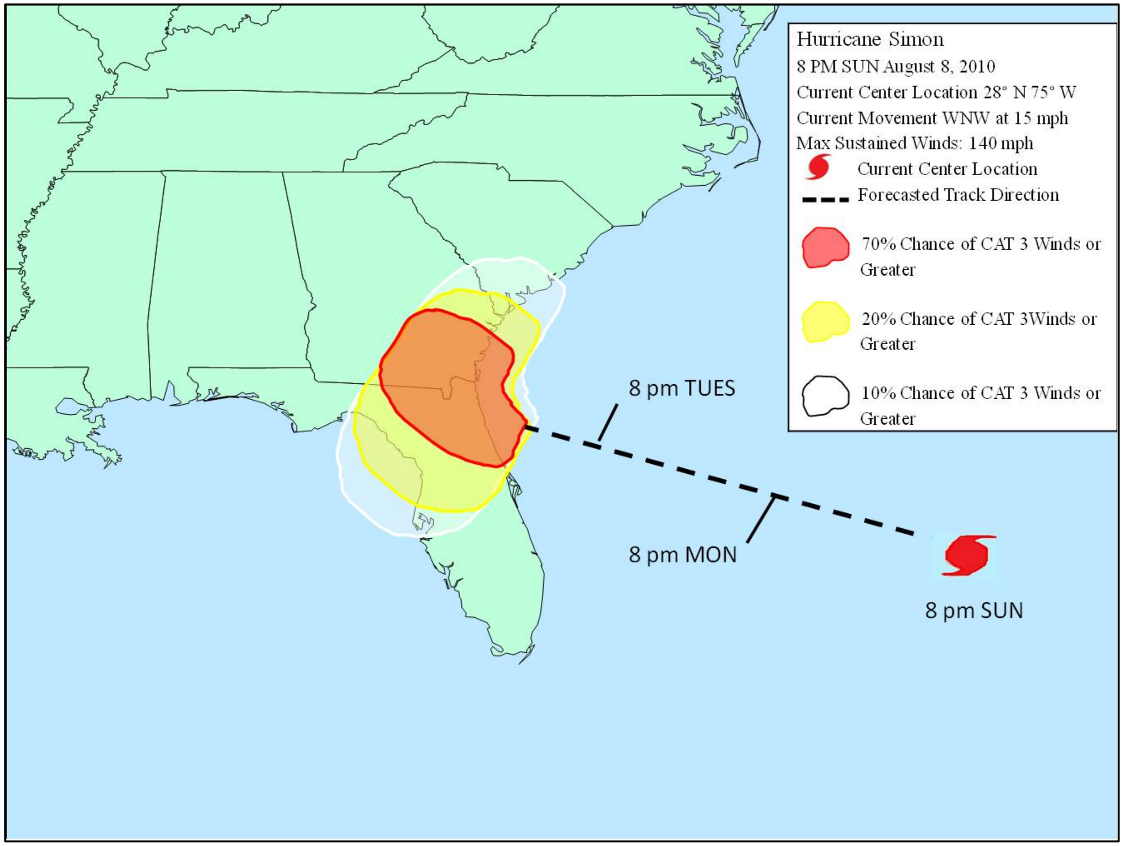


Figure 8b: Jacksonville survey version of figure 8a.

Graphic B Inspiration

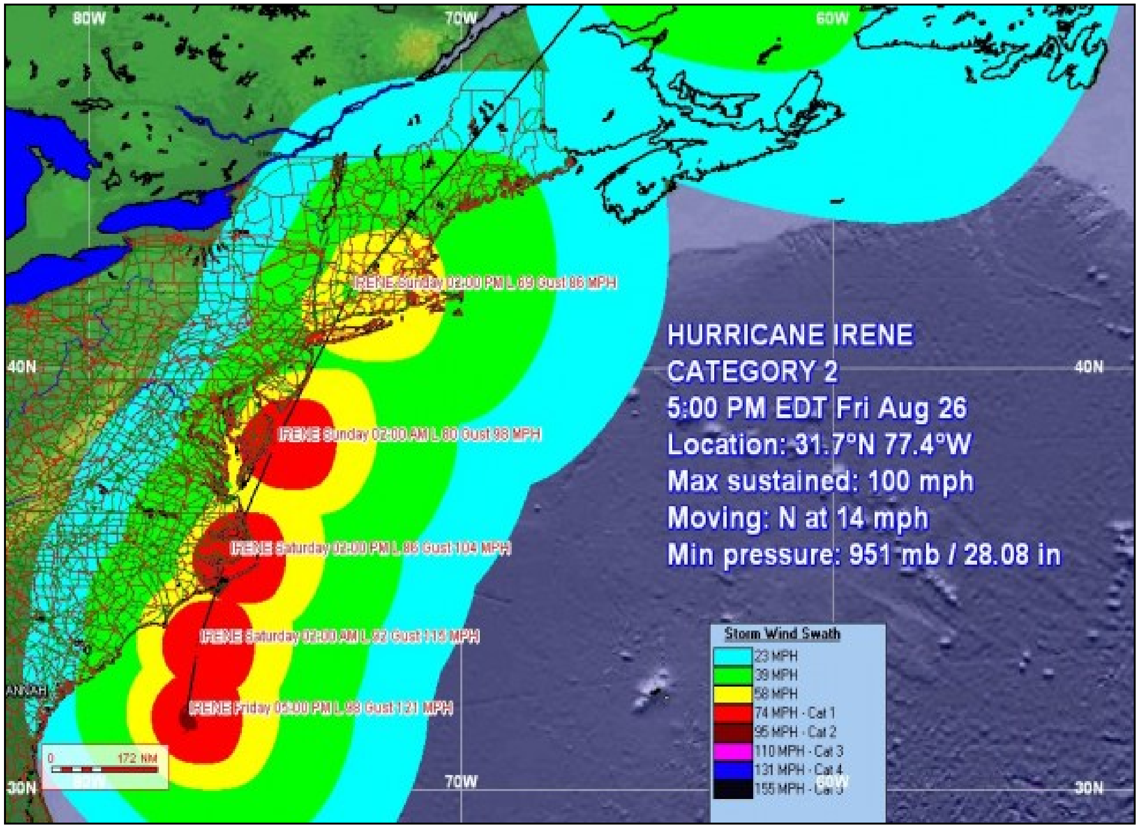


Figure 8c: Previous storms using this graphic were the inspiration for graphic B (Hurricane Irene was not the inspiration since the storm occurred nearly a year after the original graphic was created)**.** It represents different zones based on the potential for certain conditions to occur. This type of graphic was included because it lacks a cone-like structure; therefore making it a good candidate to test the response to a graphic without a cone. (Source: Palm Harbor Forecast Center)

Graphic C: Pensacola

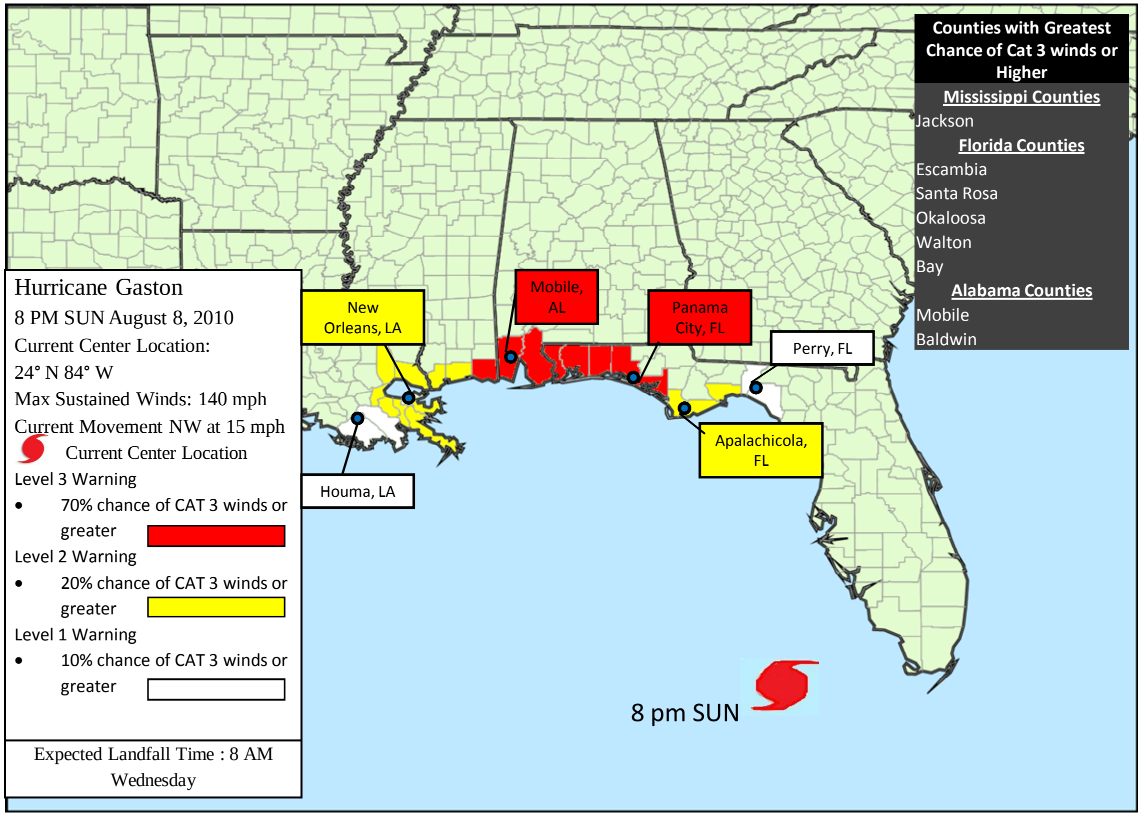


Figure 9a: County-based warnings. No cone or track line. Place-names used to help with orientation. Three levels of warning based on the same percentages as graphic B.

Graphic C: Jacksonville

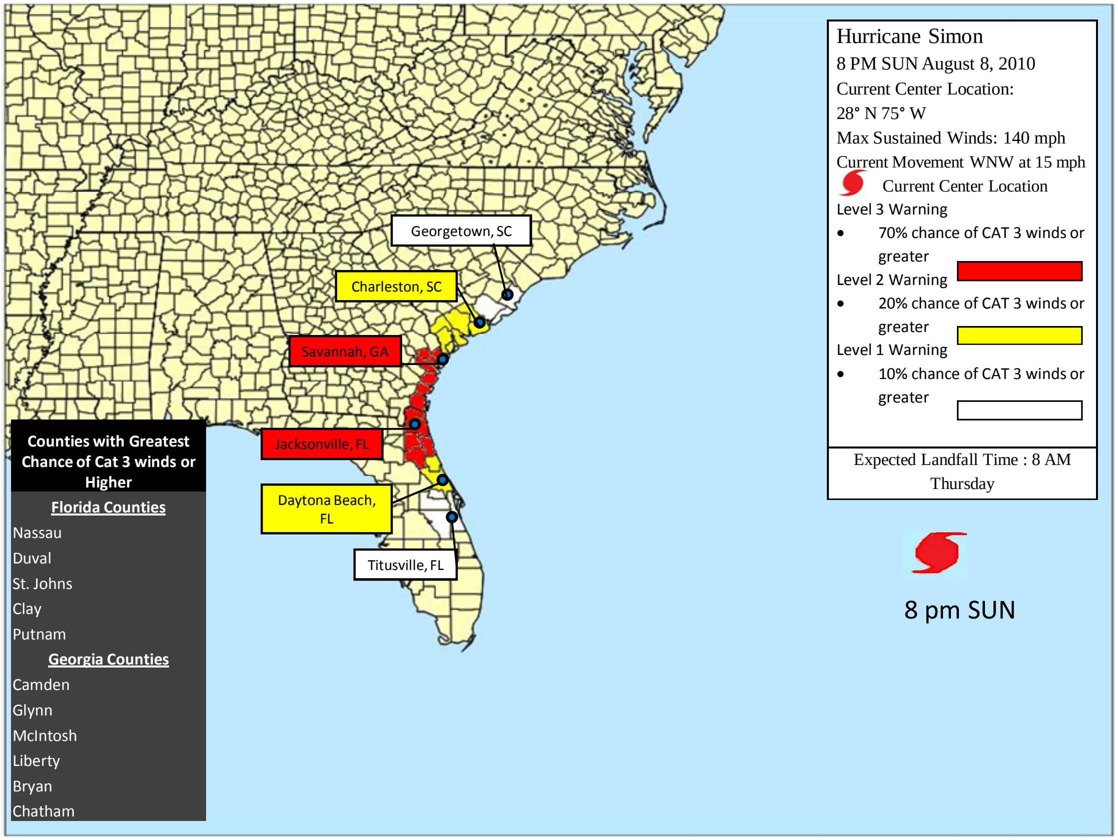


Figure 9b: Jacksonville survey version of figure 9a.

Graphic C Inspiration

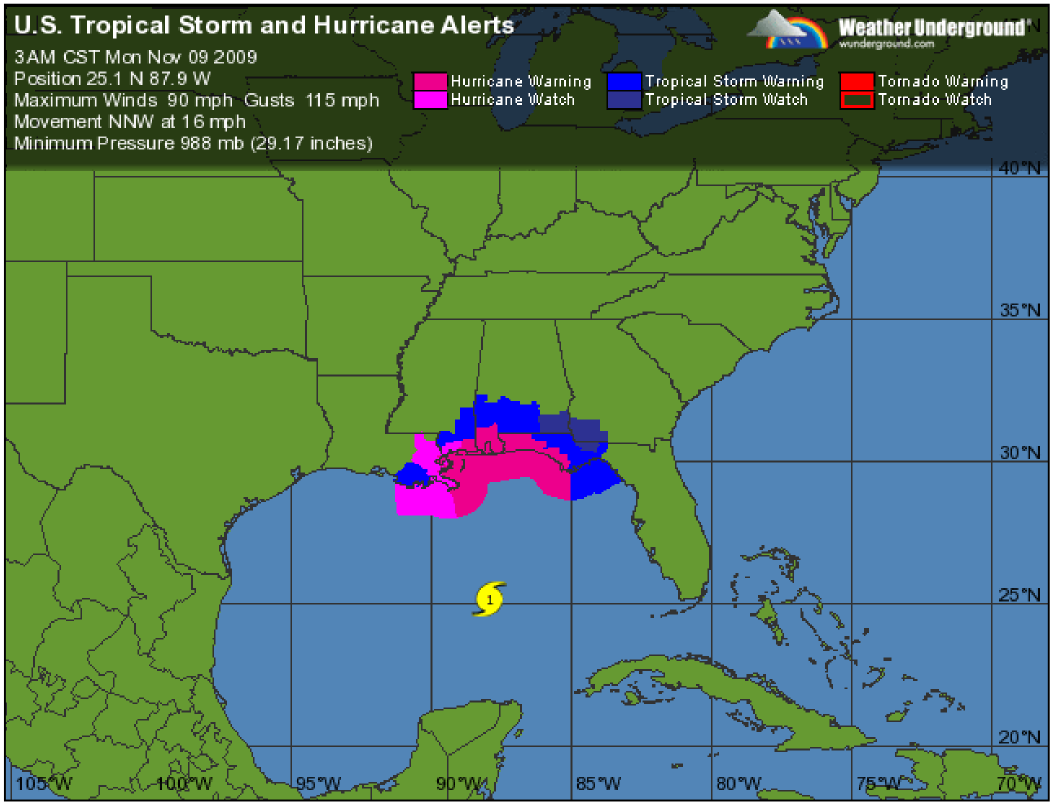


Figure 9c: This graphic is the inspiration for graphic C. It was included because it leaves out a major ingredient in which the COU is criticized for, the track line. Leaving out the track line might lessen people's perceptions that the graphic is certain in where the hurricane is going to make landfall. (Source: Weather Underground).

