HURRICANE FORECAST IMPROVEMENT PROGRAM SOCIO-ECONOMIC RESEARCH AND RECOMMENDATIONS:

FINAL REPORT

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ERG

Table of Contents

Acknowledgments

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We also want to acknowledge and thank our consultants: Betty Morrow of SocResearch, who conducted much of the exploratory research, survey development, and testing on this work, and Gina Eosco of the American Meteorological Society (AMS) for her overall input on the project, interviews with broadcast meteorologists, and assistance at the AMS 2012 WeatherFest exhibition.

Executive Summary

The National Weather Service (NWS), an agency of the National Oceanic and Atmospheric Administration (NOAA), issues suites of text and graphical products to communicate forecasts associated with severe storms. During tropical cyclone (TC) conditions, NWS's National Hurricane Center (NHC) in Miami, Florida, issues text and graphical products to communicate information about the position, movement, and characteristics of each storm as well as the potential threats.

In spite of accurate storm forecasting, many coastal residents do not take protective action during tropical and extra-tropical (ET) storms. Unclear forecast messaging may be one factor contributing to this behavior. NWS commissioned the research described in this report to better understand how it might improve communication, public understanding, and response to the threats posed by TC and ET events. The research has three overarching goals:

1. To analyze the awareness, level of concern, and communication needs of key NWS stakeholders related to TC and ET risks (including strong winds and storm surge).
2. To test and retest several graphics that NHC is considering for communicating TC storm surge, storm track, and wind forecasts.
3. To provide recommendations to help the NWS continue to improve its communication of TC and ET risks to its diverse user community.

The work focused on four key NWS stakeholder groups: the general public, emergency managers (EMs), broadcast meteorologists (BMs), and Warning Coordination Meteorologists (WCMs) working in NWS Weather Forecast Offices (WFOs). The research centered on geographic areas subject to both TCs and ETs. The project is part of a larger NOAA effort to solicit opinions for improving hurricane forecasting and communication with key NWS stakeholder groups.

ES.1 Product Testing

The ERG team completed the social science and research work in several stages. At the start of the project in the fall of 2011, the team conducted a literature review to synthesize research conclusions and recommendations that could help the NHC improve its hurricane communication products and overall outreach and messaging. In the winter of 2012, the team began pre-testing several prototype graphics with small groups, with an emphasis on a storm surge warning map and variations of a storm surge inundation map. The testing captured the impressions of representatives of the key stakeholder groups (EMs, the media, the public, and WCMs) using several venues. This pre-testing continued at several meetings and workshops through the spring of 2012.

During the summer of 2012, the ERG team and researchers at the National

NOAA's Storm Surge Improvement Projects

In 2008, NOAA established a Hurricane Forecast Improvement Program (HFIP) to improve the accuracy and reliability of hurricane forecasts, to extend the lead time for hurricane forecasts with increased certainty, and to increase confidence in hurricane forecasts.

In 2009, NOAA established the Storm Surge Roadmap to bring together its team of experts to work on the top priorities for the storm surge program. The Roadmap lays out a comprehensive plan for improving NOAA's storm surge products and services.

Center for Atmospheric Research (NCAR) and SocResearch[1] conducted several Web-based surveys to more quantitatively capture the opinions of the four key stakeholder groups. Survey questions were developed in consultation with the NWS staff involved in both the Storm Surge Roadmap and the HFIP Socioeconomic Working Group. The surveys asked respondents to comment on several prototypal forecast graphics and, in some cases, to compare graphics. Respondents were asked to rate each graphic on specific criteria, such as ease of understanding, usefulness, and effectiveness. They were encouraged to provide additional commentary and suggestions for improving the graphics being tested. (Storms on the maps were named "Hurricane X" to avoid biases.)

The surveys focused on the following prototypal graphics:

- Variations of a **storm surge inundation map** (Figure ES-1) that showed the potential for coastal flooding in an area due to a storm. The maps used different color schemes and labels to depict the potential depth of ocean water in a region from storm surge. Pre-testing with the different stakeholder groups helped to refine the maps and address areas of confusion. Ultimately, the surveys tested three prototypes: 1) a solid blue map depicting the entire area under a storm surge with no depth information, 2) a map in gradients of blue showing the potential depth of the water expected in a region, and 3) a map in multiple colors showing the potential depth of water in a region in feet correlated to hazard categories (e.g., low = 3 feet or less above ground at that location, moderate = 3 to 6 feet above ground at that location, high = 6 to 9 feet above ground at that location, and extreme = 9 feet or more above ground at that location).

  All stakeholder groups preferred the storm surge inundation map in multiple colors that showed the potential depth of the water in both feet and hazard categories. The map received high scores for both its ease of understanding and its usefulness. The public and WCMs preferred "feet above ground level" for labeling of the potential depth of water; BMs and EMs preferred "height of water above the land."

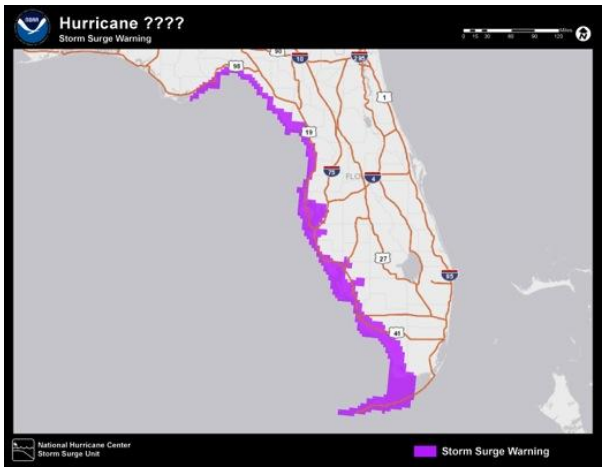
Figure ES-1. Storm Surge Inundation Map Prototypes

- A **storm surge warning map**. NWS has been exploring the possibility of developing explicit storm surge warnings that would be issued separately from NHC's present package of TC watch/warning advisories. Respondents were asked to assess a prototype storm surge warning map (Figure ES-2). If NWS were to issue a separate storm surge warning, it would distribute localized maps like this prototype for areas under the warning.

  All stakeholder groups strongly supported the storm surge warning and gave a positive assessment of the storm surge warning map.

[1] Prototype graphics were tested with different stakeholder groups under two separate NOAA-funded projects: "HFIP Socio-Economic Research and Recommendations" (EA133C-09-CQ-0034) (ERG) and "Assessing Current Storm Surge Information from the Public Perspective" (NA06OAR4310119 and NA06NWS4670013) (NCAR).

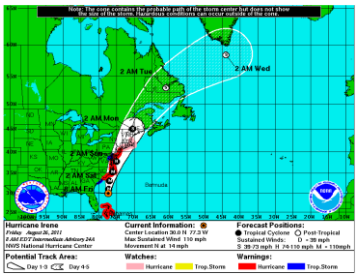
Figure ES-2. Storm Surge Warning Map

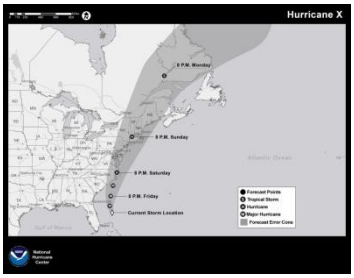


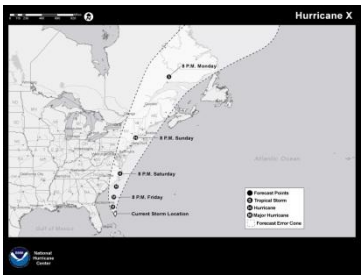
- Variations of the **tropical cyclone forecast track cone map** (also called the "cone of uncertainty") that indicates the likely path of the center of a storm. Forecasters expect the center of the storm to stay within the cone about two-thirds of the time. EMs, BMs, and WCMs were asked to assess the current graphic used to depict the track cone and two alternatives. The public reviewed just the alternative versions. (All three versions are shown in ES-3.) The impetus for developing the alternatives was to try to better depict the uncertainty associated with the storm track. In one version, the cone appeared as a transparent grey with no lines at its border; in the other version, the cone is depicted in dashed lines. The public rated the alternative graphics favorably on both ease of understanding and usefulness, yet demonstrated confusion when asked to interpret the maps. They showed a tendency to think the storm would stay within the boundaries of the track cone. BMs, EMs, and WCMs offered a mix of positive and negative comments on the current cone and the alternatives. The consensus was that the current cone is not an excellent product and could be improved, but that the public is accustomed to the current graphic and that it does provide useful information, even if is often misinterpreted.

  Stakeholders provided mixed reviews of the current cone and the two alternatives. More research is needed to clarify how this visual could be improved.

Figure ES-3. Variations of the Tropical Cyclone Track Cone Map





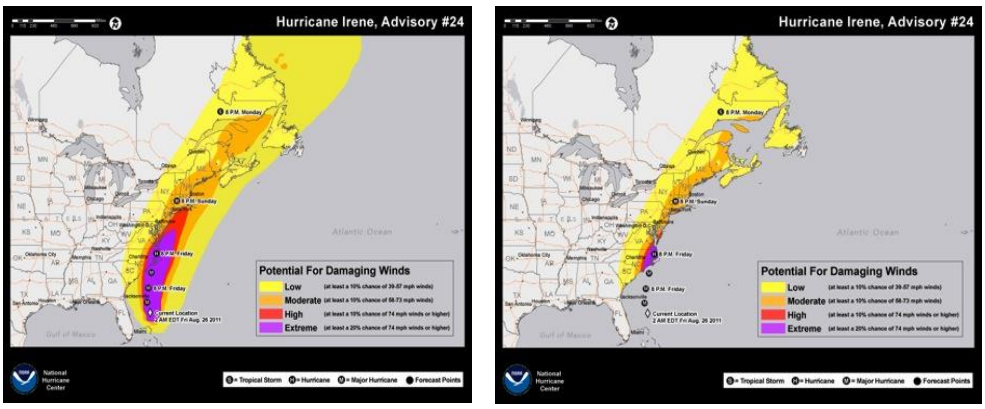


- Variations of a map (see Figure ES-4) designed to communicate the chances of an area experiencing **damaging winds.** The map categorized winds into "low," "moderate," "high," and "extreme" (based both on the wind speed in miles per hour [mph] and the probability of occurrence). The probability was 10 percent for 39 mph, 58 mph, and 74 mph winds for the "low," "moderate," and "high" categories, respectively, and 20 percent for 74 mph for the "extreme" category. One version of the map showed the full wind field over the water and the

land. The other version only showed the graphic on land areas in an attempt to highlight the potential effects to coastal residents.

All stakeholder groups strongly supported the potential for damaging winds map, with the version showing the full wind field over both land and water receiving somewhat higher scores than the land-only one. If the version of the graphic showing winds over both land and water is used, the title would have to be changed from the "potential for damaging winds" since damaging winds cannot occur over water.

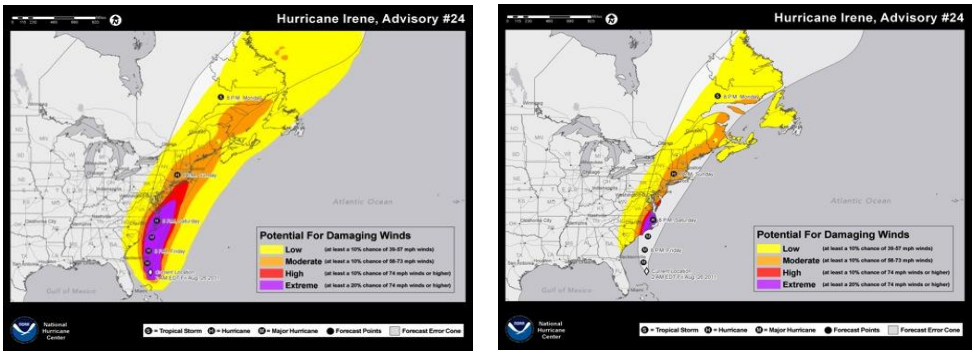
Figure ES-4. Variations of the Potential for Damaging Winds Map



- Variations of a map depicting the **potential for damaging winds combined with the tropical cyclone forecast cone** ("combined wind plus cone"). One version showed the forecast track cone over the entire wind field, and the other showed the cone over only land with the intent to better emphasize land areas under threat (see Figure ES-5). The impetus behind the development of this map was to illustrate that the winds expected in a specific tropical cyclone can occur outside the cone.