Graphic D: Pensacola

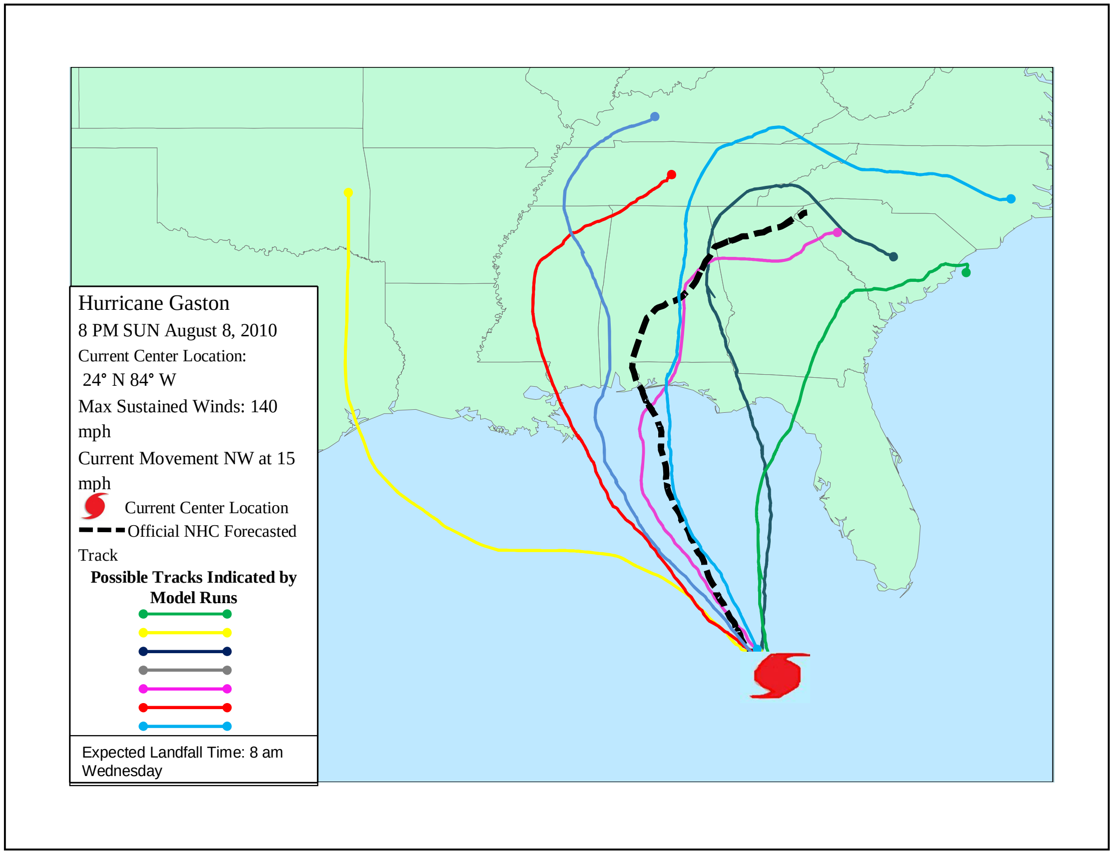


Figure 10a: Computer forecast model runs. These models are compiled into one graphic to show some of the science behind making forecasts. It can also imply different atmospheric processes that might change the trajectory of a storm. It is also known as the "spaghetti" graphic.

Graphic D: Jacksonville

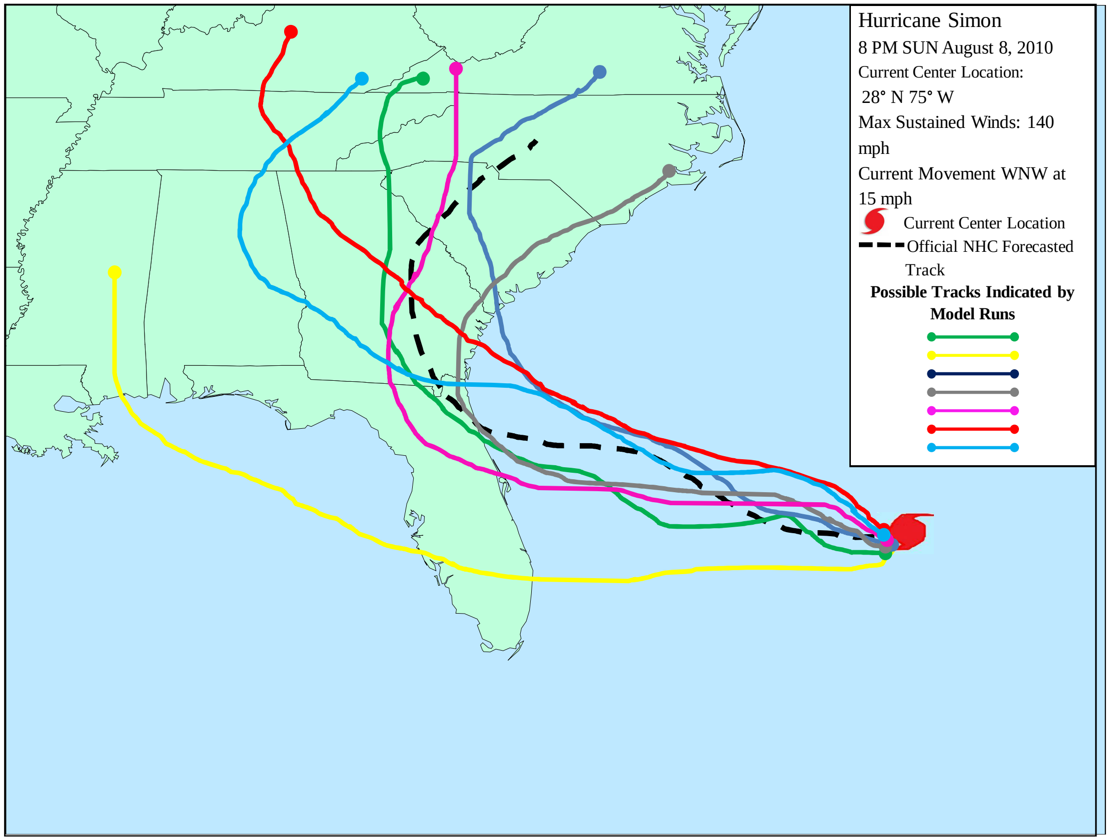


Figure 10b: Jacksonville survey version of figure 10a.

Graphic D Inspiration

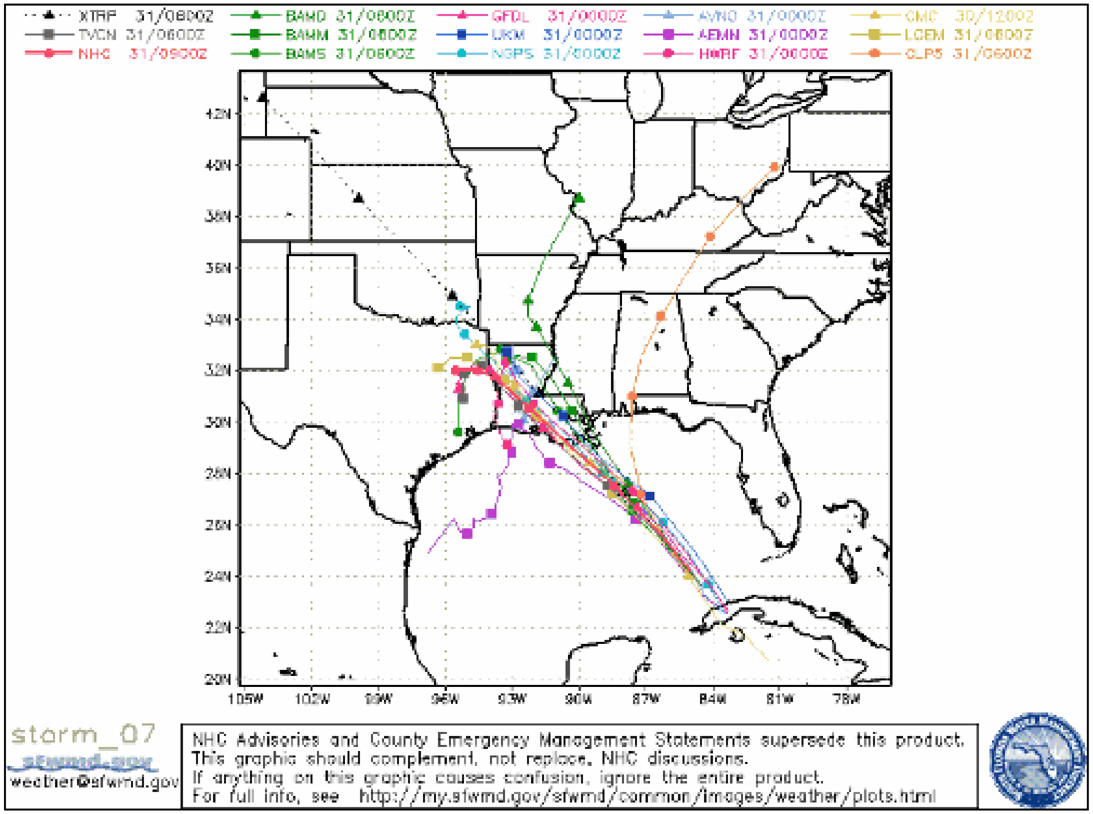


Figure 10c: Computer forecast model runs. These models are compiled into one graphic to show some of the science behind making forecasts. It can also imply different atmospheric processes that might change the trajectory of a storm. It is also known as the "spaghetti" graphic.

Graphic E: Pensacola

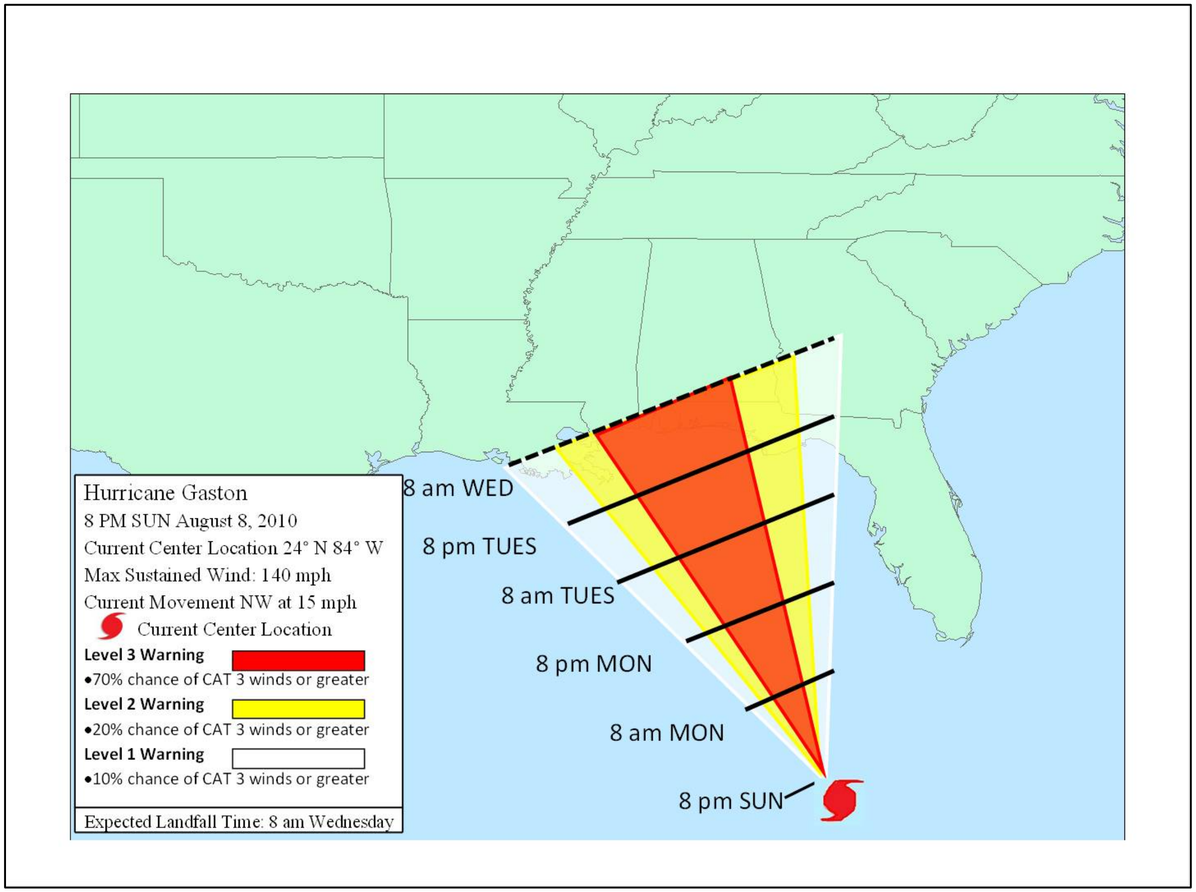


Figure 11a: Cone-like structure, similar to the COU, with the addition of color-coded warning levels. No track line. Warning levels are based on the same percentages of impact as previous graphics.

Graphic E: Jacksonville

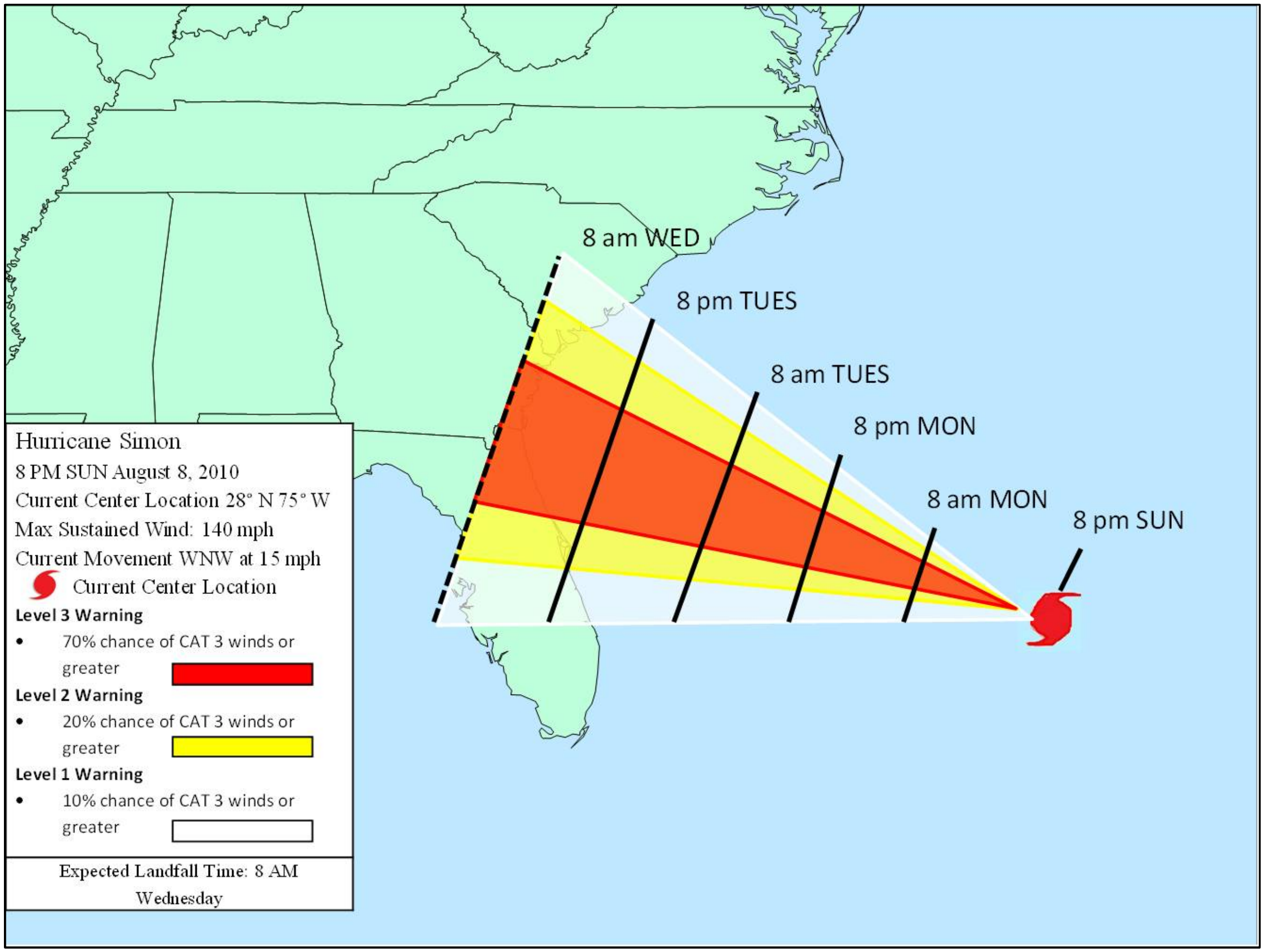


Figure 11b: Jacksonville survey version of figure 11a.