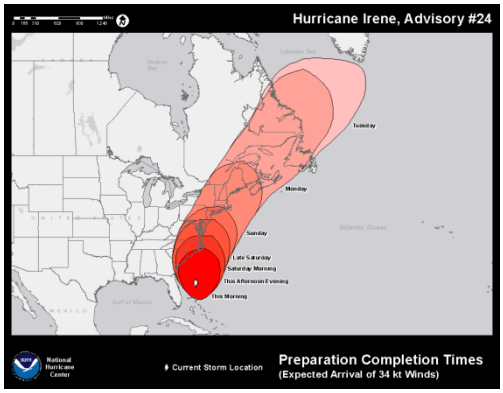
  All stakeholder groups, particularly the public, showed strong support for the combined wind and cone map, with the land-only version receiving only slightly less support from all groups.

Figure ES-5. Variations of the Combined Wind Plus Cone Map



- An **arrival of tropical storm force winds** map. The last map was created in response to EMs' requests for a product showing when they should expect the arrival of tropical storm force winds because this information drives their preparation and evacuation timelines. The prototype map showed the approximate arrival times for tropical storm force winds on the East Coast for a hypothetical storm (see Figure ES-6).

Figure ES-6. Arrival of Tropical Storm Force Winds



All stakeholder groups, particularly the media, showed strong support for the arrival of tropical storm force winds map.

Additional Research Findings on Public Awareness and Concerns

In addition to collecting stakeholder feedback on the proposed NWS storm surge and wind prototype maps, the research gathered insights into broader communication issues. The Web-based public survey revealed important findings about the public's level of concern about TC and ET events:

- About three-fourths of the coastal residents who completed the survey expressed concern about TC or ET storms. As expected, concern was higher among those living closer to the ocean.
- Nearly all respondents understood they should worry more about a Category 5 storm than a Category 1, and also that a hurricane warning was of greater concern than a watch.

It also revealed information about the public's level of concern and understanding of the threats posed by storm surge:

- About two-thirds of the respondents living two miles from the coast were either extremely or very concerned about storm surge.
- In the total sample, the most concern was about flooding from rain, followed by storm surge. Most respondents did not realize that storm surge causes the most storm deaths and ranked flooding from rain and wind above surge in that respect.

An important finding is that providing depth of water ranges may make a difference in evacuation decisions, in both positive and negative ways. A forecast of higher water levels makes people more likely to evacuate, but a forecast of lower water levels may discourage evacuation—even though the expected surge and flooding could still be life-threatening.

ES.2 Other Findings and Recommendations

Throughout the exploratory and testing stages, stakeholder groups offered up many suggestions for enhancing NWS forecast products and communication. Based on the research, the following findings and recommendations are offered to continue to enhance NWS's TC communication and better serve stakeholders' needs:

- **Consider reviewing the entire NWS TC product suite.** A number of WCMs, EMs, and BMs suggested that the NWS already provides too many products, including too many warnings. While many favored the addition of a storm surge warning, they felt that other watches and

warnings could be eliminated. Many also expressed opinions about text products, particularly public advisories, commenting on the use of all capital letters, lengthy blocks of text, and lack of clarity regarding what information is critical or has changed. EMs, BMs, and WCMs all commented about the tendency for the public to misinterpret or not understand the data behind the current "cone of uncertainty." This graphic generated much discussion, and there was a general consensus that it could be improved.

Further research is needed that looks at the total NWS storm forecast suite of products to see how it might be streamlined and modernized, as well as which graphics (such as the "cone of uncertainty") warrant additional research, refinement, and testing.

- **Move toward more modern ways of providing information and graphics.** All stakeholders mentioned the need to see maps that are scalable for smartphones and tablets. They are also interested in toggling, zooming, and clickable/mouse-over capabilities on maps to let the user look closer at a map, view different sets of types of data displays, or view text definitions or explanations. Many groups expressed strong feelings that NWS must move in this direction to stay relevant.

  It is important that the NWS modernize its forecast presentations if it is to continue to effectively communicate forecasts and save lives.

- **Improve awareness and utility of NWS storm-related websites**. The public survey revealed that both the NHC and WFO websites were underutilized. While some members of the public stated that NWS websites were important sources of information, others were not even aware these websites existed. Many stakeholders also stated that NWS storm-related websites were not user friendly. While this project did not go into depth on this topic, general comments centered around having too much information on the home pages, making it difficult to locate specific information about storm forecasts.

  NWS needs to undertake projects to publicize the presence of NWS storm-related websites, drive people to these sites (through strategies such as public education campaigns, search engine optimization, and increased NWS/NHC/WFO presence on social media sites), and ensure that people can find information easily on these sites.

- **Consider the timing of release of NWS forecast products.** There were numerous complaints from BMs and EMs about the timing of the release of NWS forecast products. For the BMs, these products tended to arrive too close to when they had to go on the air (typically at the top of the hour). EMs complained that they often arrived after they had to make important decisions, such as recommending evacuations.

  NWS has been aware of this concern. The release of these products is tied to when the data arrive at the NHC and, therefore, subject to these timing constraints.

- **Ensure the proper integration, education, and training during the implementation process.** A common thread throughout the research was the need for forecasts from the various NWS entities, such as the NHC and the local WFOs, to be coordinated into a seamless process. There were concerns among meteorologists about how new NHC products would relate to current WFO forecast products and procedures.

  NWS should continue to consult and collaborate with the local offices throughout the process of implementing the new storm surge products and when designing and implementing any future products.

ES.3 Summary

In summary, this project used social science research techniques to inform the development of new NHC storm surge forecast products and to begin the development or improvement of several track and wind products. A two-stage research process began with qualitative exploratory data collection designed to better understand the issues and to learn how various stakeholders interpreted storm surge, track, and wind graphics. This iterative process resulted in several graphics that were then tested empirically through surveys with the main users of NHC forecast communication products. The results showed extensive support for the issuance of a storm surge watch/warning and the adoption of a storm surge warning map and an inundation map. At the same time, researchers began to explore better ways to communicate storm track and wind information. These latter products will require further work, hopefully following the research design used successfully in this project.

The introduction of new and improved forecast products is only a first step. Various stakeholders, including the public, must become aware of these products, interpret them correctly to gauge the level of risk, and then make responsible protective decisions. This will require training, education, marketing, and/or outreach campaigns targeted to the context and needs of various users of NWS storm forecast products.

1 Background

The National Weather Service (NWS), an agency of the National Oceanic and Atmospheric Administration (NOAA), issues suites of text and graphical products to communicate forecasts associated with severe storms. During tropical cyclone (TC) conditions, NWS's National Hurricane Center (NHC) in Miami, Florida, issues text and graphical products to communicate the forecasts. NHC disseminates these products in various formats and media to meet the needs of a diverse user community, including Warning Coordination Meteorologists (WCMs) in NWS Weather Forecast Offices (WFOs), emergency managers (EMs), broadcast meteorologists (BMs) and other media, local decision-makers, and individual citizens.

1.1 NHC TC Products

NHC issues TC watches and warnings based on wind speed criteria. The wind threat is communicated through the Saffir-Simpson Hurricane Wind Scale[2] and probabilistic wind data and graphics. The storm track is displayed through the forecast track cone, also known as the "cone of uncertainty." Storm threat is communicated through several products, including public advisories, forecast discussions, and probabilistic storm surge products. (Complete descriptions of all of the text and graphical products that NHC produces can be found at www.nhc.noaa.gov/pdf/NHC_Product_Description.pdf.)

At the local level, NWS Weather Forecast Offices (WFOs) issue detailed hurricane local statements (HLSs) describing the hazards associated with a storm. Many WFOs also issue experimental TC impact graphics detailing expected storm impacts, such as wind and storm surge. In addition, WFOs issue coastal flood advisories, watches, and warnings for storm surge that is expected at coastal locations outside of the areas covered by NHC-issued TC watches and warnings, as well as during ETs and other events (such as high astronomical tides) resulting in coastal inundation.

1.2 Storm Surge Communication

Along the coast, storm surge is often the greatest threat to life and property from a hurricane.[3] There is strong evidence that people do not pay enough attention to the dangers of storm surge. As most recently illustrated by Tropical Storm Debby, Hurricane Isaac, and Hurricane Sandy, dangerous storm surge can occur in ET storms, tropical storms, and hurricanes classified at lower categories of the Saffir-Simpson Hurricane Wind Scale. Additionally, while the NWS forecasts for these storms, including the storm surge forecasts, were accurate, many who should have evacuated did not. For example, eight residents of Midland Beach on Staten Island drowned in the surge from Hurricane Sandy in spite of a mandatory evacuation order issued at least one day before landfall (Semple and Goldstein 2012). At least 100 people died during Sandy, most from drowning (NY Times November 17, 2012).

Well before these recent storms, NWS had been actively investigating whether new storm surge forecast communication approaches are needed to improve decision-making to protect life and property. NWS had been exploring the possibility of developing explicit storm surge warnings that would be issued separately from NHC's present package of TC watch/warning advisories. The recent storms underscore the need for such a warning.

Not only would a storm surge warning better convey the threat from deadly storm surge, but it would also address the fact that hurricane force winds and storm surge do not always occur in the same places

[2] The Saffir-Simpson hurricane wind scale assigns hurricanes a category rating from one to five based on a storm's sustained wind speeds.
[3] http://www.nhc.noaa.gov/surge

or at the same times. For example, storm surge arrived well in advance of tropical storm force winds during Hurricane Ike in 2008. A storm surge threat is also very dependent upon elevation and other details of the coastline. In some instances, storm surge can threaten communities far inland from the coast.

The storm surge warning would indicate areas where storm surge flooding is expected to threaten people's safety. If a warning for storm surge is issued, a map will show the area included in the warning, similar to the approach currently used for hurricane and tropical storm warnings. More detailed maps will also be provided for localities showing the potential inundation, or height of water, in an area.

1.3 Improving Hurricane Forecasting and Communication

In 2008, NOAA established the Hurricane Forecast Improvement Program (HFIP) to improve the accuracy and reliability of hurricane forecasts, to extend lead time for hurricane forecasts with increased certainty, and to increase confidence in hurricane forecasts. As part of its work, HFIP commissioned Eastern Research Group, Inc. (ERG), to use social science methods to:

- Analyze NHC's audiences' awareness, level of concern, and communication needs related to TC and ET risks (including strong winds and storm surge).
- Test and retest several graphics that NHC is considering for communicating storm surge, storm track, and wind forecasts.
- Provide recommendations helping NHC continue to improve its communication of TC and ET risks to its diverse user community.

The project is part of a larger NOAA effort to solicit opinions for improving hurricane forecasting and communication from key NWS stakeholders, including the general public, EMs, BMs, and WCMs located in areas subject to ETs and TCs. Collectively, this work has gathered stakeholder feedback on several prototypal storm surge, forecast track, and wind graphics.

2 Exploratory Research and Preliminary Testing

The ERG team completed the social science and research work in several stages. At the start of the project in the fall of 2011, the team conducted a literature review to synthesize research conclusions and recommendations that could help the NHC improve its hurricane communication products and overall outreach and messaging. In the winter of 2012, the team began pre-testing several prototype graphics with small groups, with emphasis on a storm surge warning and a storm surge inundation map. The testing captured the impressions of representatives of the key stakeholder groups (EMs, the media, the public, and WCMs) using several venues. This pre-testing continued at several meetings through the spring of 2012.

Related NOAA Studies: Assessing Current Storm Surge Information From the Public Perspective

Along with the work conducted directly for the HFIP, two other NOAA research projects informed this investigation. Under the NOAA project "Assessing Current Storm Surge Information From the Public Perspective," Betty Morrow of SocResearch and Jeff Lazo of the National Center for Atmospheric Research (NCAR) conducted a telephone survey in the fall of 2010 to assess the public's awareness and understanding of storm surge and to consider whether the NWS should develop new informational approaches to improve the communication and decision-making with respect to ET and TC storm surge risk. The survey collected data from 900 coastal residents. Almost 72 percent of the respondents supported the issuance of a separate storm surge warning for severe coastal flooding events. Many commented that having a separate surge warning would save lives and increase awareness, and that it would be important for people living nearest the coast to get the additional warning. The survey also suggested that a significant portion of the U.S. coastal population is not fully aware of its storm surge vulnerability. In addition, less than one in six of the respondents indicated they would evacuate for a Category 1 or Category 2 hurricane.

Dr. Morrow and Dr. Lazo also conducted an online study of emergency management programs in areas susceptible to TCs between May and August of 2011. The survey reached out to 114 EMs in coastal counties or parishes from North Carolina to Texas, as well as Hawaii and the U.S. Virgin Islands. The researchers received a total of 53 usable responses representing 52 jurisdictions. The EMs indicated that they have a great deal of concern about the storm surge threat in their communities. Many felt that their public does not have an adequate understanding of storm surge or its impacts. Even those who believed their public is well educated about surge worry about that people become complacent if there hasn't been a recent event. They support the separation of surge from the Saffir-Simpson Hurricane Wind Scale, as well as new ways to convey the potential danger to the public, including the issuance of separate surge watches and warnings, and the expression of surge using "feet above ground level." In general, the responding EMs indicated that they would like earlier surge forecasts and more graphics and visual materials to use in their communication with the public.

2.1 Literature Review

In the fall and winter of 2011, ERG reviewed more than 40 studies about hurricane risk communication and hurricane information tools. Based on this review, ERG identified the information needs, behavior patterns, and communication challenges of key NHC audiences.

The literature showed that NHC's four audiences (EMs, the media, the public, and WCMs) share several needs regarding hurricane information products. They all need products that:

- Are useful, transparent, and consistent.
- Are easy to understand and visually engaging.
- Provide context: the rationale, process, and logic behind a product.
- Provide information about the relevant hazards posed by a hurricane, such as storm surge and wind.

The literature review also revealed that each audience has its own unique communications needs. For example, the public wants information that it can trust, that resonates on an emotional level, and that explains their individual risk of bodily harm or property damage. EMs want timely, operationally useful information that helps them effectively engage with a community and organize an appropriate community response during a storm. WCMs want information products that are useful to end users, that are easy and efficient to disseminate, and that can be combined with information from other sources. The media wants information that is easy to distill and explain to the public, particularly as a storm progresses and media personnel are under increasing pressure to communicate updates.

Based on the literature review, several recommendations emerged for improving NHC products:

- Incorporate information about potential local impacts into existing products.
- Use easy-to-understand text, avoiding jargon and technical terms.
- Enhance the visual appeal and interactivity of products.
- Tailor the information to meet the needs of different audiences.
- Consider developing products that are translated into languages other than English or directed toward vulnerable groups.
- Consider ways to improve the release time, consistency, accuracy, and certainty of forecasts and products.
- Consider creating new products to fill information voids and/or streamlining the current suite of products.

The literature also suggested ways to enhance effective dissemination of NWS/NHC products:

- Use a variety of media, including new technologies like smartphones and weather apps, to disseminate hurricane information and products.
- Consider ways to highlight important information on NWS websites and make it easy for different audiences to find what they need.
- Consider ways to provide messaging and visuals through information sources that are trusted by the target audiences.
- Understand the role that social media is playing in hurricane preparedness and messaging, which organizations are using social media tools, and how the NWS's products can be effectively used in this medium.

2.2 Preliminary Testing

NOAA developed several prototype storm surge warning and inundation maps using different color schemes, categorizations, terminology, and labeling approaches. The ERG team, led by Dr. Betty Morrow, conducted exploratory research with small groups of people using these prototypes. Gina Eosco also conducted interviews with several BMs. At this early testing stage, the goal was to begin to understand possible ways people might interpret these maps. NOAA then refined the maps based on the feedback from these groups. This iterative process of testing the products, refining them, and retesting the revised graphics continued as the research proceeded. The end product was a set of graphics as well as a set of questions to be empirically tested.

2.2.1 One-on-One Webinars

Between November 2011 and March 2012, Dr. Morrow and the ERG team conducted one-on-one interviews with small groups of people in Florida using Go-To-Webinar software and a PowerPoint presentation of the visuals. The groups were as follows:

- Seven experienced directors of emergency management in coastal communities.
- Five WCMs in the WFOs in Florida.
- Thirteen citizens of Lee Country, Florida, including professionals in law enforcement, health, state and local government, college teaching, medicine, and local businesses.

The team tested six prototype storm surge inundation maps (see Figures 2-1 to 2-6) developed for the research process. The maps differed in their resolution levels: some were high-resolution with fine detail, while others were “smoothed out” to show less detail but a sharper demarcation between colored zones. Color schemes ranged from solid blue, to variations of blue, to multiple colors to indicate varying amounts of water expected. The different maps also depicted the water depth differently, including:

- Categories of very low, low, moderate, high, and extreme in a legend.
- A scale showing a range of less than 3 feet to more than 12 feet in the legend.
- A numbered scale with categories of 0 to 3 feet, 3 to 6 feet, 6 to 9 feet, 9 to12 feet, and more than 12 feet in the legend.

Figure 2-1. Potential Storm Surge Area in One Color (Blue)

Figure 2-2. Potential Storm Surge Depths in Gradients of One Color (Blue)

Figure 2-3. Potential Storm Surge Depths, Multiple Colors (Blue to Red), High-Resolution, Scale <3 to >12 Feet

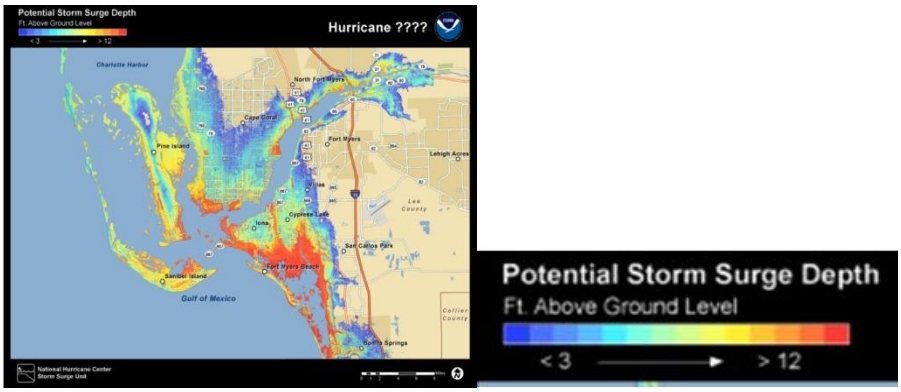


Figure 2-4. Potential Storm Surge Depths, Multiple Colors (Blue to Purple), High-Resolution, Hazard Categories

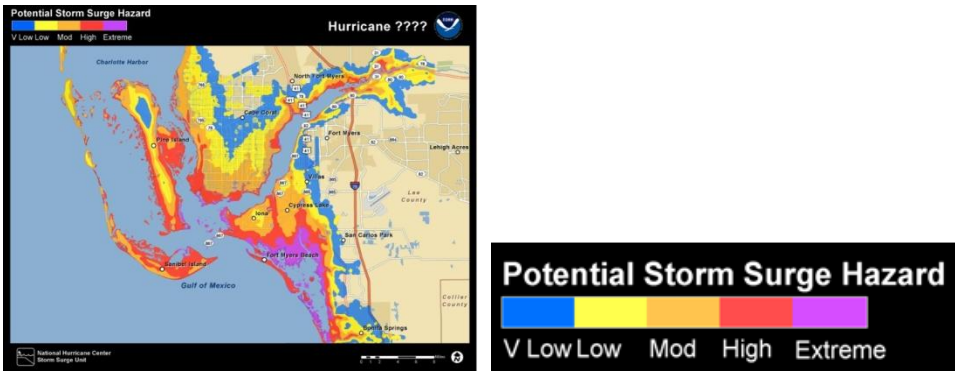


Figure 2-5. Potential Storm Surge Depths, Multiple Colors (Blue to Purple) Smoothed, Hazard Categories

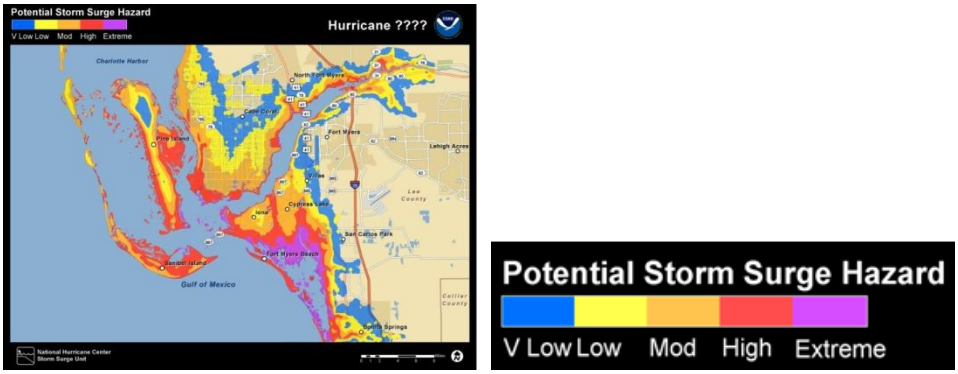
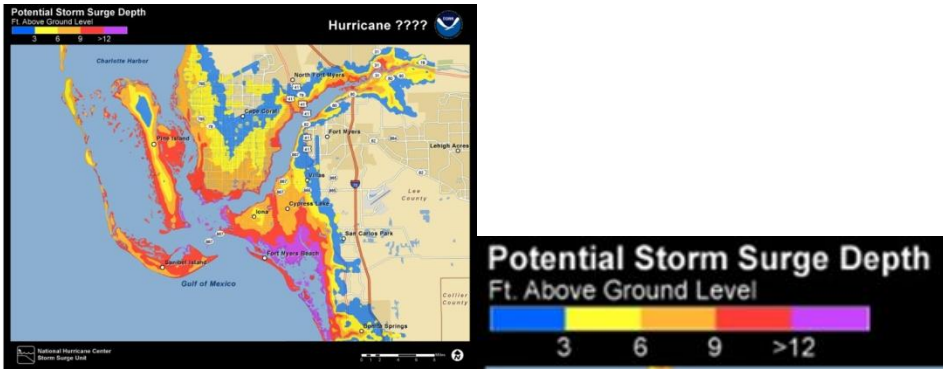


Figure 2-6. Potential Storm Surge Depths, Multiple Colors (Blue to Purple), Smoothed, Feet Above Ground Level



2.2.1.1 Emergency Managers

This exploratory work provided some important insights into how EMs might feel about these prototype storm surge maps. The findings suggested that:

- EMs are likely to favor issuing a separate storm surge warning.
- They have some questions about the criteria, timing, and content of a storm surge warning.
- Most like the name “storm surge warning” better than “extreme coastal flood warning.”
- There is some concern about conflict with evacuation zone maps.
- There is concern that detailed maps may cause some citizens to ignore evacuation orders.
- “Very low” is not a good descriptor of the depth of the water: it may be interpreted as there being nothing to worry about.

2.2.1.2 Warning Coordination Meteorologists

The webinars with the WCMs revealed the following findings:

- There are mixed feelings regarding whether a separate storm surge warning should be issued. There are unanswered questions about the criteria, timing, and mode, as well as the role of the WFOs in the process.