Graphic E Inspiration

Figure 11c: This graphic was the inspiration for graphic E. It was included because it is similar to the COU, therefore familiar, yet it uses color as another way to display uncertainty. This graphic is different form the graphic used in the survey in that the color changes with time; the color-coded cone changes color, or warning levels, based on distance form where the storm is currently forecasted to make landfall. (Source: The Weather Channel)

Graphic F Pensacola (*not included in primary study)*

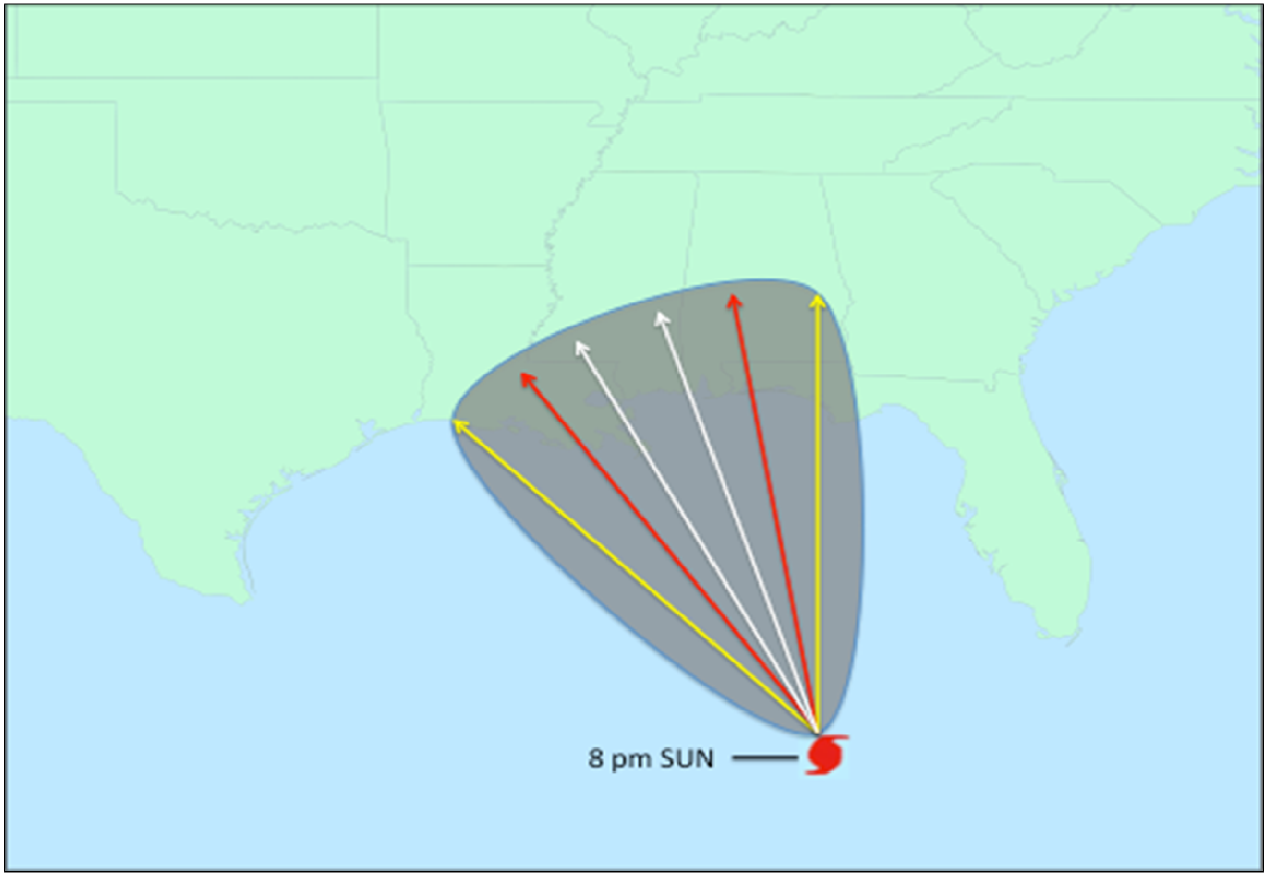


Figure 12: This graphic was used in the pilot survey of a geography 101 class. This graphic is included in this section because it was shown to a group of people. However, this graphic was so unpopular in the pilot study that the author decided to remove it from the primary study and use only the five proceeding graphics.

4.4 *Secondary Study Questionnaire Design and Methods*

The landfall of Australian cyclone Yasi in January 2011 turned the authors' attention towards Australian hurricane-warning graphics. The ABM graphic contains an abundance of information in a relatively clean and concise format. Because of the effectiveness of the ABM graphic, a secondary study was devised to compare a hypothetical Australian graphic and the color-coded cone against each other (Graphic E). The color-coded cone was compared against the Australian graphic because it was the most popular graphic from the primary study. A sample of Geography 101 students was once again used with a secondary study questionnaire consisting of only one page. The questionnaire asked the students to circle which graphic they preferred (A- hypothetical Australian graphic or B- color-coded cone). The students were then asked to provide written responses discussing why they chose that particular graphic. Written responses were optional and encouraged in the primary survey with poor response rates due to the number of questions and time involved. For quick analysis of the results, the students used rapid response clickers to choose their preferred graphic. After sufficient time was given to the students to examine the graphics, they answered either A or B for their graphic choice. This method provided percentages. A qualitative approach was taken to see which aspects of each graphic the students liked and disliked from written responses. A total of 117 students were surveyed, however, the study only used 103 surveys. Fourteen surveys were discarded because of incomplete surveys or misunderstandings of the directions.

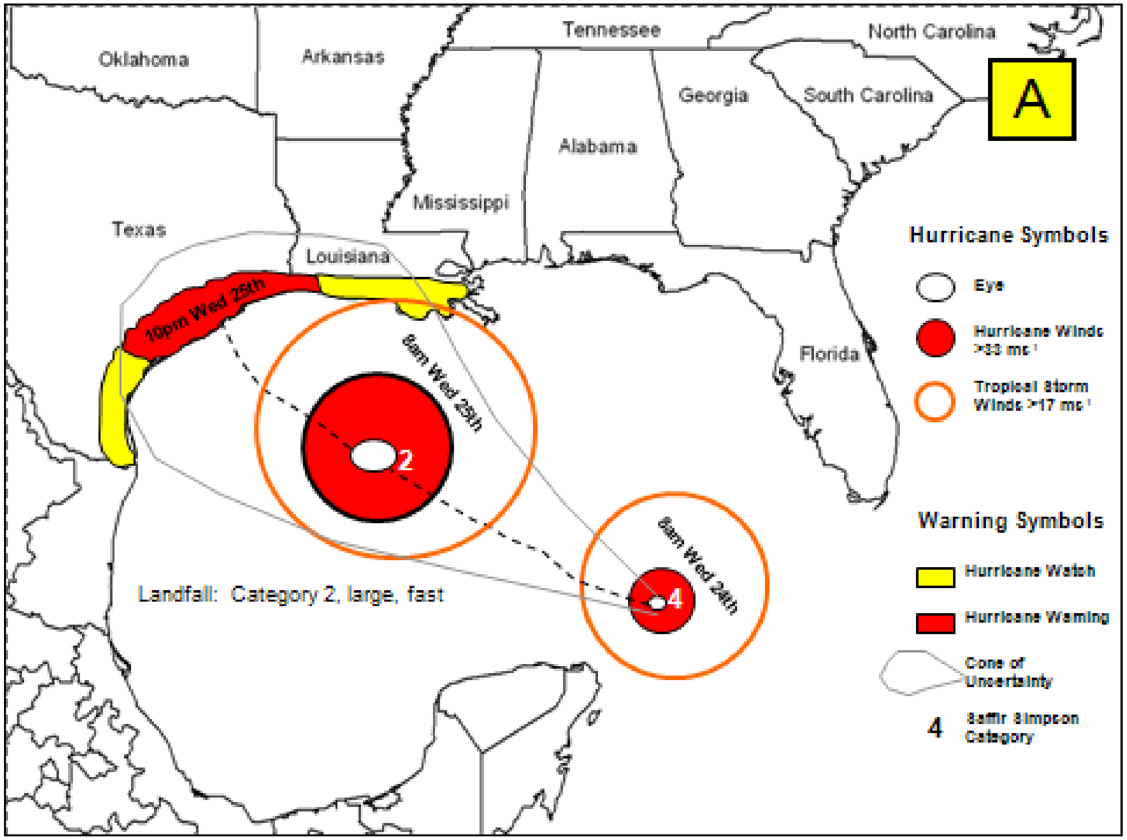


Figure 13*:* Hypothetical Australian model adapted for the United States. (Source: Senkbeil et al. 2011)

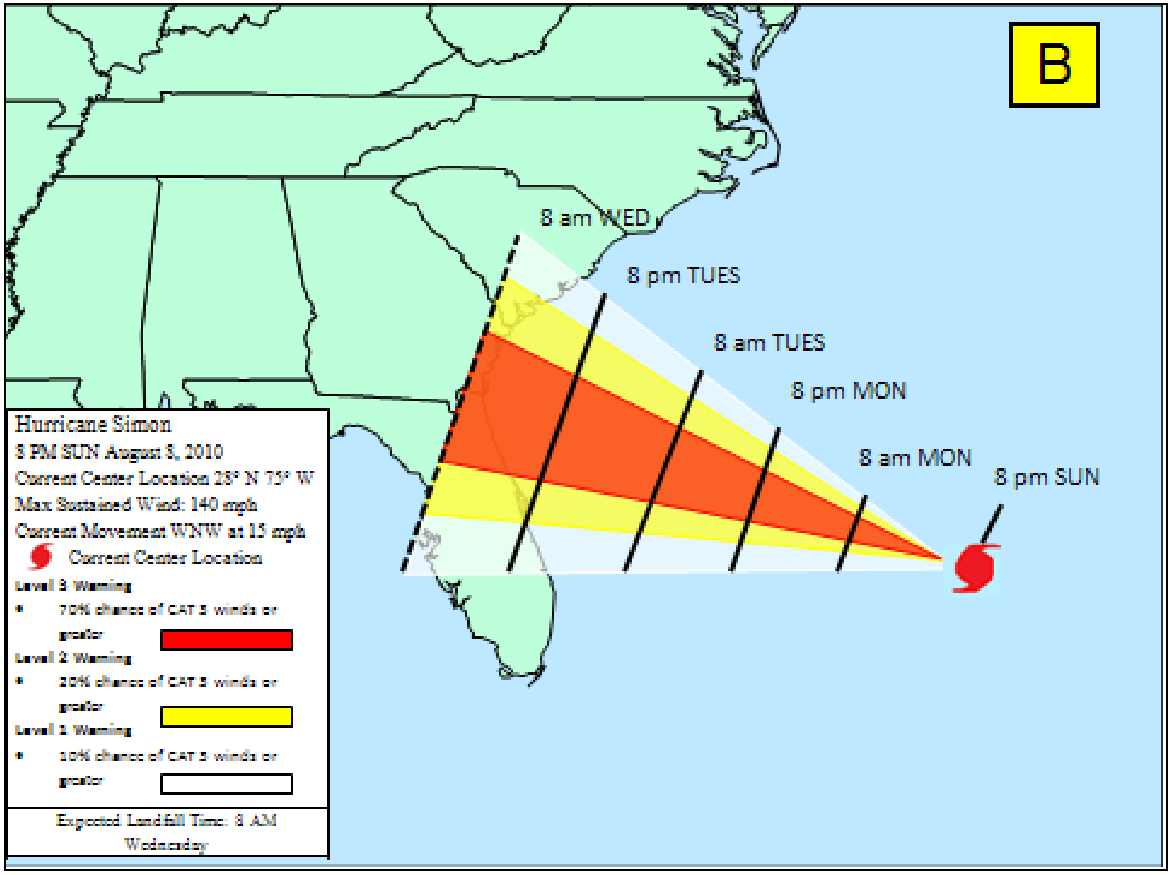


Figure 14*:* Color-coded cone. (Reference description on page 55). This graphic was chosen as a comparison to the hypothetical Australian graphic because it was the most popular graphic in the primary study.

Hurricane Warning Graphic Survey

Please circle which hurricane warning graphic YOU prefer. Then, briefly explain why you prefer this graphic.

I chose graphic.... A B

Because...____

Additional Comments: ____

Figure 15: Questionnaire given to students to record their responses. Students were asked to circle which graphic they preferred and then to provide reasons to why they chose that particular graphic. Additional comments were welcomed but not required.

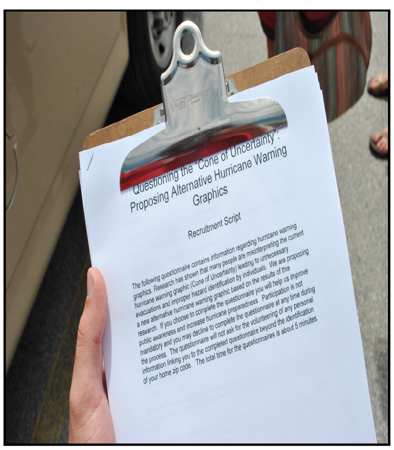
4.5 Field Methods

Having completed the IRB certification and approval process, the surveys were taken into the field September 25, 2010. The research team targeted public areas with high foot traffic to administer face-to-face, convenience sample surveys. Pensacola, FL was chosen because of its relatively active recent hurricane history. The first surveying location was a 5K run in downtown Pensacola. The team of 8 researchers separated and surveyed spectators as well as race participants after they finished. The surveys were administered simply by approaching bystanders and runners then describing the purpose of the research. A total of 105 surveys were collected at this site. Later that day, the team went to the Pensacola Seafood Festival. Team members walked around the festival collecting data from the crowd in the same manner as the race. This location was chosen for its large flow of potential participants, and the people in attendance were much more demographically diverse. In all, 215 completed surveys were collected in Pensacola, FL.

The team then traveled to Jacksonville, FL on September 26, 2010. Jacksonville was chosen because of its relatively inactive recent hurricane history. The venue chosen in Jacksonville, FL was outside of the Jacksonville Jaguars football stadium before a home game that evening. Like the Seafood festival, the football pre-game environment was chosen as a site that would have a high concentration of people in a relaxed environment. The team collected data in the aforementioned manner. A limiting factor may be the lack of diversity in the sample population. Although about the same number of surveys were gathered (174), it would be assumed that all the participants are fans of football. How that corresponds to their attention to hurricane-warning graphics is uncertain. Data collection for this study was completed at this location.