- Most like the name “storm surge warning” better than “extreme coastal flood warning.”
- Concerns were expressed about the complication of the entire warning process and how it might be streamlined for better public understanding.
- There is a preference for issuing a simple map for the public and a more detailed one for EMs and other decision-makers.
- “Very low” is not a good descriptor, as it appears to minimize the risk.
- There were mixed opinions about the use of “feet above ground level” on the maps as opposed to descriptors of the depth.

2.2.1.3 Citizens

This exploratory work provided some important insights into how the public may interpret storm surge inundation maps. The findings suggest that:

- People look for landmarks in order to find their homes on maps.
- They don’t tend to look for the legend.
- They don’t understand “feet above ground level.”
- Blue intuitively means water.
- They are used to colors indicating level of risk.
- Purple gets more attention than red.
- “Very low” may be interpreted as there being little to worry about.
- Most want some indication of water depth in feet.

2.2.1.4 Conclusions

These preliminary tests revealed some common findings that helped NOAA refine the prototype maps. Certain color schemes were clearly not effective, and one color scheme (colors ranging from blue to red) was dropped from further study. People also needed some explanation of the terminology “feet above ground level.” If categories are used to show the depth of the water, the lowest one should not be labeled “very low” because it may imply there is nothing to worry about. The smoothed maps were preferred over the finely detailed ones, and there was a clear preference for naming the warning “storm surge warning” as opposed to “extreme coastal flood warning.”

2.2.2 WeatherFest Exhibition and Interviews

In January of 2012, three members of the ERG team (Evan Fago, Dr. Betty Morrow, and Gina Eosco) with assistance from Jamie Rhome of NHC, staffed the NHC booth at WeatherFest in New Orleans, Louisiana. Leading up to the American Meteorological Society’s Annual Meeting, WeatherFest is a free event open to the public; it is designed to expose children of all ages to science and math and encourage them to pursue careers in these fields.

ERG staffed a booth showcasing both a children’s activity and poster boards of the different graphic prototypes under consideration at that point in the testing. The children’s activity modeled conditions during a hurricane so that children could see how a storm surge forms and witness its impact on model coastlines. The activity used tinted water (ocean water), a hair dryer (wind), and sugar cubes (coastline) to show how water can push up against the land during a hurricane.

ERG also rotated a display of seven poster boards (each containing a single prototype visual—four for storm surge, three for hurricane track and wind impacts) within the booth. ERG encouraged visitors who came to the booth to offer comments about how effectively each visual communicated the hazards depicted. This informal exercise was designed to encourage casual dialogue and supplement the more formal user testing that would follow.

On behalf of NHC, ERG displayed and engaged attendees in discussion about the following four storm surge graphics (see Figures 2-7 to 2-10).

The findings from these discussions and informal testing on the different storm surge graphics were as follows:

- The overwhelming majority of people preferred the storm surge inundation maps depicted in multiple colors.
- More than one person recommended that NOAA develop a map that contained *both* quantitative (feet above ground level) information about forecasted surge depth and qualitative surge hazard levels.
- Several people liked the specificity of actual numbers.
- Others commented that they did not prefer the low, medium, high, and extreme categories—"What does extreme really mean?" They explained that everyone has a different definition of extreme, and therefore, this visual was not communicating a specific message to them.
- There was confusion regarding "feet above ground level." While this terminology is intended to simplify public understanding, it may take some outreach to clarify its meaning.

Figure 2-7. Potential Storm Surge Area in One Color

Figure 2-8. Potential Storm Surge Depths in Gradients of One Color (Blue)

Figure 2-9. Potential Storm Surge Depths, Multiple Colors, Feet Above Ground Level

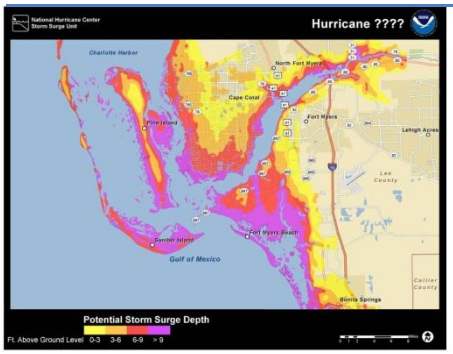
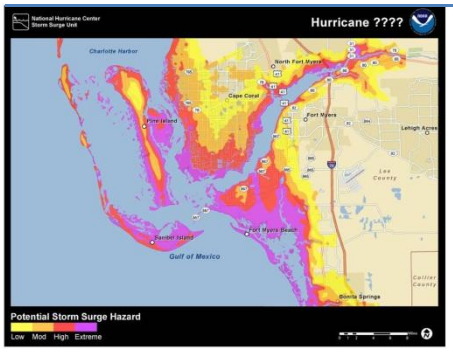


Figure 2-10. Potential Storm Surge Depths, Multiple Colors, Hazard Categories



2.2.3 National Hurricane Conference Polling

In March 2012, two members of the ERG team (Evan Fago and Dr. Betty Morrow) staffed the NHC booth at the 2012 National Hurricane Conference in Orlando, Florida. As the nation's premier forum for education and professional training in hurricane and disaster preparedness, this event represented an ideal opportunity for ERG to collect valuable feedback from the EM and first responder stakeholder groups. Ultimately, this feedback helped further guide NHC's development and refinement of the prototype visuals.

Over a two-day period, ERG collected voluntary, anonymous input from more than 80[4] people related to a series of prototypal graphics displayed in the NHC booth (see inset photo).[5] To collect this feedback, ERG used a service called PollEverywhere, whereby people submitted their preferences for different visuals using their cell phones via text message or a mobile Web browser. ERG also enabled people to provide feedback using printed copies of the survey.

As well as collecting feedback about preferences for different visuals, ERG compiled information about each respondent's occupation, workplace location (coastal or inland), and years of professional experience in their current occupation. Using these supplemental data, ERG was able to confirm that the reported preferences for visuals were independent of occupation, location, and years of experience.[6] Of the people reporting their occupation, there was a near even split between "emergency manager" and "other." Only two people identified themselves as "first responders." More than 69 percent of respondents reported working in coastal jurisdictions. The reported years of experience was fairly evenly distributed. The largest group (representing 29 percent of all respondents) reported having more than 20 years of experience in their current occupation. The next largest group (representing 23 percent of all respondents) reported having between zero and five years of experience in their current occupation.

The following graphics were tested:

- Four versions of the **storm surge inundation map** (see Figure 2-11): one in solid blue, one in gradients of blue, one in multiple colors showing the water depth in feet above ground level, and one in multiple colors showing the water depth in qualitative hazard categories (low, moderate, high, extreme).
- A map displaying the area that would be under a **storm surge warning** (see Figure 2-12).
- Two versions of the **potential for damaging winds map** (see Figure 2-13): one showing the hazard wind field over both land and water, the other showing the hazard over only land to better emphasize land areas under threat. Four categories—"low," "moderate," "high," and "extreme," each defined in terms of miles per hour—are depicted in different colors to show the

[4] ERG actually engaged more than 150 people at the NHC booth; only a portion of them, however, voluntarily provided documented input.

[5] To collect this feedback, ERG received approval from the Office of Management and Budget for an information collect request (OMB Control Number 0690-0030).

[6] As a result of this finding, a breakout of responses to the seven questions by occupation, workplace location, and years of experience is not included in this report.

chances of an area experiencing different levels of damaging winds. The probability range is 10 percent of 39 mph, 58 mph, and 74 mph for the "low," "moderate," and "high" categories, respectively, and 20 percent of 74 mph for the "extreme" category.

- Two versions of the **tropical cyclone forecast cone** (see Figure 2-14), typically referred to as the "cone of uncertainty": one map shows the cone with a solid black line showing the edges, and the other map presents the cone with a dashed line around the edges as perhaps a better way to indicate uncertainty of the storm's track.
- Four versions of the **potential for damaging winds map combined with the tropical cyclone forecast cone** (see Figure 2-15): one map shows a forecast track cone over the entire wind field; and the other shows the cone over only the portion over land with the intent to better emphasize land areas under threat. Two additional options (Figure 2-16) display the cone for a storm directly approaching land. One again shows the wind field over land and water; the other shows the wind field over land only. The impetus behind the development of these maps is to illustrate that the winds expected in a specific tropical cyclone can occur outside the cone.
- One **arrival of tropical storm force winds map.** The last map (Figure 2-17) was created in response to EMs' requests for a product showing when they should expect the arrival of tropical storm force winds because this drives their preparation and evacuation timelines.

Figure 2-11. Storm Surge Inundation Maps

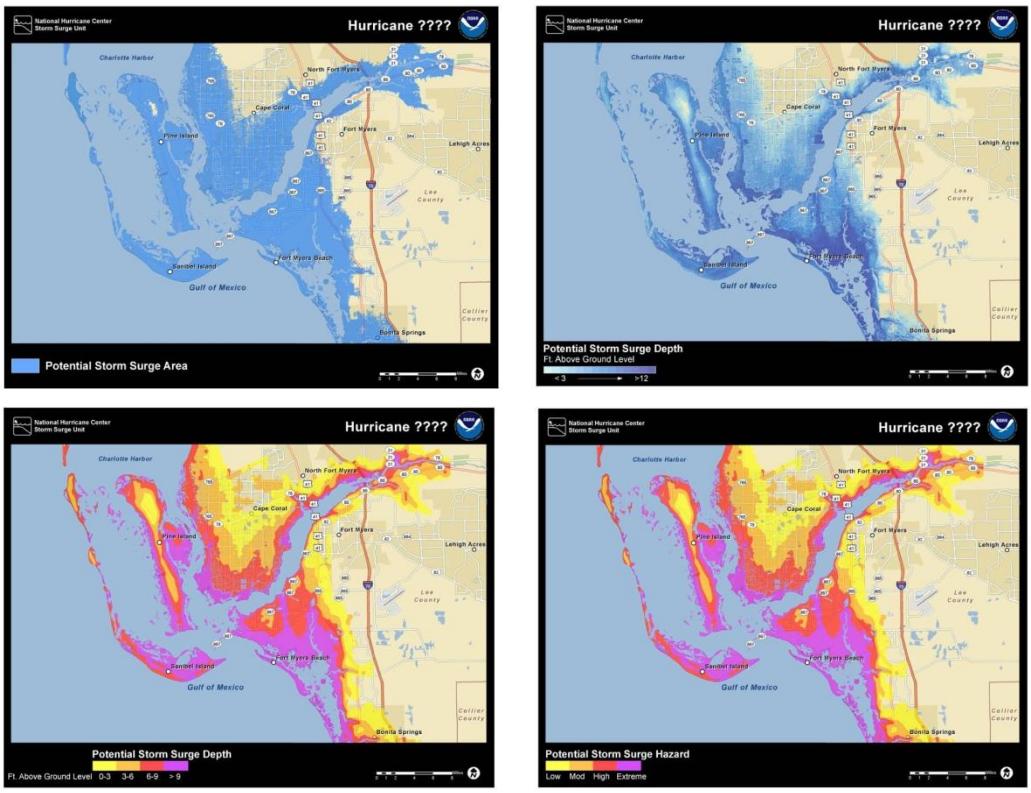


Figure 2-12. Storm Surge Warning Map

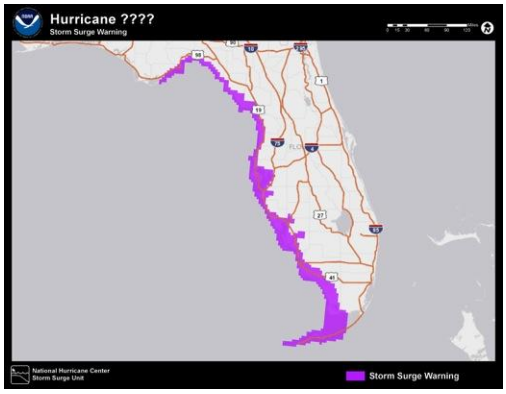
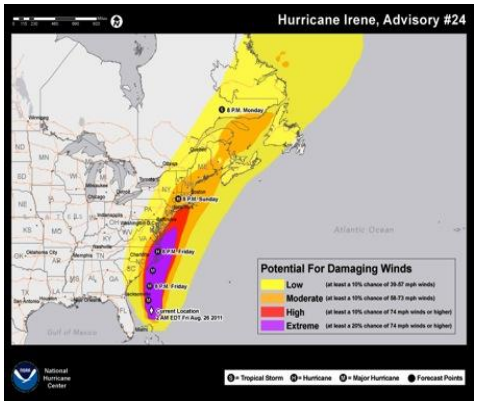