4.5.1 <u>Field Work Pictures</u>

Figure 16: Picture of the survey team outside the Seafood Festival in Pensacola, FL



Figures 17-19: The nine-page in-field survey (17), Dr. Jason Senkbeil talking with a resident of Pensacola, FL (18) and a team member surveying a resident at the Seafood Festival (19).

4.6 Statistical Analysis

After the survey responses were collected from each location, a usable sample was chosen from each site. From Pensacola, FL, 215 surveys were collected but were narrowed down to 166 complete surveys. From Jacksonville, FL, 174 surveys were collected and reduced to 149. Samples were reduced due to the following reasons: incomplete surveys, misinterpretation of directions, age restrictions, and residential restrictions (participants were not residents of Pensacola/Jacksonville, FL). First, descriptive statistical analysis was conducted on the data. Descriptive analysis provided information on overall graphic preference as well as the age and gender distribution of the participants. Next, statistical tests were used to ascertain the relationships between graphic preference vs. location, age, and gender, as well as the relationship between graphic preference and the use of hurricane-warning graphics.

4.6.1 Descriptive Summary

Graphic preference at both locations was summarized using count data. Data from both locations were combined to assess overall graphic preference of the participating residents. This data was displayed in percentages. These preliminary results provide insight into possible trends in further analysis.

Eight age groups were created encompassing all participants. Groups in six- year increments are as follows: 19-24, 25-30, 31-36, 37-42, 43-48, 49-54, 55-60, > 60. Six-year increments were chosen because of convenience. After the age of 60, the participants' ages covered a much larger range over much fewer respondents than the preceding age groups. Therefore, the author wanted to have the last major age group to end on an even number. Gender distribution was established using similar methods of analyzing count data. Female participants were be labeled 1 in Microsoft Excel and male participants were labeled 2. Sums of both 1's and 2's were calculated and displayed as percentages. Distribution of the age and genders of participants is pertinent to determine if the sample represents the population.

Count data was used to understand the distribution of how often hurricane-warning graphics play a role in making evacuation decisions. Participants were given four options: never, occasionally, most of the time, and always. In Microsoft Excel, responses were recorded as 1s (never), 2s (occasionally), 3s (most of the time), and 4s (always).

4.6.2 Kruskal Wallis Tests

Two separate Kruskal Wallis tests were performed to test for significant differences in graphic preference between the two locations and also for two categories of gender. Thus, the grouping variable is the binary location or gender, and the test variable became the 5 different hurricane-warning graphics. A critical test value and p value was produced for significant differences in location and gender preference for all five graphics.

4.6.3 Mann Whitney Tests

The Kruskal Wallis test determined significant differences in gender or location preference between at least two of the five graphics. Therefore, the graphics appearing to have the largest magnitude difference were directly compared to each other using Mann Whitney tests. This is similar to performing a parametric 1 way ANOVA with post hoc tests.

4.6.4 Chi Square Contingency Tables

A row x column contingency table with a chi square statistic was employed to assess the relationship of graphic preference vs. age and graphic preference vs. frequency of graphics usage. This test was chosen for these variables because both variables contain multiple subcategories. For age, all eight age subcategories were tested against each graphic. Expected vs. observed counts within groups and within graphics were analyzed in conjunction with p-values to determine the strength of the relationship. For use of graphics, all four use subcategories were tested against each graphic. Methods of analysis follow the aforementioned methods for the analysis of age.

Table 3: Process of statistical relationships procedures (type of tests performed on each variable grouping).

Explanation of Statistical Process		
Relationships Tested	*Goal of Test*	*Test Performed*
Graphic Preference (G.P.) vs. Location	Relationship between G.P. and Pensacola/Jacksonville	Kruskall Wallis
Graphic Preference vs. Gender	Relationship between G.P. and Male/Female	Kruskal Wallis
	Relationship between Graphic C for women and Graphic D for men	Mann-Whitney
Graphic Preference vs. Age	Relationship between G.P. and each age group	Chi- Square Contingency Table
Graphic Preference vs. Role of H.W. Graphics	Relationship between G.P. and the frequency of graphic usage	Chi-Square Contingency Table

4.6.5 Qualitative Analysis of Two Popular Graphics

The preferred graphic from this research was compared to a hypothetical Australian graphic (Senkbeil et al. 2011) in order to further examine another promising alternative graphic.

A Geography 101 class ranked these two graphics based on their personal preference. The class was asked to choose between the two graphics and explain why they chose that particular graphic. The forced qualitative explanation was an important addition to better understand personal preferences. Qualitative responses were analyzed and recorded based on the similarity of responses.

CHAPTER 5: RESULTS

5.1 *Primary Study Results*

5.1.1 **Descriptive Statistics-** Location

Summarizing descriptive statistics was the first step in the results process. Figure 20 portrays the breakdown of the percentage of participants that preferred each graphic in each location, and the percentage for the overall sample. Pensacola, FL and Jacksonville, FL preferred graphic E the most (45% and 36% respectively). Almost half of the Pensacola participants liked graphic E whereas a little over a third of the participants from Jacksonville liked graphic E. From there, the order in which participants ranked the graphics is the same with some minor differences in the amount of preference. Following in descending order of preference was graphic A (23%), C (17%), B (11%), and then D (8%). From this, it is concluded that graphic D was the least preferred at both locations and that participants prefer graphic B and D the same since the percentages were identical across all groups. Therefore, it would be fair to say that the only practical differences in graphic preference between these two locations pertain to graphic A, C, and E.

In summary, graphic E was the preferred graphic for both locations with 40% of the people sampled choosing this graphic. Respondents generally liked this graphic equally. The second most preferred graphic for both locations was the COU. Therefore it can be said that a cone-like structure is well received since graphic A and E are the most liked. And lastly, graphic D the “spaghetti” graphic was the least preferred in both locations.

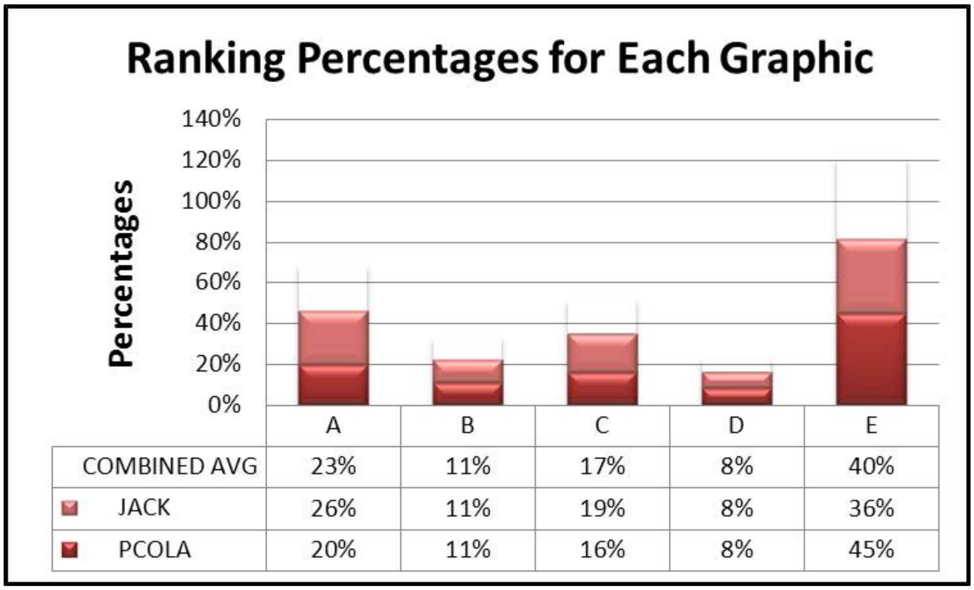


Figure 20: Ranking percentages for each graphic denoted into rankings for Pensacola, FL (PCOLA), Jacksonville, FL (JACK), and the combined percentages for all participants in the study (COMBINED).

5.1.2 **Descriptive Statistics**- Age and Gender Distribution

A total of 315 surveys were collected from the field. This information was used to see the sample's distribution of male and female participants. 166 (53%) of the 315 participants were female and 149 (47%) were male, indicating an acceptable distribution. More females were surveyed in Pensacola, FL than in Jacksonville, FL.

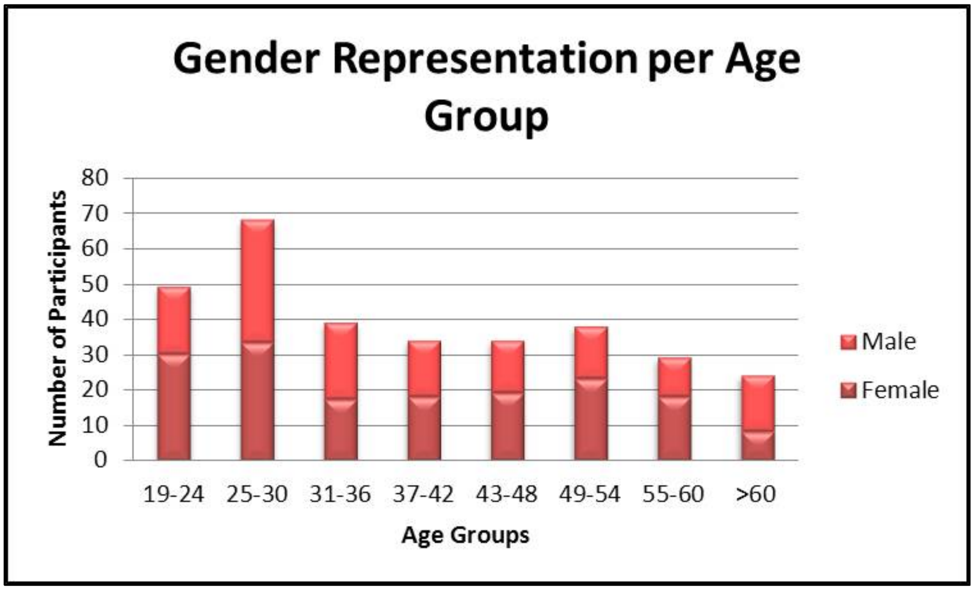


Figure 21: Gender and age distribution of all participants. Total numbers of female and male participants are represented for each age group.

Age data were collected from each survey to determine if there was any relationship between age and graphic preference. That relationship will be discussed in later sections. This section pertains to the basic age distribution of all participants. The participants' ages were put into eight different age groups in 6-year increments as described in Methods. Figure 21 shows the distribution of the ages of all participants. From the figure, one can determine that the distribution is slightly positively skewed. The mode of the sample is the 25-30 age range. The least represented age ranges were 55-60 and > 60.

5.1.3 **Descriptive Statistics**- Participants' Use of Graphics

In addition to age and gender information, participants were asked how often hurricane-warning graphics play a role in evacuation decisions. The options for the participants were never, occasionally, most of the time, and always. Figure 22 depicts the results from Pensacola, FL, Jacksonville, FL and the combined results. In Pensacola, 15% of the respondents reported never using the graphics. Respondents reported using the graphic occasionally 16%, most of the time 32% and always 36%. In Jacksonville, respondents reported never using graphics 13% of the time, occasionally 32%, most of the time 36% and always 19%. From the combined results, never using graphics was chosen 14% of the time, occasionally 24%, most of the time 34% and always 34%.

It is encouraging to see that the Never category had the lowest response ranking at both locations. When looking at Pensacola responses, one can see that there is a positive relationship with the number of responses and the use of hurricane-warning graphics. The number of users increases, as there is an increase in the frequency of category. Jacksonville responses are not the same. Never is the lowest ranked use, but unlike Pensacola, Jacksonville participants have a much greater occasional graphics use. From there, most of the time responses increase slightly, and then the response ranking for always is much lower than Pensacola. It is hypothesized that Pensacola's more frequent use of graphics is related to its more active hurricane history when compared to Jacksonville.

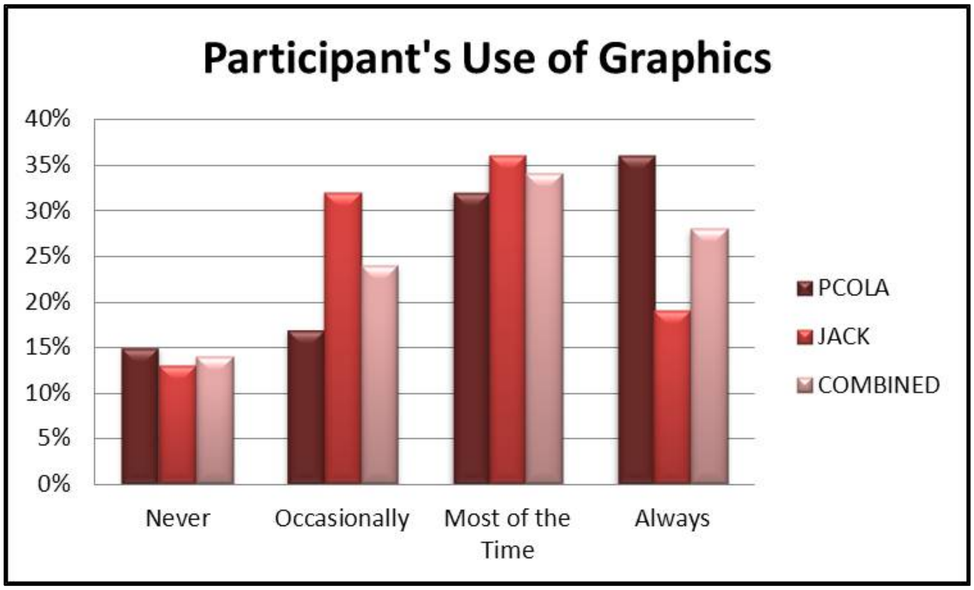


Figure 22: Participants' use of hurricane-warning graphics divided into Pensacola (PCOLA), Jacksonville (JACK), and combined residents. Pensacola residents had the highest response rates for always. Jacksonville residents had the highest response rate for occasionally and most of the time had the highest response rate of the combined participants.

5.1.4 **Statistical Relationships-** Graphic Preference versus Location and Gender

5.1.4-1Kruskal Wallis- Graphic Preference versus Location

A Kruskal Wallis test was used to determine if there was a statistical difference between graphic preference and location. This showed no statistically significant results. This was expected given the descriptive statistics previously mentioned. P-values for the graphics were, in alphabetical order 0.707, 0.391, 0.600, 0.772, and 0.253. To reiterate, graphic E was the most preferred, followed by graphic A, at both locations. The orders of graphic rankings were the same at both locations, with minor differences in the amount of preference.

5.1.4-2 Kruskal Wallis- Graphic Preference versus Gender

A Kruskal Wallis test was used to determine if there was a statistically significant difference between graphic preference and gender. Nearly significant results were found for graphic C and D using this method. Graphic C had a p-value of 0.064 and graphic D had a p-value of 0.088. These values present us with the insight that men prefer graphic D more often than women and women prefer graphic C more often than men. Since these p-values were on the verge of significance, further investigation was pursued using a Mann-Whitney test. Using the Mann-Whitney test, the preferences of men and women were directly compared for graphics C and D. Results were found to be insignificant with p-values for graphic C and D of 0.223 and 0.136 respectively.

5.1.5 **Statistical Relationships**- Graphic Preference versus Age and Role of Hurricane Warning Graphics

5.1.5-1 Chi Square Contingency Table- Graphic Preference versus Age

A chi square contingency table was used to determine if there was a statistical difference between graphic preference and age. There were eight subcategories for age. Results show that there is no statistical difference between age and graphic A, B, C, or E. There is a significant difference for age and graphic D. The p-value for this result is 0.017. Expected vs. observed counts within groups and within graphics were analyzed along with p-values to determine the strength of the relationship (Figure 23). The contingency table shows that older and middle-aged (specifically 43-48 age group) men preferred this graphic the most (Table 6, Appendix B (page 100)). The 25-30 age group either highly ranked it or lowly ranked it and the 19-24 age group overwhelmingly ranked graphic D very low. This is true with only a few exceptions.