Figure 2-13. Potential for Damaging Winds Maps



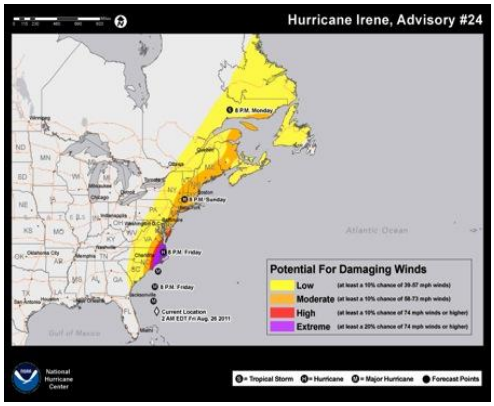
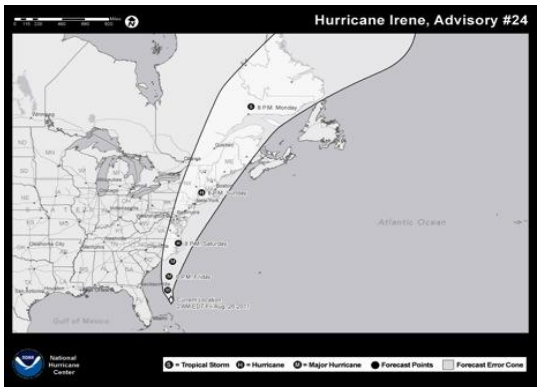


Figure 2-14. Tropical Cyclone Forecast Cone Maps



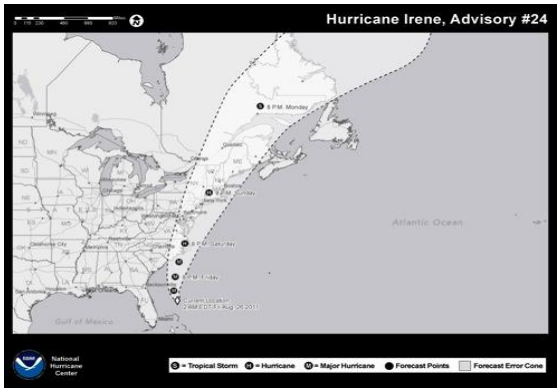
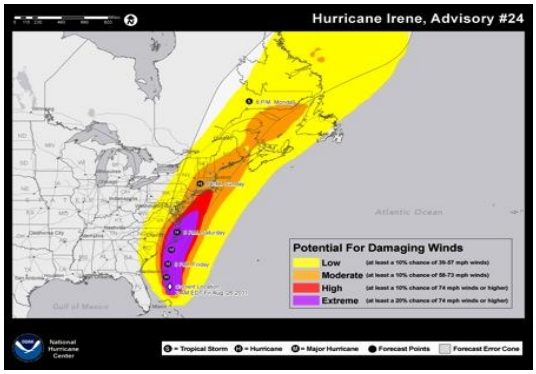


Figure 2-15. Combined Wind Plus Cone Maps



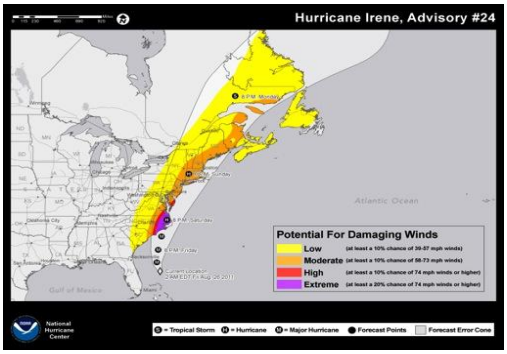


Figure 2-16. Combined Wind Plus Cone Maps—Storm Directly Approaching Land

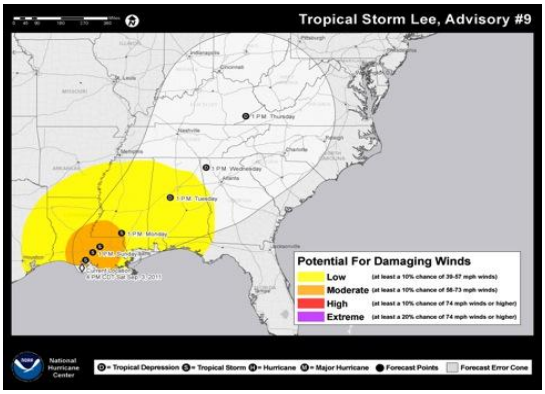
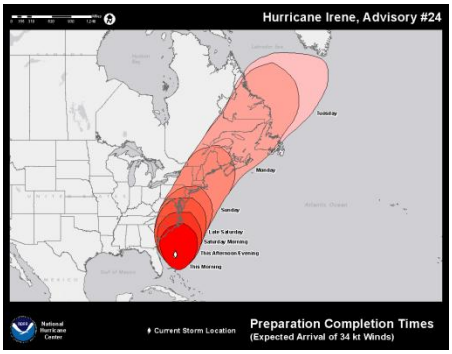


Figure 2-17. Arrival of Tropical Storm Force Winds



The polling findings were as follows:

- The majority (57 percent) of all respondents preferred the storm surge hazard graphic presenting discrete quantitative ranges of forecasted surge depth using multiple colors.
- Nearly 71 percent of all respondents reported that the storm surge warning prototype map would be either "very effective" (19 percent) or "probably effective" (52 percent) at communicating the threat associated with storm surge.
- More than two-thirds of all respondents reported a preference for the potential for damaging wind map presenting the complete wind hazard data field over both land and water.
- Almost two-thirds (64 percent) of all respondents reported a preference for the tropical cyclone forecast cone ("cone of uncertainty") graphic that presents the cone with a dashed border.
- For the graphic presenting both the potential for damaging winds and the cone of uncertainty: 60 percent of all respondents reported a preference for the wind hazard graphic presenting the complete wind hazard data field over both land and water for a storm where the track is parallel to the coast.
- A total of 70 percent of all respondents reported a preference for the wind hazard graphic presenting the complete wind hazard data field over both land and water for a storm where the track is more perpendicular to the coast.
- More than 92 percent of all respondents reported that the map communicating the approximate arrival time of tropical storm force winds would be either "very useful" (58 percent) or "probably useful" (34 percent).

While the results from this convenience sample were not generalizable in a research sense, they provided guidance regarding what products should be empirically tested in the next phase of this project.

2.2.4 Federal Emergency Managers' Hurricane Preparedness for Decision Makers' Courses

In January and February of 2012, Dr. Morrow had an opportunity to discuss the inundation maps, as well as several current or prototype maps related to track and wind, with 75 emergency managers attending three Federal Emergency Management Agency (FEMA) courses at the NHC. Attendees were very supportive of a storm surge warning. They raised some of the same concerns about criteria and timing expressed by others previously, but the NHC staff present were able to answer most questions. The findings were as follows:

- Workshop attendees supported the storm surge warning and map.
- They strongly supported the multicolor storm surge inundation map depicting feet above ground level.
- The group preferred the potential for damaging winds map showing the entire wind field over both land and water.
- Nearly all attendees support the current cone of uncertainty. They felt that people are comfortable with it and that it was a useful tool.
- Attendees reacted favorably to the combined wind and cone graphic. Most preferred the version that showed the entire wind field over both land and water.
- They like the concept of the arrival of tropical storm force winds map, but not the execution.

2.2.5 Media Interviews

In January and February of 2012, Gina Eosco conducted informal exploratory interviews with several BMs. They provided the following general observations and suggestions about their graphical needs:

- Broadcasters tend to produce their own graphics. As such, they need the raw numbers for the data in the highest resolution possible. Suggested formats included gridded, GIS-based, or KML. They also prefer NHC not reduce the graphics to a few colors and provide enough detail in the raw data for them to delineate color categories. Each station has a "color palate," and each graphic must follow that palate. Before making any significant changes, they emphasized talking to the vendors to ensure the software programs can digest the NHC data.
- BMs are interested in a graphical product that accounts for a storm's asymmetry.
- They are also interested in seeing a graphical product that accounts for effects of land in the wind radii products. For example, sometimes when the radii intersect with land, the effects of the land will reduce wind speeds.
- Each graphical product should take into account the same background variables and provide a consistent level of data.

3 Testing

During the summer of 2012, the ERG team and researchers at the National Center for Atmospheric Research (NCAR) and SocResearch conducted several Web-based surveys to capture the opinions of NHC's user community on the refined prototype visuals:

- Coastal EMs in both TC and ET areas.
- BMs at major local TV stations in TC and ET coastal markets.
- Members of the public.
- NWS WCMs at WFOs serving coastal areas.

Researchers developed the survey questions in consultation with NWS staff. The surveys asked respondents to assess each map on two criteria: "ease of understanding" and "usefulness in communicating to the public." They also answered questions about their level of concern about TC and ET events and storm surge, hurricane experience, sources of storm-related information, and responses to evacuation orders.

The surveys built on the exploratory work conducted earlier (described in Part 2 of this report) as well as other completed and in-progress work, including an earlier National Science Foundation–funded study of the hurricane forecast communication process (Demuth et al. 2012), qualitative exploratory interviews with stakeholders in hurricane-vulnerable areas (Lazrus et al. 2012) and prior surveys on public preferences (Lazo and Waldman 2011; Lazo et al. 2010).

Respondents assessed the following prototype graphics:

- Variations of a **storm surge inundation map:** one in solid blue, one in gradients of blue, and one in multiple colors showing the water depth in both feet above ground level correlated to hazard categories (low = 3 feet or less above ground at that location, moderate = 3 to 6 feet above ground at that location, high = 6 to 9 feet above ground at that location, extreme = 9 feet or more above ground at that location). The words "above ground at that location" were added to the legend to attempt to better explain "feet above ground level."

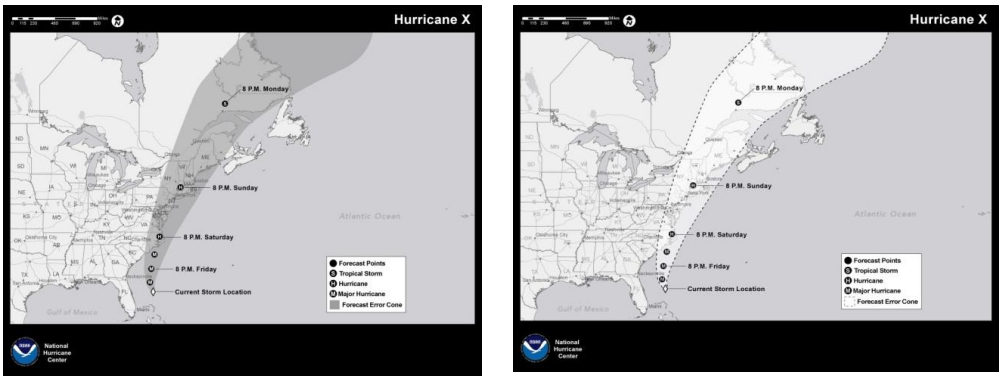
Figure 3-1. Storm Surge Inundation: Prototype Maps

- One map displaying the area that would be under a **storm surge warning** in purple (Figure 3-2).