Speculation on an explanation for this result could be due to an increase in knowledge and possessions with age. This would incline these participants to pay closer attention to hurricane-warning graphics to assist decision-making regarding personal property in addition to safety.

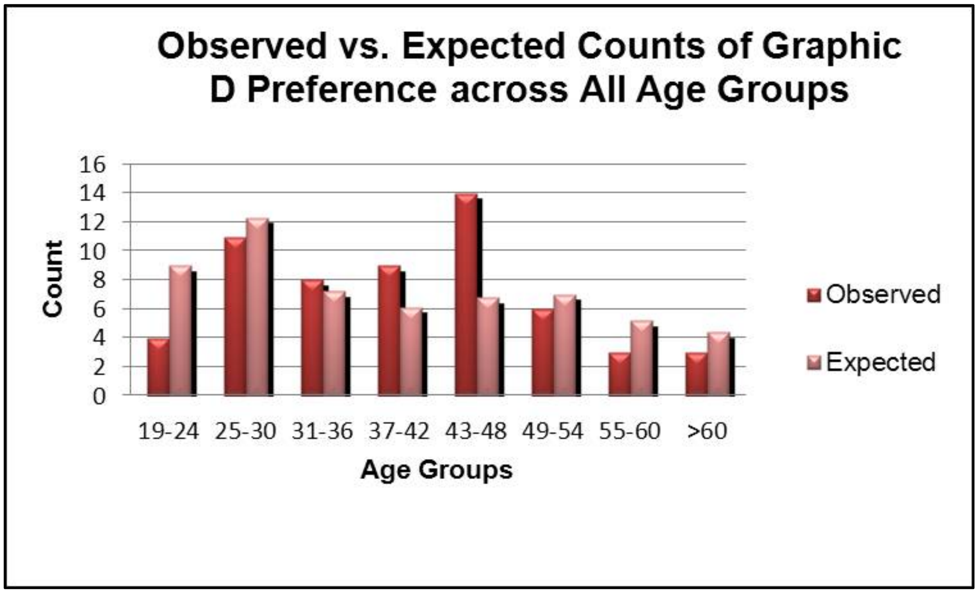


Figure 23: Observed vs. expected counts of graphic D preference compared across all age groups. Expected counts are derived from the chi-square contingency table crosstabulation.

5.1.5-2 <u>Chi Square Contingency Table- Graphic Preference versus Role of Hurricane-warning Graphics</u>

A second chi square contingency table was used to determine the relationship between graphic preference and the role of hurricane-warning graphics. The results show that there is no statistically significant difference between these two variables. Further analysis of the results indicates that respondents who liked graphic D tended to use hurricane-warning graphics every time when making evacuation decisions. Since graphic D is not that common on major outlets, the people that are using hurricane-warning graphics the most are more likely to see this graphic when they are searching for information to make their decisions. Graphic D proponents are most likely the section of the public that actively seek information on their own to have all the necessary tools to make decisions.

5.2 *Secondary Study Results*

5.2.1 Results of Two Popular Graphic Comparison

In a supplemental study using an additional hurricane graphic, a sample of Geography 101 students chose the hypothetical Australian graphic 64 percent to 36 percent for the color-coded cone. Of the 103 students surveyed, 66 students preferred the hypothetical Australian graphic and 37 students preferred the color-coded cone. Qualitative results provide reasons as to why these students made the choices they did (Table 4). The most common reason for picking a graphic was that it was easy to understand. This would seem like a positive sign but it provides some inconclusive information on what the students comprehend. It is pleasing to hear that these graphics are easy to understand, however it is undetermined whether or not these graphics are producing visual validity. Therefore, the more specific qualitative responses that were given are much more helpful to understanding what aspects about these graphics the students like and dislike.

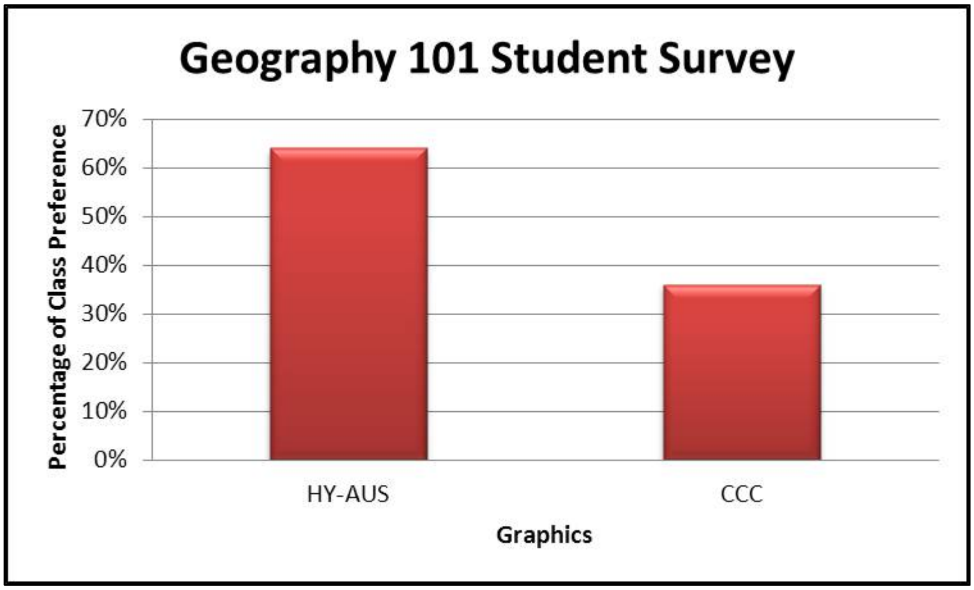


Figure 24: Percentage of GY 101 students' preference for the hypothetical Australian graphic and the color-coded cone. The HY-AUS (64%) was preferred over the CCC (36%).

Table 4: Qualitative responses for preference of hypothetical Australian graphic and color-coded cone.

Hypothetical Australian Graphic		**Color-Coded Cone**	
Most Popular Student Reasons for Choosing Respective Graphic			
Reason	Number of Responses	Reason	Number of Responses
Circle Aspect	5	Percentages of Impact	4
Size, Strength, and Speed	6	Simple and Easy	9
Better Prepares People in the Path	15	Quickly Understood	11
More Detailed/More Information	32	Time Information	11

CHAPTER 6: POST ANAYLSIS SUGGESTIONS

Current hurricane-warning graphics used operationally do not warn about the potential hazards that are associated with land-falling hurricanes. People often use these graphics to make evacuation decisions based on hazards at their locations (Brommer and Senkbeil 2010). It is odd that hurricane-warning graphics do not portray this important aspect to the public. Risk communicators have recently begun to discuss the need for incorporating post landfall hazards into an existing warning graphic. On the other hand, existing graphics have already created confusion, and adding more shapes and colors to an already ambiguous graphic could complicate matters. Despite the potential complications, efforts were made to create graphics that attempt to incorporate post landfall hazards. These efforts stemmed from comments from participants.

Respondents from both the primary and secondary study wanted the graphics to show what type of hazards they would experience and when they would experience these hazards. Four additional hurricane-warning graphics were created that include inland hazards. The graphics all represent spatial and temporal hazard information based on the same storm. These graphics have not been field-tested and their effectiveness and likeability is unknown. Future research will focus on testing these graphics against some of the favored graphics discussed in this thesis.

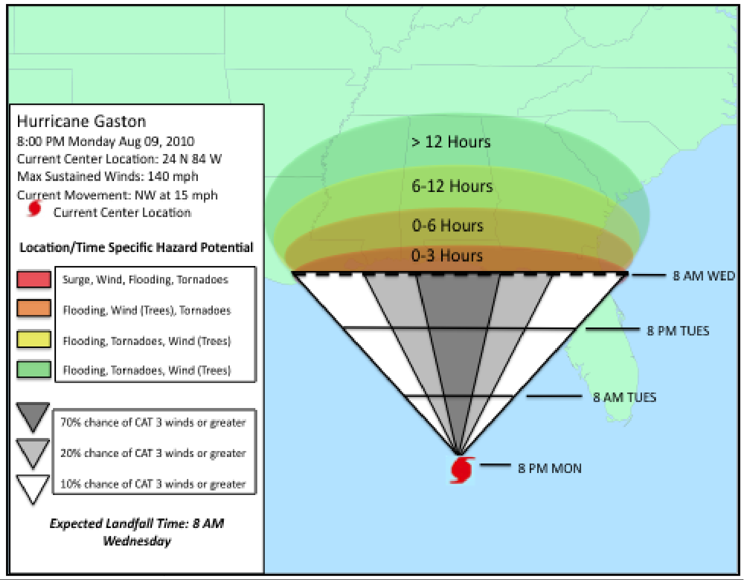


Figure 25: Hurricane-warning graphic that includes a cone-like structure and inland hazards. . The inland hazards are outlined in color and expected times for experiencing those specific hazards are included in the colored zones.

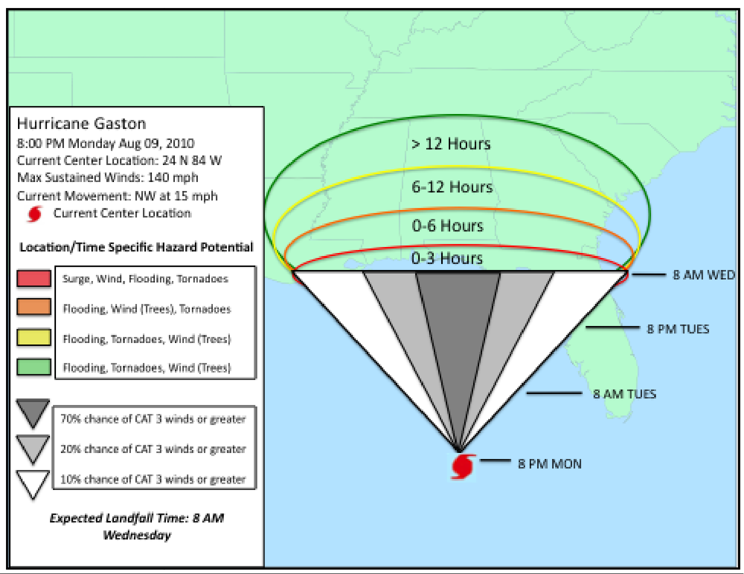


Figure 26: Hurricane-warning graphic that includes a cone-like structure and inland hazards. . The inland hazards are outlined in color and expected times for experiencing those specific hazards are included in the colored zones.

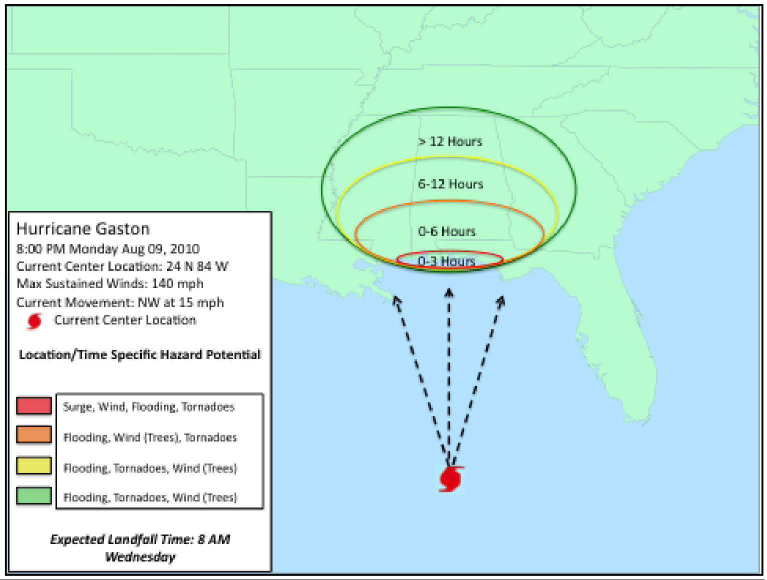


Figure 27: Hurricane-warning graphic that includes a forecasted path and inland hazards. The inland hazards are outlined in color and expected times for experiencing those specific hazards are included in the colored zones. The forecasted path is shown using three arrows to represent the potential tracks.

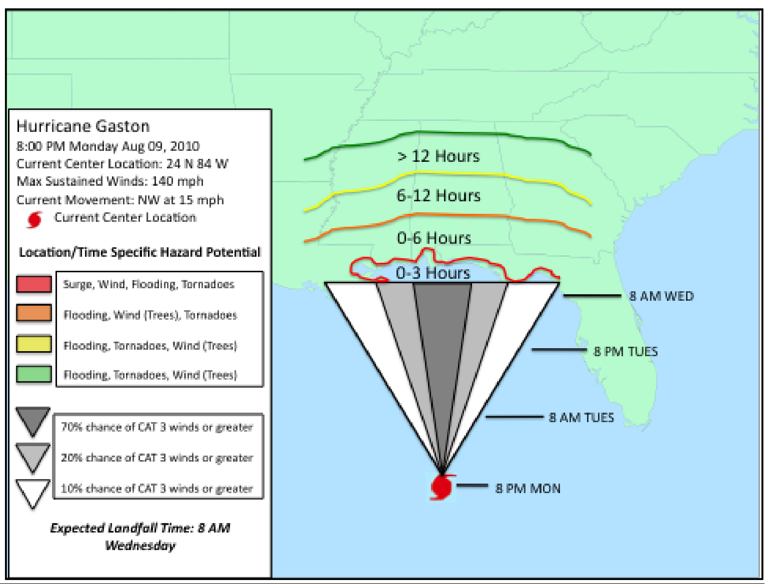


Figure 28: Hurricane-warning graphic that includes a cone-like structure and inland hazards. The inland hazards are outlined in color and expected times for experiencing those specific hazards are included in the colored zones.

The preceding graphics represent a category four storm moving north at 15mph. They portray the forecasted path of the storm through the use of a color-coded or shaded cone. The shades of grey depict the same percentage-based likelihood of as graphic E (color-coded cone). These graphics go further to display the different hazards associated with landfall based on locations and time. The different color circles/lines represent different hazard zones. Each zone provides information on what type of hazard can be expected and in what time frame, meaning arrival time of hazards. The legend displays all the potential hazards for each zone and the time of occurrence is displayed on the map.

The idea behind these graphics arose from feedback received from fieldwork. Also, from the qualitative data, it was realized that some were trying to draw conclusions of the potential hazards that were to be expected based on the forecast graphic. However, many of these conclusions were incorrect. Many participants were incorrect in understanding which hazard they were most prone to receive. The most common response was that the resident did not have to worry about flooding issues. It appeared that they were only thinking about flooding from surge waters, not precipitation. These thoughts were also reversed. Many believed that they would be inundated with surge, when in reality they would not. These inaccurate assumptions could lead to potentially flawed decision-making. Therefore, it is believed that a graphic that depicts both the forecasted path of the storm and the hazards that are to be expected would be invaluable to residents in the path of the hurricane.

CHAPTER 7: CONCLUSION

Heightened salience of natural disasters, especially hurricanes, has led many scientists, public officials and government agencies to question the effectiveness of hurricane-warning graphics and to understand how the public is interpreting these graphics. The centerpiece of information used by the NHC and the media to communicate the risks associated with land-falling hurricanes is the COU. The purpose of this graphic is to provide information on a tropical cyclone so that residents can make timely and responsible evacuation decisions (Broad et al., 2007). This research has found that many people rely on this graphic when making their decisions therefore, it is imperative to gather as much information as possible about how this graphic and other graphics influence the public. By using demographic criteria, insight into what aspects of hurricane-warning graphics coastal residents like and dislike can be gained. This knowledge can be the building blocks for the implementation of a more effective warning system.