Figure 3-2. Storm Surge Warning: Prototype Map

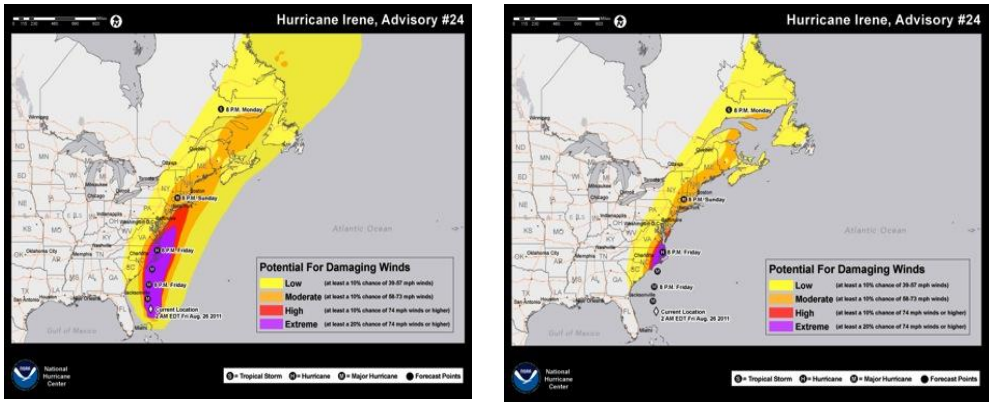
- Variations of the current **tropical cyclone forecast track cone** ("cone of uncertainty"). Respondents were shown one map in which the cone is a transparent gray and uses dashed lines for the edges as perhaps a better way to indicate uncertainty, and another option that shows the a transparent gray cone with no lines at the edges.[7] Surveys with the EMs, BMs, and WCMs also asked respondents to comment on the current cone (white with a solid black line showing the edges). (See Figure 3-3.)

Figure 3-3. Tropical Cyclone Forecast Track Cone: Prototype Maps



- Variations of the **potential for damaging winds map** in which "low," "moderate," "high," and "extreme" (each defined in terms of miles per hour) were depicted in different colors against a light gray U.S. map. The probability is 10 percent for 39 mph, 58 mph, and 74 mph for the "low," "moderate," and "high" categories, respectively, and 20 percent for 74 mph for the "extreme" category (see Figure 3-4).

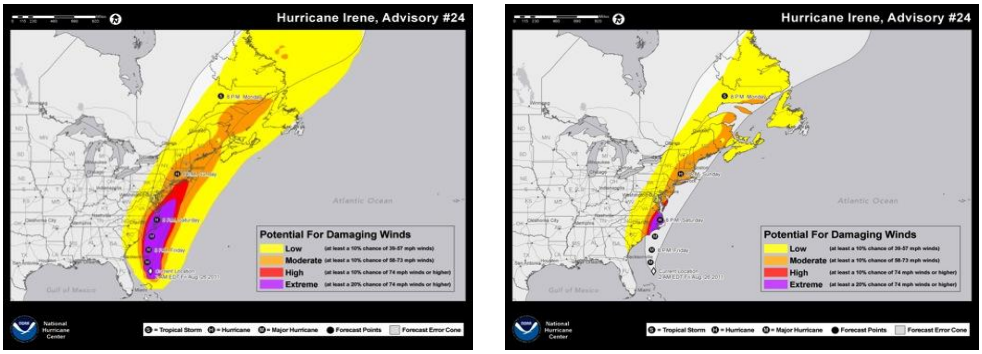
Figure 3-4. Potential for Damaging Winds: Prototype Maps



- Two **potential for damaging winds combined with the tropical cyclone forecast cone** ("wind plus cone") maps: one shows a forecast track cone over the entire wind field, and the other shows the cone over only the portion over land with the intent to better emphasize land areas under threat. These maps are designed to show that the winds expected in a specific tropical cyclone can occur outside the cone (see Figure 3-5).

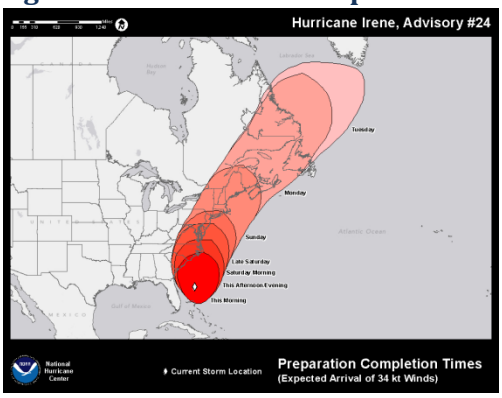
[7] A problem with this exercise, however, was that, as presented, the current cone map provided more information (such as being in color and having more labeling and text) than the alternatives. Therefore, this was not a valid test of cone preference, and the cone issue requires further study.

Figure 3-5. Wind Plus Cone: Prototype Maps



- One **arrival of tropical storm force winds map.** The last map was created in response to EMs' requests for a product showing when they should expect the arrival of tropical storm force winds, because this drives their preparation and evacuation timelines. (See Figure 3-6.)

Figure 3-6. Arrival of Tropical Storm Force Winds: Prototype Map



3.1 Results of the Emergency Manager Survey

In June and July of 2012, NCAR researchers sent email invitations to the directors of emergency management in every county/parish/borough/territory bordering the Atlantic, Gulf, and Pacific coasts, and Alaska. In some cases, such as Connecticut, several counties were grouped together with regional emergency managers. Researchers compiled the sample list manually based on identifying EMs in coastal counties as identified by GIS experts at NCAR. EMs were identified through Web searches and input from lists of EMS. A total of 204 EMs were sent invitations; 113 EMs completed the survey, or at least most of it, for a response rate of 55 percent. About 57 percent of the respondents were directors of their agencies, 28 percent were EMs, and 14 percent were "other" (usually employed by public safety agencies). They had been in emergency management for an average of 16 years and in their current position for an average of seven years. About 90 percent reported their jurisdiction to be vulnerable to TC storms and 91 percent to ET storms. The approximate populations of their jurisdictions varied from less than 50,000 to more than 1 million, with most having between 50,000 and 500,000 residents. Table 3-1 reports the number of respondents from each coastal state or territory.

Table 3-1. Location of Respondents

Coastal State or Territory	Number Contacted	Number of Respondents
Alaska	5	4
Alabama	2	0
California	15	11
Connecticut	3	1
Delaware	3	1
Florida	36	23
Georgia	6	4
Hawaii	4	4
Louisiana	19	9
Maine	8	3
Maryland	5	3

Coastal State or Territory	Number Contacted	Number of Respondents
Mississippi	3	1
North Carolina	16	9
New Jersey	8	3
New York	6	4
Oregon	7	6
Rhode Island	5	3
South Carolina	6	3
Texas	28	11
U.S. Virgin Islands	1	0
Virginia	6	4
Washington	7	4
Totals	**204**	**113**

The findings were as follows:

- A total of 83 percent of the EMs thought the NWS should issue storm surge watches, and 87 percent supported a storm surge warning. Many believed these products will result in the public paying more attention to a storm's hazards, better-informed responses, and greater emphasis on coastal flooding in emergency management decision-making.
- The EMs gave the storm surge warning graphic high marks on effectiveness, but many called for higher resolution and more localized information.
- The EMs preferred the multicolored storm surge inundation map, and most preferred that the depth of the water be labeled "height of water above the land."
- The EMs favored the current "cone of uncertainty" over the two alternatives presented, with 97 percent of the EMs giving the current cone positive ratings on ease of understanding and usefulness. They gave both alternatives lower scores on ease of understanding and usefulness.
- The EMs gave positive reviews to the map communicating the potential for damaging winds. About two-thirds preferred the map showing the entire wind field over land and water.
- Two-thirds of the EMs preferred the combined wind and cone map showing the entire wind field over both land and water. Those in support of this map liked that it conveyed marine interests and that it showed the size of the storm. Those that favored the land-only map thought it highlighted the danger better for the general public.
- EMs showed strong support for the arrival of tropical storm force winds map in terms of both ease of understanding and usefulness, with some reservations expressed about how the general public might use this information incorrectly.

3.2 Results of the Broadcast Meteorologist Survey

From June to July of 2012, NCAR researchers conducted a survey of main or chief BMs at local television stations (ABC, CBS, Fox, and NBC) serving the Atlantic, Gulf, and Pacific coasts as well as Alaska, Puerto Rico, and Hawaii. In all, 121 people received invitations and 51 completed the survey, for a response rate of 42 percent. About 82 percent reported their area as vulnerable to TCs and 90 percent to ETs. (Table 3-2 shows the location of the respondents.) Most of the television stations represented in the

survey cover large markets, both in territory and population. More than 77 percent of the BMs reported their market area population as 1 million or more, and another 10 percent covered a population between 500,000 and 1 million. About 85 percent of the respondents indicated their title as "chief meteorologist." They have been meteorologists for an average of 19 years and have been in their current positions for an average of 12 years.

Table 3-2. Location of Respondents

Coastal State or Territory	Number of Respondents
Alaska	0
Alabama	1
California	4
Connecticut	1
Delaware	0
District of Columbia	1
Florida	13
Georgia	1
Hawaii	1
Louisiana	7
Maine	2
Maryland	2

Coastal State or Territory	Number of Respondents
Mississippi	0
North Carolina	2
New Hampshire	0
New Jersey	0
New York	2
Oregon	1
Puerto Rico	1
Rhode Island	1
South Carolina	1
Texas	4
Virginia	1
Washington	3
Totals	**51**

The findings were as follows:

- The BMs did not think the public is well prepared for the kind of hazards most related to this survey, including heavy rain, coastal storm surge, and flash floods.
- The BMs strongly supported the NWS issuing storm surge watches/warnings: 90 percent agreed that watches should be issued, and 95 percent supported a storm surge warning. Most believed these products would result in BMs paying greater attention to these threats in their weathercasts and in the public paying more attention to storm surge.
- A proposed graphic for showing the area under a surge warning received high marks on effectiveness, but there were calls for higher resolution and more localized information.
- The BMs preferred the multicolored storm surge inundation map, and most preferred that the depth of the water be labeled "height of water above the land," followed closely by "depth of water above land."
- The BMs gave the current cone of uncertainty higher positive ratings then either of the two alternatives presented for both ease of understanding and usefulness. These maps received many comments, reflecting considerable thought on this matter. The consensus was that while the current cone could be improved, the public was used to it even if they didn't always understand the data it represented. They knew it had to do with track uncertainty. A common complaint was that the public tended to think the total storm would fall within the confines of the track.
- They gave positive reviews to the map communicating the potential for damaging winds and were asked to comment only on the version showing the wind field over both land and water. The BMs rated the map highly for its ease of understanding and usefulness. Some respondents were very enthusiastic about it, and 17 percent gave it an excellent rating.

- The majority of the respondents gave positive ratings to both of the combined wind and cone maps, but were not enthusiastic about either one. Several commented that the map had too much information and that it might confuse the public.
- They gave strong support to the arrival of tropical storm force winds map, with 95 percent of the BMs giving it a positive rating on ease of understanding and usefulness.

3.3 Results of the Public Internet Survey

In June and July of 2012, ERG conducted a Web-based survey of people living in areas subject to TC or ET events. Researchers administered the survey (OMB #0648-342) online using an email list purchased from a commercial vendor. The total sample consisted of 459 respondents living with 50 miles of the Atlantic Ocean or Gulf of Mexico coasts (i.e., Maine to Texas). The list contained information on the email address owner's location, which was used to identify potential recipients along Atlantic and Gulf of Mexico coastlines. It was an "opt-in" list, meaning that addresses on it had agreed to receive email correspondence such as surveys.

The survey was sent to 276,131 email addresses from the purchased list, with 225,224 emails (81.6 percent) sent back as undeliverable.

This large number of returns indicates some freshness issues with the purchased list. The survey successfully reached 50,907 email addresses. It is not possible to discern how many surveys reached "inactive" (i.e., no longer used) addresses or were directed to "junk mail" folders. Seventy people responded to the survey mailout that they were not interested in taking the survey (and asked to be removed from the mailout listing), and 15 people provided incomplete responses.