The results of this study show that a color-coded-cone graphic similar to the COU was the most preferred regardless of location. The second most preferred graphic at both locations was the current COU; therefore, it would be safe to say that most coastal residents have a preference for a graphic with a cone-like structure. It should be mentioned that the COU was the only graphic that did not use percentages; therefore, this could lead some respondents to view this graphic as less accurate or less certain. These factors might have had a hand in the participants ranking the COU behind the CCC. Results were also found, suggestive but not statistically significant, that led us to believe that men prefer some graphics more than women and vice versa. This is also true for different age groups. Differences between Pensacola, FL and Jacksonville, FL occurred between the respondents' use of hurricane-warning graphics in decision-making. It was found that people in Pensacola, FL use graphics more often than people in Jacksonville, FL. Pensacola residents reported always using hurricane-warning graphics seventeen percent more often than residents in Jacksonville. This is most likely attributed to the difference in hurricane histories. How large an effect hurricane history has on graphic preference is still not fully understood from this study. Pensacola's last major impact from a hurricane was Ivan in 2004. Pensacola has a recurrence interval for all hurricanes of 6 years and major hurricanes of 21 years based on a period from 1901-2005. Conversely, Jacksonville's last measureable impact from a hurricane was Dora in 1964. Jacksonville's recurrence interval for all hurricanes is 21 years and for a major hurricane is 105 years. Of note is the fact that Jacksonville has not been hit by a major hurricane during the last 105 years. It appears that different hurricane histories play a considerable role in hurricane-warning graphic usage and comprehension. A future study that strictly pertains to the role of different hurricane histories on graphic usage and comprehension may be beneficial in the future.

There are some limiting factors to this study when discussing its value to the understanding of public perception of hurricane-warning graphics. The demographic distribution of participants reflected the population of Pensacola and Jacksonville, but the only residents surveyed lived in different cities of the same state. Results may be different when surveying residents of different states along the Gulf of Mexico and the Atlantic coasts. Also, respondents were not asked to explain the visual validity of the graphics. This aspect of research was not pursued to avoid trespassing on the intellectual property of other researchers. In the future it is hoped that this research can be updated to include an assessment of visual validity of these graphics. From this study, limited knowledge was gained in respect to how well residents comprehend the message behind the graphics. This is another area, along with hurricane history impacts, that needs to be explored to add to the overall understanding of the communication process between scientists and the public.

The most significant contribution of this study is the knowledge gained regarding warning graphic preference from a large sample of potential users. Furthermore, suggestions provided by respondents in the field led to the formation of a brief secondary study using the favored graphic from the field against a newly designed version. Further elaboration by the author about improvements to graphics led to the creation of several experimental graphics where an attempt is made to incorporate more specific hazard information. With further field testing and a detailed analysis of visual validity, perhaps one of these graphics or something similar may eventually replace the Cone of Uncertainty. Nevertheless, this research potentially presents important information that NHC, NWS, and local TV personnel could incorporate into a future warning scenario.

CHAPTER 8: REFERENCES

Allen, G.L., C.R. Miller Cowan, and H. Power, 2006: "Acquiring Information from Simple Weather Maps: Influences of Domain-Specific Knowledge and General Visual-Spatial Abilities". *Learning and Individual Differences*, **16**, pp. 337-349.

Altheide, David L., 1985: "Media Power". Beverly Hills, CA: Sage.

Atallah Eyad H. and L. F. Bosart, 2003: "The Extratropical Transition and Precipitation Distribution of Hurricane Floyd (1999)". *Monthly Weather Review*, **131**, pp. 1063–1081.

Atallah, Eyad H. and A. R. Aiyyer, 2007: "Precipitation Distribution Associated with Landfalling Tropical Cyclones Over the Eastern United States". *Monthly Weather Review*, **135**, pp. 2185–2206.

Baker, Earl J., 1979: "Predicting Response to Hurricane-warnings: A Reanalysis of Data from Four Studies". *Mass Emergencies*, **4**, pp. 9-24.

Baker, Earl J., 1991: "Hurricane Evacuation Behavior". *International Journal of Mass Emergencies and Disasters*, **9**, pp. 287-310.

Barnes, Michael D., C. L. Hanson, Len M. B. Novilla, Aaron T. Meacham, Emily McIntyre, and Brittany C. Erikson, 2008: "Analysis of Media Agenda Setting During and After Hurricane Katrina: Implications for Emergency Preparedness, Disaster Response, and Disaster Policy". *American Journal of Public Health*, **98**, pp. 604-610.

Belanger, J. I., Curry, J. A. and Hoyos, C. D., 2009: "Variability in Tornado Frequency Associated with U.S. Landfalling Tropical Cyclones". *Geophysical Research Letters*, **36**, pp. L17805.

Blake E.S., E.N. Rappaport, and C.W. Landsea, 2007: "The Deadliest, Costliest, and Most Intense Tropical Cyclones from 1851 to 2006 (and other frequently requested hurricane facts)". NOAA Technical Memorandum NWS TPC-5.

Broad, K., and A. Leiserowitz, 2007: "The Cone of Uncertainty and Hurricane Forecasting". http://iserp-6.webservices.lamptest.columbia.edu/news/articles/cone-uncertainty.

Broad, K., A. Leiserowitz, J. Weinkle, and M. Steketee, 2007: “Misinterpretations of the “Cone of Uncertainty” in Florida during the 2004 Hurricane Season”. Bulletin of the *American Meteorological Society*, **88**, pp. *651-665.*

Bostrom, A., 1997: “Risk Perceptions: ’Experts‘vs. ’Lay People‘”. Duke Environmental Law Policy, Forum 8, 101–115.

Botterill, Linda and Nicole Mazur, 2004: “Risk and Risk Perception: A Literature Review”. *Rural Industries Research and Development Corporation*, pp. 1-22.

Brommer, David M. and Jason C. Senkbeil, 2010: “Pre-Landfall Evacuee Perception of the Meteorological Hazards Associated with Hurricane Gustav”. *Natural Hazards,* **55**, *pp. 353-369.*

Canham, M. and Mary Hegarty, 2009: “Effects of Knowledge and Display Design on Comprehension of Complex Graphics”. *Learning and Instruction,* **20**, pp. 155-166.

Carr, F. H., and L. F. Bosart, 1978: “A Diagnostic Evaluation of Rainfall Predictability for Tropical Storm Agnes, June 1972”. *Monthly Weather Review*, **106**, pp. 363–374.

Choi, Y. and Ying-Hsuan Lin, 2008: “A Content Analysis of the Newspaper Coverage of the Three Major Hurricane in 2005”. *Public Relations Review,* **34**, pp. 294-296.

Combs D.L., R.G. Parrish, S.J. McNabb, 1996: “Deaths Related to Hurricane Andrew in Florida and Louisiana, 1992”. *International Journal of Epidemiology*, ***25****,* pp. 537–44.

Dash, N. and H. Gladwin, 2007: “Evacuation Decision Making and Behavioral Response: Individual and Household”. *Natural Hazards,* **8**, pp. 69-77.

Delworth, T. L., and M. E. Mann, 2000: “Observed and Simulated Multidecadal Variability in the Northern Hemisphere”. *Climate Dynamics,* **16**, pp. 661–676.

Doswell, C. A., III, 2004: “Weather Forecasting by Humans—Heuristics and Decision Making”. *Forecaster’s Forum,* **19**, pp. 1115–1126.

Dow, K. and S. L. Cutter, 1998: “Crying Wolf: Repeat Response to Hurricane Evacuation Orders”. *Coastal Management,* **26**, pp. 238–252.

Dow, Kirstin and Susan L. Cutter, 2000: “Public Orders and Personal Opinions: Household Strategies for Hurricane Risk Assessment”. *Environmental Hazards,* **2**, pp. 143-155.

Durham, Frank, 2008: “Media Ritual in Catastrophic Time: The Populist Turn in Television Coverage of Hurricane Katrina”. *Journalism*, **9**, pp. 95-116.

Dwyer, F. M., 1978: “Strategies for Improving Visual Learning”. State College, PA: Learning Services.

Ebi, Kristie L. and Jordana K. Schmier, 2005: “A Stitch in Time: Improving Public Health Early Warning Systems for Extreme Weather Events”. *Epidemiologic Reviews*, **27**, pp. 115-121.

Edmonds, A. S., and S. L. Cutter. 2008: “Planning for Pet Evacuations During Disasters”. *Journal of Homeland Security and Emergency Management,* **5***, pp. 1-18.*

Elsner, J. B. and A. B. Kara, 1999: “Hurricanes of the North Atlantic”. Oxford University Press.

Emanuel, Kerry, 2005: “Increasing destructiveness of Tropical Cyclones over the Past 30 Years”. *Nature,* **436**, pp. 686-688.

Eosco, Gina, 2008: “A Study of Visual Communication: Cyclones, Cones and Confusion”. Cornell University.

Farris, G.S., Smith, G.J., Crane, M.P., Demas, C.R., Robbins, L.L., and Lavoie, D.L., eds., 2007: “ *Science and the Storms—the USGS Response to the Hurricanes of 2005*. U.S. Geological Survey Circular pp. 6-11.

Fischhoff, Baruch, 2009: “Risk Perception and Communication”. Oxford Univeristy Press.

Folland, C. K., D. E. Parker, and T. N. Palmer, 1986: “Sahel Rainfall and Worldwide Sea Temperatures, 1901–85”. *Nature,* ***320***, pp. 602–607.

Hammer, B, and Thomas W. Schmidlin, 2002: “Response to Warnings during the 3 May 1999 Oklahoma City Tornado: Reasons and Relative Injury Rates”. *Weather Forecasting*, **17**, 577–581.

Ho, Ming-Chou, Daigee Shaw, Shuyen Lin, and Yao-Chu Chiu, 2008: “How Do Disaster Characteristics Influence Risk Perception?”. *Risk Analysis,* **28**, pp. 635-643.

Holland, G. J., and P. J. Webster, 2007: “Heightened Tropical Cyclone Activity in the North Atlantic: Natural Variability or Climate Trend?”. *Philosophical Transactions of the Royal Society A: Mathematical, Physical, and Engineering Sciences,* **365,** pp. 2695-2716.

Horlick-Jones, T., 2005: "Informal Logics Of Risk: Contingency And Modes Of Practical Reasoning”. *Journal of Risk Research,* **8**, pp. 253-272.

Irish, J. L., D. T. Resio, and J. J. Ratcliff, 2008: “The Influence of Storm Size on Hurricane Surge”. *Journal of Physical Oceanography,* **38**, pp. 2003–2013.

Jagger, T. H., and J. B. Elsner, 2006: “Climatology Models for Extreme Hurricane Winds Near the United States”. *Journal of Climate,* **19**, pp. 3220–3226.

Jani A., M. Fierro, S. Kiser, 2006: “Hurricane Isabel-Related Mortality—Virginia, 2003”. *Journal of Public Health Management Practices,* **12**, pp. 97–102.

Knight, D. B. and R. E. Davis, 2007: “Climatology of Tropical Cyclone Rainfall in the Southeastern United States”. *Physical Geographer,* **28**, pp. 126–147.

Knutson, L.S and R. E. Tuleya, 2004: “Impact of CO2-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization”. *Journal of Climate,* **17**, pp. 3477–3495.

Konrad, C. E., M. F. Meaux, and D.A. Meaux, 2002:“Relationships Between Tropical Cyclone Attributes and Precipitation Totals: Considerations of Scale. *International Journal of Climatology,* **22**, pp. 237–247.

Lam, C. C., 2005 “Strategies of Tropical Cyclone Warning to Maximize Relevance and Effectiveness”. Typhoon Committee Regional Workshop on Effective Tropical Cyclone Warning, pp. 1-18.

Lee, K. L., R. J. Meyer, and E. T. Bradlow, 2009: “Analyzing Risk Response Dynamics on the Web: The Case of Hurricane Katrina”. *Risk Analysis,* **29**, *pp.* 1779-1792.

Leik, Robert K., T. Michael Carter, and John P. Clark, 1981: “ Community Response to Natural Hazard Warnings”. Minneapolis, MN: University of Minnesota.

Lindell, M., J. Lu, and C. Prater, 2005: “Household Decision Making and Evacuation in Response to Hurricane Lili”. *Natural Hazards Review,* **6**, *pp.* 171.

Lipkus I.M., Hollands J., 1999: “The Visual Communication of Risk”. *Monograph National Cancer Institute*, **25**, pp.149–62.

Lipkus, I.M., 2007: “Numeric, Verbal, and Visual Formats of Conveying Health Risks: Suggested Best Practices and Future Recommendations”. *Medical Decision Making*, **27**, pp. 696–713.

Lowe, D.G., 1999: “Object Recognition from Local Scale-Invariant Features”. *International Conference on Computer Vision*, Corfu, Greece, pp. 1150–1157.

Marks, Frank D. and Lynn K. Shay, and PDT-5, 1998: “Landfalling Tropical Cyclones: Forecast Problems and Associated Research Opportunities”. *Bulletin of the American Meteorological Society,* **79**, pp. 305-323.

Matyas, Corene, 2007: “Quantifying the Shapes of U.S. Landfalling Tropical Cyclone Rain Shields”. *The Professional Geographer*, **59**, pp. 158-172.

Matyas, Corene, 2008: “Shape Measures of Rain Shields as Indicators of Changing Environmental Conditions in a Landfalling Tropical Storm”. *Meteorological Applications,* **15**, pp. 259–271.

Mayhorn, C.B., M.S. Wogalter, and J.S. Bell. 2004. “Homeland Security Safety Symbols: Are We Ready?”. *Ergonomics in Design*, **4**, pp. 6-14.

McKinney, N., Houser, C. and Meyer-Arendt, K., 2011: “Direct and Indirect Mortality in Florida During the 2004 Hurricane Season”. *International Journal of Biometeorology*, **55**, pp. 533-546.

Miles, Brian and Stephanie Morse, 2007: “The Role of News Media in Natural Disaster Risk and Recovery”. *Ecological Economics,* **63**, pp. 365-373.

National Oceanographic and Atmospheric Administration, 2005: Frequently Asked Questions About the *Atlantic Multidecadal Oscillation (AMO).* http://www.aoml.noaa.gov/phod/amo_faq.php.

Nimmo, D. and J. E. Combs, 1985: “Nightly Horrors: Crisis Coverage in Television Network News”. *University of Tennessee Press.*

Otway, H., 1992: “Public Wisdom, Expert Fallibility: Toward a Contextual Theory of Risk”. *Social Theories of Risk,* pp. 215-228.

Peebles, D. and Cheng, P. C.-H., 2003: “Modeling the Effect of Task and Graphical Representation on Response Latency in a Graph-Reading Task”. *Human Factors,* **45**, pp. 28-46.

Pielke Jr., R. A. and R. A. Pielke Sr., 1997: “Hurricanes: Their Nature and Impacts on Society”. Wiley, New York.

Pielke, Roger A., Mary W. Downton, 2000: “Precipitation and Damaging Floods: Trends in the United States, 1932–97”. *Journal of Climate*, **13**, pp. 3625–3637.

Pielke, R. A., Jr., C. Landsea, M. Mayfield, J. Laver, and R. Pasch, 2005: “Hurricanes and Global Warning”. *Bulletin of the American Meteorological Society*, **86**, pp. 1571–1575.

Piotrowski, Chris and Terry R. Armstrong, 1998: “Mass Media Preferences in Disaster: A Study of Hurricane Danny”. *Social Behavior and Personality,* **26**, pp. 341-346.

Rappaport, E.N, 2000: “Loss of Life in the United States Associated with Recent Atlantic Tropical Cyclones”. *Bulletin of the American Meteorological Society*, **81**, pp. 2065–2074.

Schmidt, Silvio, Claudia Kemfert and Peter Hoeppe, 2008: “Tropical Cyclone Losses in the USA and the Impact of Climate Change: A Trend Analysis Based on a New Dataset”. DIW Berlin Discussion Paper No. 802.

Schultz, Lori A. and Daniel J. Cecil, 2009: “Tropical Cyclone Tornadoes, 1950-2007”. *American Meteorological Society*, **137**, pp. 3471-3483.

Schlesinger M.E. and N. Ramankutty, 1994: “An Oscillation in the Global Climate System of Period 65–70 Years”. *Nature*, **367**, pp. 723–726.

Schmidlin, T.W., 2009: “Human Fatalities from Wind-Related Tree Failures in the United States, 1995-2007”. *Natural Hazards*, **50**, pp. 13-25.

Senkbeil, J.C. and S.C. Sheridan, 2006:“A Postlandfall Hurricane Classification System for the United States”. *Journal of Coastal Research*, **22**, pp. 1025–1034.

Senkbeil, J.C., D. M. Brommer, P. G. Dixon, M. E. Brown, and K. Sherman-Morris, 2009: “The Perceived Landfall of Evacuees form Hurricane Gustav”. *Natural Hazards.*

Senkbeil, J. C., D. M. Brommer, and I. J. Comstock, 2011: “Tropical Cyclone Hazards in the USA”. *Geography Compass,* **5**, pp. 544-563.

Shah, P., R.E. Mayer, and M. Hegarty, 1999: “Graphs as Aids to Knowledge Construction: Signaling Techniques for Guiding the Process of Graph Comprehension”. *Journal of Educational Psychology,* **91**, pp. 690-702.

Shepherd, J. M. and T. Knutson,2007: “The Current Debate on the Linkage Between Global Warming and Hurricanes”. *Geography Compass,* **1**, *pp*. 1–24.

Sherman-Morris, K., 2005: “Enhancing Threat: Using Cartographic Principles to Explain Differences in Hurricane Threat Perception”. *The Florida Geographer*, **36**, pp. 61-83.

Simkin, D.K. and R. Hastie, 1986: “An Information-Processing Analysis of Graph Perception”. *Journal of the American Statistical Association,* **82**, pp. 454-465.

Slovic, Paul, 1987: “Perception of Risk”. *Science*, **236**, pp. 280-285.

Sorensen, John H., 2000: “Hazard Warning Systems: Review of 20 Years of Progress”. *Natural Hazards Review,* **1**, pp. 119-125.

Stewart, Alan E., 2011: “Gulf Coast Residents Underestimate Hurricane Destructive Potential”. *Weather Climate and Society*, **3**, pp.116–127.

Tanner, Andrea, Daniela B. Friedman, Alexis Koskan and Daphney Barr, 2009: “Disaster Communication on the Internet: A Focus on Mobilizing Information”, *Journal of Health Communication: International Perspectives*, **14**, pp. 741-755.

Tversky, B., J.B. Morrison, and M. Betrancourt, 2002: “Animation: Can it Facilitate?”. *International Journal of Human-Computer Studies,* **57**, pp. 247-262.

Walters, Lynne M. and Susanna Hornig, 1993: “Faces in the News: Network Television News Coverage of Hurricane Hugo and the Loma Prieta Earthquake”. *Journal of Broadcasting and Electronic Media* ,**57**, pp. 219-231.

Webster, P. J., G. J. Holland, J. A. Curry, and H. R. Chang, 2005: “Changes in Tropical Cyclone Number, Duration, and Intensity, in Warming Environment”. *Science*, **309**, pp. 1844–1846.

Whitehead, J.C., 2003: “One Million Dollars per Mile? The Opportunity Costs of Hurricane Evacuation”. *Ocean and Coastal Management*, 46: 1069-1083.

Windham, Gerald O., Ellen I. Posey, Peggy J. Ross and Barbara G. Spencer, 1977: “Reactions to Strom Threat During Hurricane Eloise”. Social Science Research Center Report 51. State College, MS: Mississippi State University.

Zhang, H., J. B. Halverson, J. Simpson, E. J. Zipser, 2008: “Hurricane ‘Rainfall Potential’ Derived from Satellite Observations Aids Overland Rainfall Prediction”. *Journal of Applied Meteorology and Climatology*, **47**, pp. 944–959.

Zinn, Jens O., 2008: "Introduction: The Contribution Of Sociology To The Discourse On Risk And Uncertainty". *Social Theories Of Risk And Uncertainty: An Introduction*, edited by J. O. Zinn. Malden, MA: Blackwell. Pp, 1-17.

Appendix A: Primary Study Questionnaire

Questioning the "Cone of Uncertainty": Proposing Alternative Hurricane Warning Graphics

Recruitment Script

The following questionnaire contains information regarding hurricane-warning graphics. Research has shown that many people are misinterpreting the current hurricane-warning graphic (Cone of Uncertainty) leading to unnecessary evacuations and improper hazard identification by individuals. We are proposing a new alternative hurricane-warning graphic based on the results of this research. If you choose to complete the questionnaire you will help us improve public awareness and increase hurricane preparedness. Participation is not mandatory and you may decline to complete the questionnaire at any time during the process. The questionnaire will not ask for the volunteering of any personal information linking you to the completed questionnaire beyond the identification of your home zip code. The total time for the questionnaires is about 5 minutes.

Consent and Information Form for Survey Respondents

Title of the Project:
Questioning the "Cone of Uncertainty": Proposing Alternative Hurricane Warning Graphics

Researcher Names and Contact Information:
Dr. Jason Senkbeil (**jcsenkbeil@bama.ua.edu**)
Dept. of Geography, University of Alabama, Box 870322, Tuscaloosa, AL 35487-0322

Laura Radford (lmradford@crimson.ua.edu)

Purpose of the Research: The goal of this research is to identify short-comings with current hurricane-warning graphics. Respondents will view a series of alternative graphics and determine which graphic conveys the information best in their opinion. Using survey results, we hope to propose a new hurricane-warning graphic.

Procedure: The survey should take about 5 minutes. You must be at least 19 years old.

Confidentiality: All information you give us will be anonymous and impossible to relate to you.

Participation: Your participation in this research is voluntary and you will not receive any compensation for participating. Feel free to stop at any time or refuse to answer any question.

Benefits: There are no known immediate benefits to you for participating in this study. We hope that this research will improve future communication of hurricane risk to the public.

Risks: It is not possible to identify all potential risks in research procedures, but we have taken steps to minimize any known risks.As a participant, the main risk you face is potentially experiencing feelings of anger, frustration, sadness, etc. as we ask you questions regarding the threat of hurricane hazards. We understand that hurricanes may have affected your life in many serious ways, both personal and professional.

HRC Contact: If you have any questions about your rights as a research participant you may contact Ms. Tanta Myles, The University of Alabama Research Compliance Officer at 205-348-5841 or toll free 1-877-820-3066

The research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context.

Age:________ Gender:_________ Zip Code of your residence:____________

Have you ever been in a tropical storm or a hurricane? Circle one.

Yes No

If yes, which ones? ____

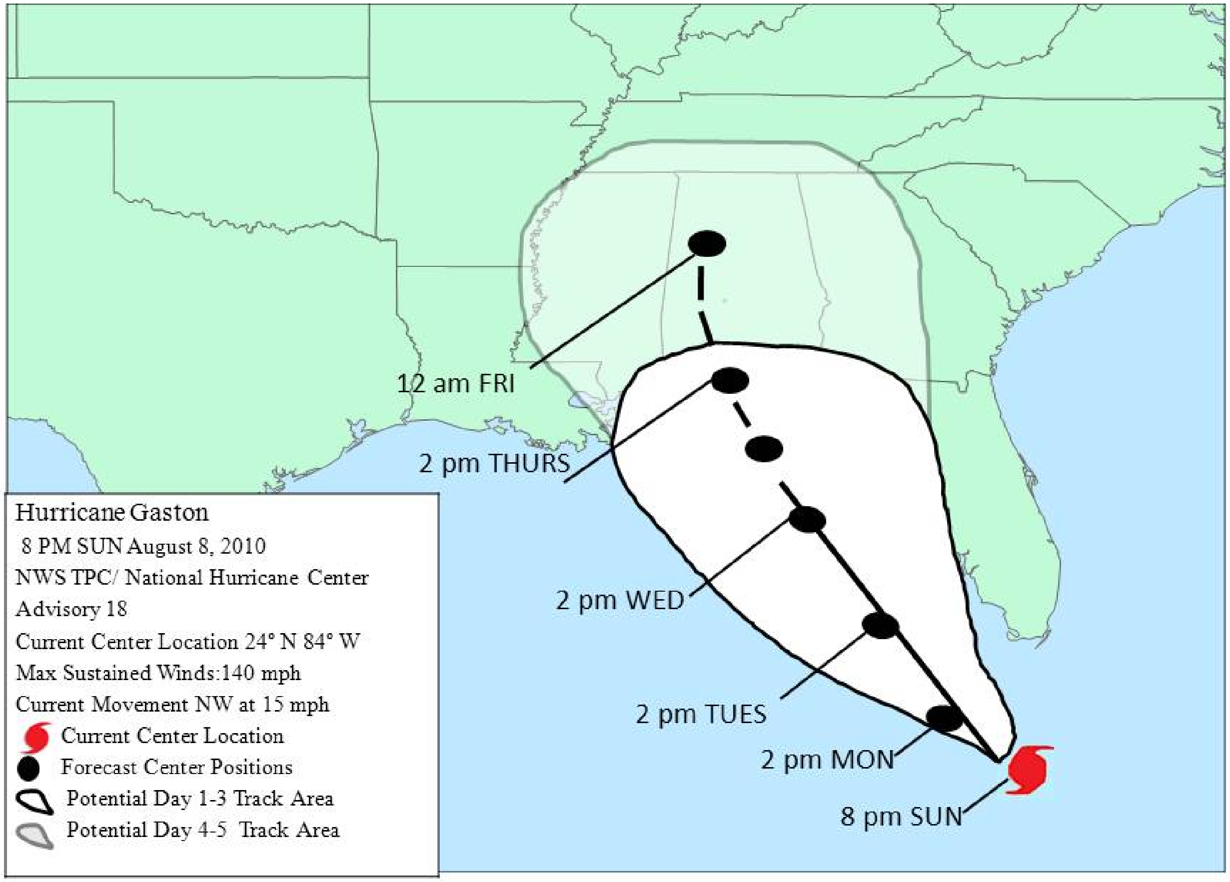
What was the Saffir Simpson category at landfall for these storms? ____

How often do hurricane warning graphics play a role in your decision to evacuate or not evacuate before a storm makes landfall? Circle one.

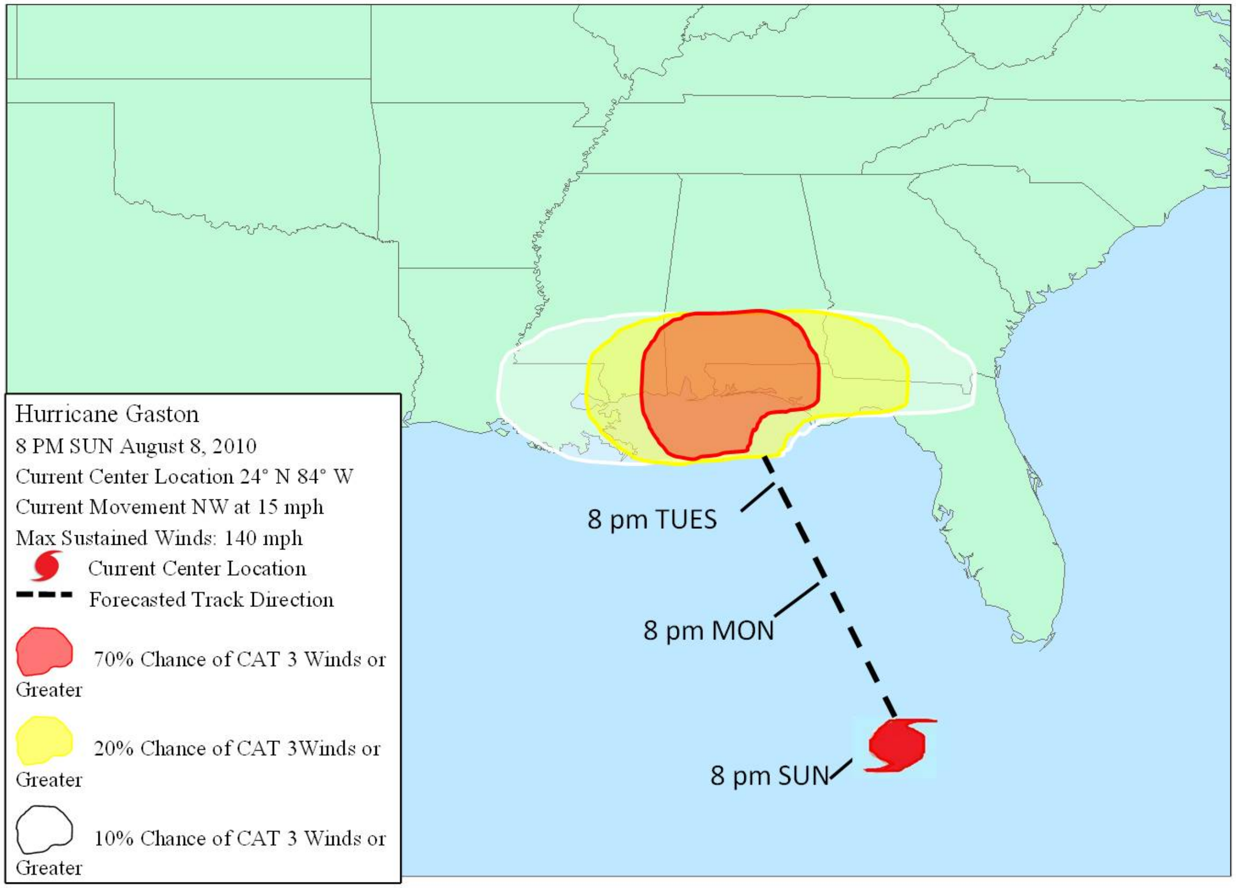
Never Occasionally Most of the Time Every Time

Please view the following alternative hurricane warning graphics then answer the question following the maps.