Since there is no way to tell how many people who received an email actually read it and refused to take the survey, it was not possible to reliably calculate a response rate. It was possible however, to calculate a "cooperation rate," which is the percentage of people *known* to be eligible to complete the survey who actually did so.

The American Association for Public Opinion Research's *Standard Definitions* provides several approaches for calculating cooperation rates. Researchers used the approach that provided the most conservative (lowest) cooperation rate. Additionally, any respondent who did not complete the entire instrument was classified as a "refusal" in the cooperation rate calculation. (These responses were considered partially complete in the analysis of the data, however.) The cooperation rate used for this survey is defined as:

$$COOP1 = I \div ((I+P) + (R+O)) \times 100$$

where I is the number of fully complete surveys, P is the number of partially complete surveys, R is the number refusals, and O is the number of people who indicated that they would not complete the survey. The survey outcomes involved 459 completes (I), 15 partial responses (P), and 70 known refusals (R+O), for a cooperation rate of 84.4 percent.

The survey sample was divided into two subsamples based on location:

- One subsample lived within 10 miles of the coast and answered questions about both storm surge and wind graphics.
- The other subsample lived further inland, between 10 and 50 miles of the coast, and answered questions about wind graphics.

While all 459 survey respondents answered the storm track and wind questions, only those located in areas subject to storm surge (177 respondents) answered the storm surge portion of the survey.

Table 3-3 shows the demographics represented by the survey respondents.

Table 3-3. Sample Demographics[8]

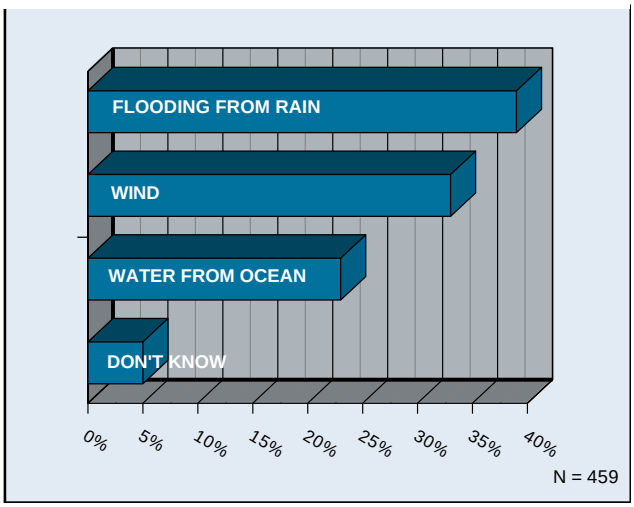
Demographic	Sample (%)
Education	
Less than high school	1
High school graduate	7
Some college or vocational school	31
College graduate	32
Graduate degree	28
Gender	
Male	51
Female	49
Age	
21–40	17
41–60	52
61–75	27
Over 75	3
Hispanic or Latino	
Yes	7

Demographic	Sample (%)
Race	
White	89
African-American	4
Other	8
Housing	
Single-family home	75
Apartment or condominium	13
Mobile or manufactured home	5
Townhouse or other	6
Household income	
$10,000 or less	2
$10,001–$20,000	4
$20,001–$30,000	5
$30,001–$50,000	12
$50,001–$80,000	19
$80,000–$100,000	14
Over $100,000	29

The findings were as follows:

- In the total sample, the most concern was about flooding from rain, followed by storm surge. About two-thirds of the respondents living 2 miles from the coast were either extremely or very concerned about storm surge.
- Most respondents did not realize that storm surge causes the most storm deaths and ranked flooding from rain and wind above surge in that respect (see Figure 3-7).

Figure 3-7. Opinions on What Hazard Causes Most Deaths



- About three-fourths of the coastal residents who completed the survey expressed concern about TC or ET storms. As expected, concern was higher among those living closer to the ocean. Nearly all respondents understood they should worry more about a Category 5 storm than a Category 1, and also that a hurricane warning was of greater concern than a watch.
- Slightly over 92 percent of those living within 10 miles of a coast support the NWS issuing a separate storm surge warning. They believed this separate warning would make them take the threat more seriously. “Storm surge warning” received the highest support as a name for the warning, closely followed by “extreme coastal flood warning.” The proposed map for showing

[8] Rates are for those who answered each demographic question. Less than 1 percent of the respondents did not answer each question, with the exception of income, which 16 percent of respondents did not answer.

the area under a storm surge warning (see Figure 3-1) was considered effective at some level by 96 percent of the subsample.

- All three of the inundation maps received high assessments. When asked to choose one, 97 percent of the respondents chose the map in multiple colors. "Feet above ground level" was considered the clearest wording for expressing expected water levels.
- An important finding is that providing depth of water ranges may make a difference in evacuation decisions, in both positive and negative ways. A forecast of higher water levels makes people more likely to evacuate, but a forecast of lower water levels may discourage evacuation—even though the expected surge and flooding could still be life-threatening.
- Respondents gave the two new versions of the forecast track cone similar high ratings, but one-third or less of the respondents considered them excellent products. With the translucent gray cone with no lines, respondents were slightly more likely to understand that damaging winds could extend beyond the cone.
- The respondents reacted very positively to a graphic showing the potential for damaging winds, but results were mixed when they were asked to interpret the map.
- Respondents also reacted positively to both versions of the combined wind and cone map, and they favored the map showing the wind field over both land and water. Most interpreted this combined map correctly for a given region.
- The map illustrating the arrival of tropical storm force winds also received a positive review, and the majority of respondents interpreted it correctly.

3.4 Results of the NWS Warning Coordination Meteorologist Survey

In June and July 2012, ERG researchers surveyed WCMs from the Eastern, Southern, Western, Pacific, and Alaska NWS Regions (see Table 3-4). WCMs from regional offices were also invited to participate. Researchers sent survey invitations to 70 WCMs, and 54 completed the survey[9] for a response rate of 77 percent.

Table 3-4. Location of Respondents

NWS Region	Number Contacted	Number of Respondents	Response Rate (%)
Eastern	22	17	77
Southern	28	24	86
Western	13	9	69
Pacific	3	2	66
Alaska	4	2	50
Totals	**70**	**54**	

The sample consisted of very experienced WCMs with their tenure in meteorology ranging from 13 to 42 years, with a median of 25 years. They have worked for NWS from 9 to 30 years with a median of 21 years. Their time as WCMs ranges from one to 19 years, with a median of six years. Fifty-three percent of WCMs surveyed said they serve in an area subject to storm surge, and 95 percent stated their areas were subject to winds from TC and ET cyclones.

[9] Several answered most of the key questions but did not complete the survey.

Results from the survey are as follows:

- WCMs expressed considerable skepticism throughout this survey regarding surge issues. Some are not convinced that a separate storm surge warning will be effective, and there were wide differences of opinion about text and graphic formats.
- About three-quarters preferred the storm surge inundation map that used multiple colors to define four categories of inundation. The results on labeling the depth of the water were mixed, but "above ground level" had the highest ratings for being "very clear" or "clear" at 86 percent. A distant second was "depth of water above land" at 66 percent.
- The WCMs expressed mixed feelings about the current cone of uncertainty. None rated it as "excellent" for either ease of understanding or usefulness to the public; respondents provided feedback that the current cone presents too much information and is hard to interpret. The alternative cones did not fare much better, with some WCMs remarking that these visuals suffered from the same issues as the current cone. They noted it was hard to compare the maps because they presented different types of information.[10]
- WCMs reacted favorably to the map showing the potential for damaging winds, but expressed concerns, particularly related to the probabilities and terms used.
- Slightly more than half of the WCMs preferred the map communicating the potential for damaging winds combined with the tropical cyclone forecast track cone that shows the entire wind field over both land and water, as opposed to the map that masks the portion over water. However, many believed the overlay of track and wind probabilities will cause confusion.
- Many WCMs expressed the need for products to have interactive capabilities, such as zooming, multiple layers, and clickable or mouse-over functions to provide more detail and explanation.
- WCMs were also concerned about how any new products would relate to WFO forecast products and procedures already in place and urged NWS to consult with local offices throughout the design and implementation process.

[10] A problem with this exercise was that, as presented, the current cone map provided more information (such as being in color and having more labeling and text) than the alternatives. Therefore, this was not a valid test of cone preference, and the cone issue requires further study.

4 Conclusions

This multi-year research project has resulted in the collection of valuable information for the continual enhancement of the NWS's forecast communication of TC and ET storms. It provides insights into stakeholders' (EMs, the media, the public, and WCMs) concerns related to storms, their understanding of storm terminology, and their perceptions of several prototype forecast products.

Many of the forecast products assessed, including the storm surge warning map, the multiple-color storm surge inundation map, and the combined track cone and potential for damaging winds map, have excellent potential for improved forecast communication in their present forms. While the prototypal forecast track cone maps were well received, their assessments were relatively lower and further research is needed to determine if there are other ways that can communicate the uncertainty of the forecast map in a more clear way. A map depicting the approximate time of arrival of tropical force winds received positive reviews.

4.1 Storm Surge Products and Forecast Communication

This research provided strong evidence that people do not pay sufficient attention to the danger of storm surge. Concern about storm surge is very high among EMs and the media, but much less so among the coastal public. BMs did not think the public was well prepared for heavy rain, coastal storms, and flash floods. EMs believed that most people who are vulnerable to storm surge or coastal flooding in their jurisdictions do not adequately understand their vulnerability.

4.1.1 Storm Surge Warning

An important finding is the extent to which all of the stakeholder groups (EMs, the public, the media, and WCMs) favor a separate storm surge warning. Support for the storm surge warning map is very high among the EMs, the media, and the public, and a little less so among WCMs. Most think the storm surge warning should be called just that, and their reasons are as expected: to draw more attention to the threat. They believe this separate warning will cause them to take the threat more seriously. BMs also think a storm surge warning will prompt them to pay greater attention to these threats in their weathercasts.

Positive Support for Storm Surge Warning

76%: EMs TC survey

87%: EMs ET-TC survey

95%: BMs survey

72%: Public telephone survey

94%: Public online survey

77%: NWS WCMs

While the support for a separate storm surge warning was extensive, there were some counterarguments. Some thought there were already too many warnings. In ET areas particularly, some stakeholders believed the extreme coastal flood warning is sufficient. There was some concern regarding the nature of warnings, in terms of whether the NWS can provide reliable storm forecasts in sufficient time for protective decisions to be made.

4.1.2 Storm Surge Inundation Map

All of these stakeholder groups gave high assessments to the storm surge inundation graphic (see Figure 4-1), with the map in multiple colors being the top choice among all groups. The groups differed on what they considered to be the clearest wording for expressing expected water levels. While the public tended to prefer "feet above ground level," BMs chose "height of water above the land." EMs also reacted most favorably to "height of water above the land," followed closely by "depth of water above

land." The question was not presented exactly the same way to each group, so a quantitative comparison is not possible. In each stakeholder group there were some who felt "feet about ground level" was confusing to the public and would require outreach to clarify. Further research on whether the amount of water should be expressed as "height" or "depth" might be useful.

An important finding is that providing depth of water ranges may make a difference in the public's evacuation decisions, in both positive and negative ways. Individuals appeared to be more likely to evacuate for areas where higher water levels were forecast. People appeared to be less likely to evacuate in areas where lower water levels were forecast—even though the expected surge and flooding could still be life-threatening.

4.2 Track and Wind Products

Improvement of TC track and wind forecast products is still in its early stages. The testing of various versions of the cone of uncertainty, the potential for damaging winds map, and the arrival of tropical force winds map completed as part of this project should be considered exploratory. The results reported here, however, can provide important insights that will require further development and testing.