Graphic A

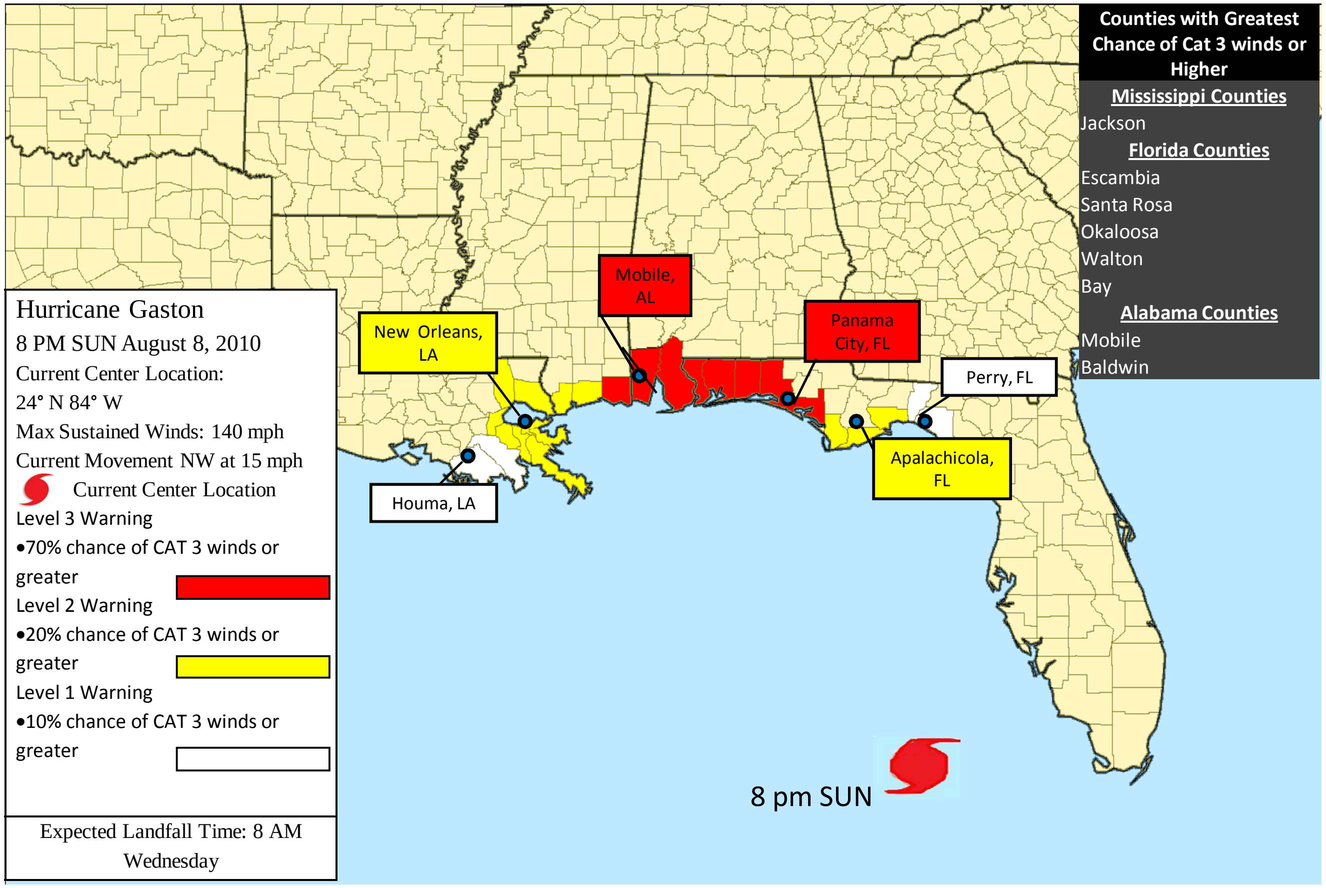

12 am FRI
2 pm THURS
2 pm WED
2 pm TUES
2 pm MON
8 pm SUN
Hurricane Gaston
8 PM SUN August 8, 2010
NWS TPC/ National Hurricane Center
Advisory 18
Current Center Location 24° N 84° W
Max Sustained Winds:140 mph
Current Movement NW at 15 mph
Current Center Location
Forecast Center Positions
Potential Day 1-3 Track Area
Potential Day 4-5 Track Area

Graphic B

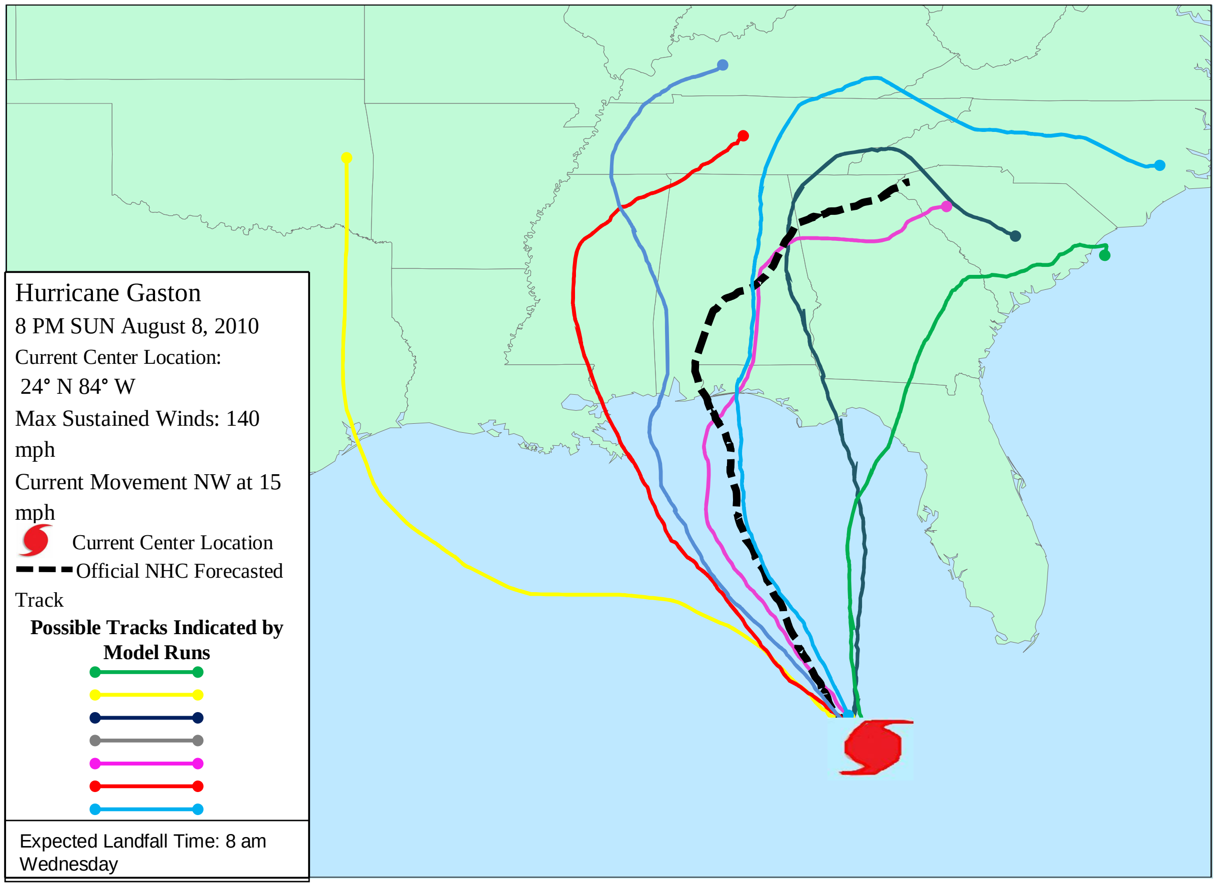


Hurricane Gaston
8 PM SUN August 8, 2010
Current Center Location 24° N 84° W
Current Movement NW at 15 mph
Max Sustained Winds: 140 mph
Current Center Location
Forecasted Track Direction
70% Chance of CAT 3 Winds or Greater
20% Chance of CAT 3Winds or Greater
10% Chance of CAT 3 Winds or Greater
8 pm TUES
8 pm MON
8 pm SUN

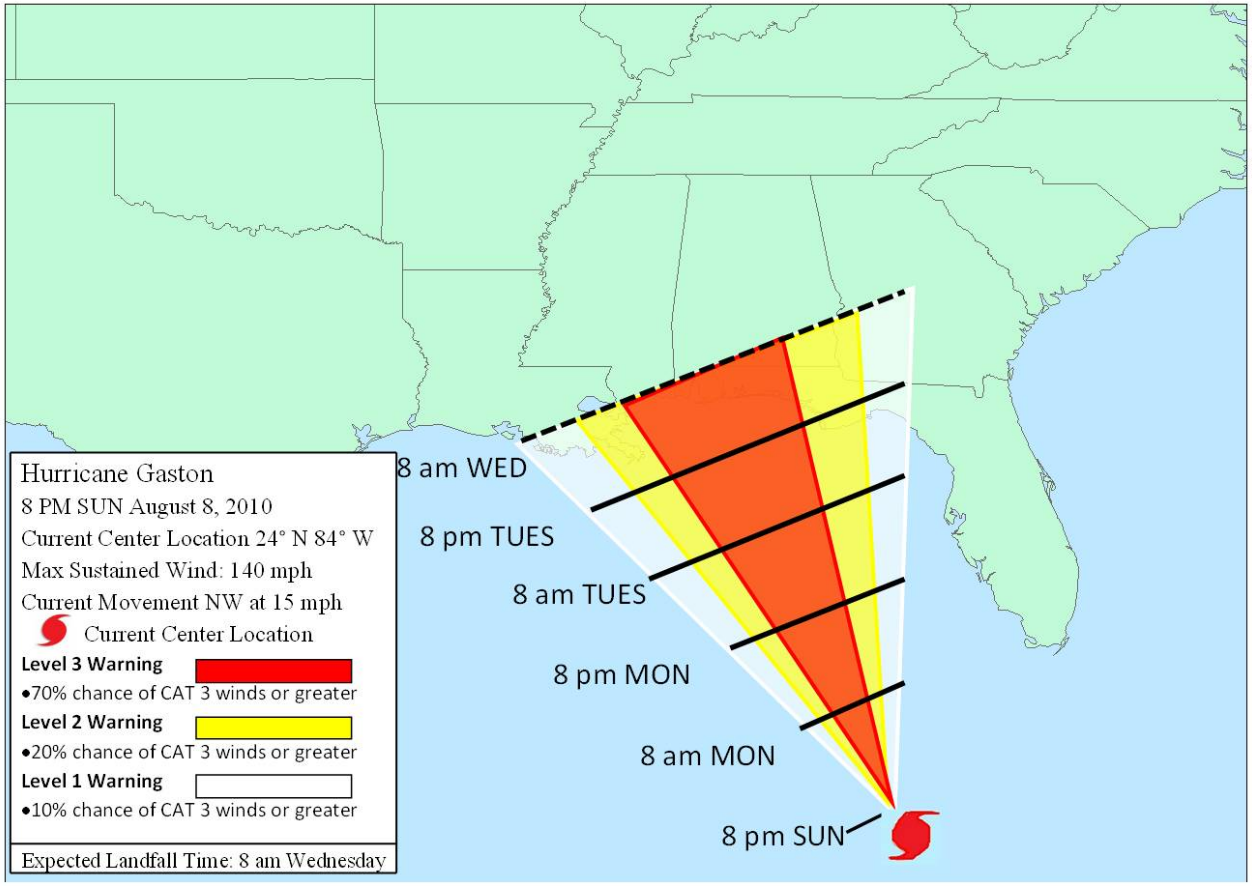
Graphic C


Counties with Greatest Chance of Cat 3 winds or Higher
Mississippi Counties
Jackson
Florida Counties
Escambia
Santa Rosa
Okaloosa
Walton
Bay
Alabama Counties
Mobile
Baldwin
Mobile, AL
Panama City, FL
New Orleans, LA
Perry, FL
Apalachicola, FL
Houma, LA
8 pm SUN
Hurricane Gaston
8 PM SUN August 8, 2010
Current Center Location:
24° N 84° W
Max Sustained Winds: 140 mph
Current Movement NW at 15 mph
Current Center Location
Level 3 Warning
•70% chance of CAT 3 winds or greater
Level 2 Warning
•20% chance of CAT 3 winds or greater
Level 1 Warning
•10% chance of CAT 3 winds or greater
Expected Landfall Time: 8 AM Wednesday

Graphic D


Hurricane Gaston
8 PM SUN August 8, 2010
Current Center Location:
24° N 84° W
Max Sustained Winds: 140 mph
Current Movement NW at 15 mph
Current Center Location
Official NHC Forecasted Track
Possible Tracks Indicated by Model Runs
Expected Landfall Time: 8 am Wednesday

Graphic E



Hurricane Gaston
8 PM SUN August 8, 2010
Current Center Location 24° N 84° W
Max Sustained Wind: 140 mph
Current Movement NW at 15 mph
Current Center Location
Level 3 Warning
•70% chance of CAT 3 winds or greater
Level 2 Warning
•20% chance of CAT 3 winds or greater
Level 1 Warning
•10% chance of CAT 3 winds or greater
Expected Landfall Time: 8 am Wednesday
8 am WED
8 pm TUES
8 am TUES
8 pm MON
8 am MON
8 pm SUN

Please rank the following hypothetical alternative hurricane warning graphics that YOU prefer (not the one that you think will work the best for the public, but the one that you personally prefer). 5 being the graphic you prefer the most and 1 being the graphic you prefer the least.

A	B	C	D	E
________	________	________	________	________

After viewing the graphics, we welcome all comments and suggestions you have to offer. Thank You.

Thank you for your participation.

Appendix B: Statistical Outputs

Table 5: Age vs. graphic preference (Graphic D) Chi- Square test statistics output.

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	46.079[a]	28	.017
Likelihood Ratio	45.120	28	.021
Linear-by-Linear Association	11.875	1	.001
N of Valid Cases	315		

a. 11 cells (27.5%) have expected count less than 5. The minimum expected count is 1.90.

Table 6: Age vs. graphic preference (Graphic D) chi-square crosstabulation output.

Groups * D Crosstabulation

			D					
			1	2	3	4	5	Total
Groups	19-24	Count	25	11	8	4	1	49
		Expected Count	18.2	9.5	8.4	9.0	3.9	49.0
		% within Groups	51.0%	22.4%	16.3%	8.2%	2.0%	100.0%
		% within D	21.4%	18.0%	14.8%	6.9%	4.0%	15.6%
	25-30	Count	34	9	7	11	6	67
		Expected Count	24.9	13.0	11.5	12.3	5.3	67.0
		% within Groups	50.7%	13.4%	10.4%	16.4%	9.0%	100.0%
		% within D	29.1%	14.8%	13.0%	19.0%	24.0%	21.3%
	31-36	Count	14	9	6	8	2	39
		Expected Count	14.5	7.6	6.7	7.2	3.1	39.0
		% within Groups	35.9%	23.1%	15.4%	20.5%	5.1%	100.0%
		% within D	12.0%	14.8%	11.1%	13.8%	8.0%	12.4%
	37-42	Count	12	5	6	9	1	33
		Expected Count	12.3	6.4	5.7	6.1	2.6	33.0
		% within Groups	36.4%	15.2%	18.2%	27.3%	3.0%	100.0%
		% within D	10.3%	8.2%	11.1%	15.5%	4.0%	10.5%
	43-48	Count	7	4	7	14	5	37
		Expected Count	13.7	7.2	6.3	6.8	2.9	37.0
		% within Groups	18.9%	10.8%	18.9%	37.8%	13.5%	100.0%
		% within D	6.0%	6.6%	13.0%	24.1%	20.0%	11.7%
	49-54	Count	12	10	8	6	2	38
		Expected Count	14.1	7.4	6.5	7.0	3.0	38.0
		% within Groups	31.6%	26.3%	21.1%	15.8%	5.3%	100.0%
		% within D	10.3%	16.4%	14.8%	10.3%	8.0%	12.1%
	55-60	Count	8	6	8	3	3	28
		Expected Count	10.4	5.4	4.8	5.2	2.2	28.0
		% within Groups	28.6%	21.4%	28.6%	10.7%	10.7%	100.0%
		% within D	6.8%	9.8%	14.8%	5.2%	12.0%	8.9%
	>60	Count	5	7	4	3	5	24

		Expected Count	8.9	4.6	4.1	4.4	1.9	24.0
		% within Groups	20.8%	29.2%	16.7%	12.5%	20.8%	100.0%
		% within D	4.3%	11.5%	7.4%	5.2%	20.0%	7.6%
	Total	Count	117	61	54	58	25	315
		Expected Count	117.0	61.0	54.0	58.0	25.0	315.0
		% within Groups	37.1%	19.4%	17.1%	18.4%	7.9%	100.0%
		% within D	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%