In the surveys, the EMs, BMs, and WCMs all had an opportunity to compare the current tropical cyclone forecast cone (commonly known as the "cone of uncertainty") against two alternatives (see Figure 4-2). The public just assessed the alternatives. The EMs favored the current cone, but only 11 percent thought it was an excellent product. They provided both positive and negative feedback, with some commenting the public was accustomed to the graphic and that it provided useful information, and others stating that they believed the public misinterpreted the map and did not understand the uncertainty associated with

Figure 4-1. Responses to Storm Surge Inundation Map

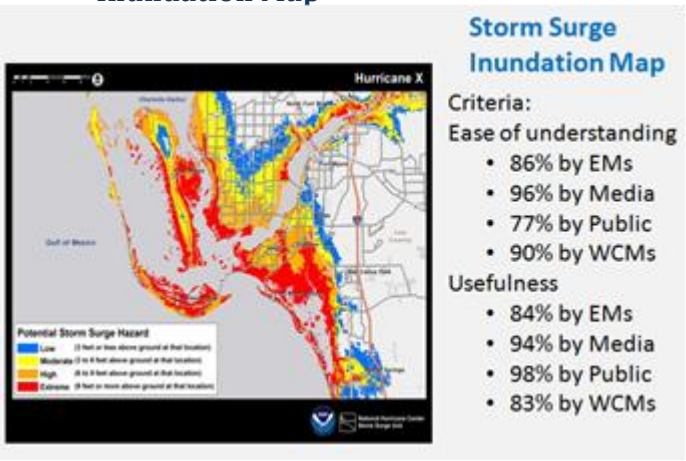
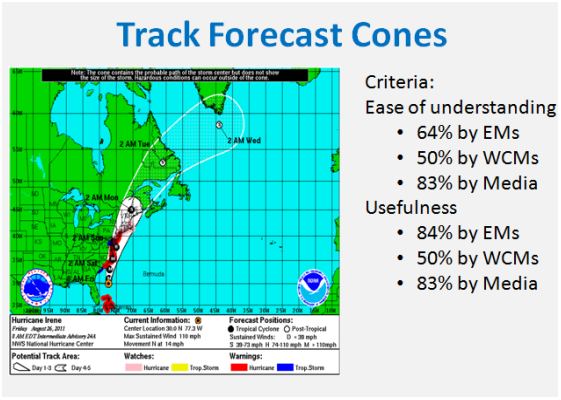
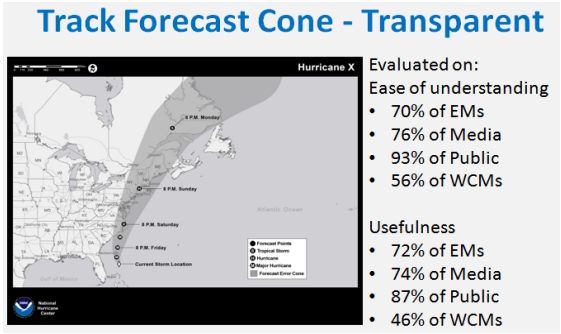
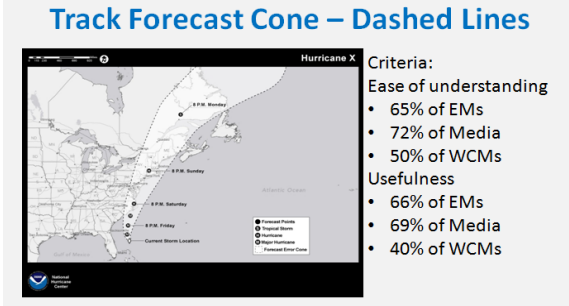


Figure 4-2. Responses to Track Forecast Cones







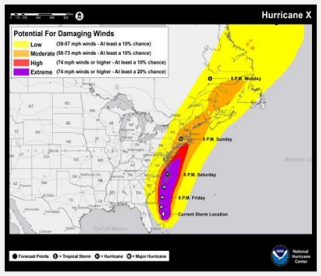
the cone.

BMs also gave the current cone higher positive ratings than its two alternatives. The consensus was that while the current cone could be improved, the public was used to it, even though people didn't always understand the data it represented. They also noted the public tends to think the total storm will fall within the confines of the track.

Taking the public perspective, the WCMs expressed mixed feelings about the current cone. None rated it as "excellent" for either ease of understanding or usefulness to the public; however, combining the scores of those who thought it was "very good" and "good" resulted in a 50 percent positive rating on both ease of understanding and usefulness. A problem with this exercise was that, as presented, the current cone map provided more information (such as being in color and having more labeling and text) than the alternatives. Therefore, this was not a valid test of cone preference, and the cone issue requires further study. The public gave the alternative graphics favorable positive ratings, but demonstrated confusion when asked to interpret them. Their interpretations indicated the same kind of confusion often found with the current forecast cone: some appeared to think the storm would stay within the boundaries of the track cone. While respondents underestimated their chances of getting damaging winds using both maps, they were more likely to understand that the winds could extend outside the cone when using the translucent gray cone with no lines.

Figure 4-3. Responses to Potential for Damaging Winds/Combined Cone

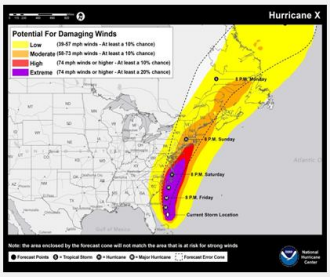
Potential for Damaging Winds



Criteria:
Ease of understanding
- 91% of EMs
- 83% of media
- 99% of public
- 74% of WCMs

Usefulness
- 94% of EMs
- 88% of media
- 99% of public
- 70% of WCMs

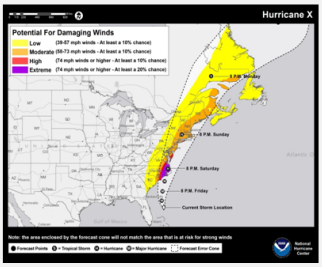
Potential for Damaging Winds Plus Tropical Cyclone Forecast Cone



Criteria:
Ease of understanding
- 75% of EMs
- 62% of Media
- 95% of Public
- 57% of WCMs

Usefulness
- 75% of EMs
- 64% of Media
- 55% of WCMs

Potential for Damaging Winds Plus Cone – Land Only



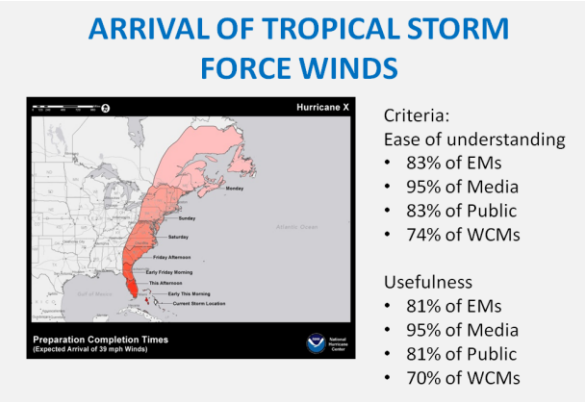
Criteria:
Ease of understanding
- 75% of EMs
- 64% of Media
- 55% of WCMs
- 89% of Public

Usefulness
- 75% of EMs
- 62% of Media
- 90% of Public
- 50% of WCMs

Survey respondents responded positively to the potential for damaging winds map (see Figure 4-3), and it was especially popular with the public. When combined with the cone of uncertainty, the public responders favored the map showing the wind field over both land and water and were able to interpret it correctly for a given region. EMs also gave high marks to the potential for damaging winds map. When combined with the cone, the EMs' comments focused on the lack of congruence between the wind and cone. Some of the EMs felt the map would be confusing when high wind probabilities are outside of the cone. Among the EMs, about two-thirds thought the map showing the wind field over both land and water best communicated the urgency at each location and captured the marine interests. BMs tended to feel that the combined wind and cone map had too much information and would be confusing to the public. The WCMs were less positive about the potential for damaging winds map and gave it less positive scores for both ease of understanding and usefulness. Slightly more than half of the WCMs favored the map showing the entire wind field over both land and water, but they gave both maps fewer favorable ratings. Many believed the overlay of track and wind probabilities would cause confusion.

The NWS developed the last prototype in response to a frequent EM and media requests for a product they could use to show decision makers and the public, estimates of when tropical storm force winds would reach their areas. All stakeholder groups, particularly EMs and BMs, provided positive support of this product (see Figure 4-4).

Figure 4-4. Responses to Arrival of Tropical Storm Force Winds



5 Recommendations

Throughout the exploratory and testing stages, stakeholder groups offered up many suggestions for enhancing NWS forecast products and communication. Based on the research, the following recommendations are offered to continue to enhance TC communication and better serve stakeholders' needs.

5.1 Product Suites

Respondents to these surveys were given the opportunity to provide comments about each product and about TC forecast communication in general. Many complained that the NWS provides too many products, including too many warnings. While they favored the addition of a storm surge warning, many felt other watches and warnings could be eliminated. While only indirectly related to the focus of this report, when asked open-ended questions about forecast products, there were numerous complaints about there being too much text and the proverbial complaint about the use of all capital case in advisories. Further research is needed that looks at the total NWS storm forecast suite of products to see how it might be streamlined and modernized.

5.2 Map Resolution

Many stakeholders commented on the need to have high-resolution graphics with as much detail as possible, given the uncertainties of a forecast. They pointed out that people can have difficulty reading maps and tend to think in terms of neighborhoods and parts of a city or town. Several people suggested that street mapping is key, and that people need to know their approximate location by identifying streets and highways. It needs to be emphasized, however, the science of storm surge forecasting does not presently allow the level of specificity that people ideally want to see.

5.3 Interactivity and Compatibility

Stakeholders would like to see the maps be scalable for smartphones and tablets. They are also interested in toggling, zooming, and clickable/mouse-over capabilities on maps to allow a user an opportunity to look closer at a map, view different sets of types of data displays, or view definitions or explanations. A number of people favored GIS formats with multiple layers that would facilitate the addition or subtraction of various TC and ET products within one map (such as the potential for damaging wind field and the forecast track cone). Many groups expressed strong feelings that NWS must move in this direction to stay relevant.

Some suggestions called for the use of simulation, such as the Storm Surge Simulator in use in Miami-Dade County where residents can type in their address and visualize the height of water on a person or a home. This is not for individual storms, but rather is based on a series of sampled storm surge modeling runs and is intended to show storm surge potential.

Many comments were made about NWS websites, including that they were not user friendly, were confusing, were too cluttered and had not kept up with commercial websites. The public survey revealed that they were also underutilized, particularly those of local WFOs. Projects need to be undertaken to improve NWS storm-related websites and to publicize them to the general public. In general, given the level and quality of communication technology the public uses today, it is important that the NWS improve its forecast presentations if it is to continue to effectively communicate forecasts and save lives.

5.4 Timing

There were numerous complaints from BMs and EMs about the timing of the release of NWS forecast products. For the BMs, these products tended to arrive too close to when they had to go on the air (typically at the top of the hour). EMs complained that they often arrived after they had to make important decisions, such as recommending evacuations. Some said they had to make decisions earlier than 48 hours (when the NWS watches were called) based on their timelines to have everything done before the arrival of tropical storm force winds. The release of these products is tied to when the data arrives at the NHC and, therefore, will be difficult to change (Demuth et al. 2012).

5.5 Integration, Education, and Training

A common thread throughout these surveys was the need for forecasts from the various NWS entities, such as the NHC and the local WFOs, to be coordinated into a seamless process. There were concerns about how any new NHC products would relate to current WFO forecast products and procedures. The WCMs and BMs urged NHC to consult with local offices throughout the design and implementation process. There were suggestions to review the entire TC forecast communication process to see how it might be streamlined and simplified to better highlight the important points, particularly where public safety is involved. The public needs to know and understand the forecast and does not care where it originates. This issue was illustrated recently in the case of Hurricane/Post-Tropical Storm Sandy. Changes in the physical characteristics of the storm lead to intra-agency issues that were not important to the public, but affected the nature of forecast communication.

5.6 Summary

The introduction of new and improved forecast products is only a first step. Various stakeholders, including the public, must become aware of these products, interpret them correctly to gauge the level of risk, and then make responsible protective decisions. This will require marketing and outreach campaigns targeted to the context and needs of various users of NWS storm forecast products.

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