JP1.7 USING UNCERTAINTY INFORMATION TO IMPROVE HURRICANE IMPACT COMMUNICATION

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1. INTRODUCTION

On the morning of 28 August 2005, forecasters at the National Weather Service (NWS) Weather Forecast Office (WFO) in Slidell, LA, which serves New Orleans, southeast Louisiana, and southern Mississippi, correctly recognized Katrina as a potentially catastrophic event. Critical phrases, such as "most of the area will be uninhabitable for weeks" and "water shortages will make human suffering incredible by modern standards" were seized on by local and national broadcast media, as well as emergency managers, to convey a level of danger that may have spurred many more residents to evacuate in an area that had experienced its share of near-misses since Camille in 1969 (Goldsmith, 2006).

However, the decision to use these clarion calls-to-action was made largely by assessing *deterministic* forecast guidance from the National Oceanic and Atmospheric Administration (NOAA)/NWS National Hurricane Center, including sustained wind speeds based on a combination of tropical cyclone models, minimum central pressure and wind speed diagnostics, aircraft reconnaissance, and human expertise; and storm surge guidance, based largely on initial conditions applied to the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model (Jelesnianski, et. al., 1992).

While the resulting devastation which followed Katrina justified the use of catastrophic impact wording, in hindsight, the lack of incorporating uncertainty information (or, for want of a positive term, forecast confidence), into the process is a bit troubling for an inexact science as meteorology. For every high certainty event such as Katrina, there are others for which greater uncertainty exists. In some cases, forecaster confidence is tempered by uncertainty, which, if not assessed correctly, can lead to a "missed" event. Conversely, a forecast not tempered by subtle, or hidden, uncertainty, can result in a false alarm. Improvements in dynamic tropical cyclone models, aided by increasing computing ability, provides the opportunity to better assess uncertainty in all facets of tropical meteorology.

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In 2005, probabilities were incorporated, experimentally, into NHC guidance for 18 ms^{-1} (34 kt), 26 ms^{-1}, and 33 ms^{-1} (64 kt) winds, and became official in 2006 (Knabb, et. al., 2008). When Katrina was bearing down on the Mississippi and Louisiana coasts, data were available for perusal, in both text and graphical (Figure 1) form. However, for the local WFO, there was not yet a method to include the probabilistic data into the process to determine impact. Even if there had been a method, there was very limited data available to calculate the statistics necessary to produce probabilities of 51 ms^{-1} (100 kt) wind, denoting the onset of Category 3 winds on the Saffir-Simpson scale.

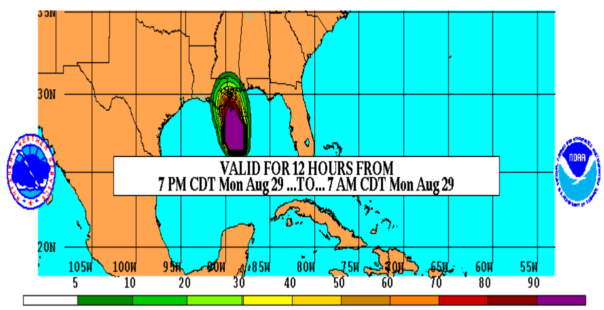

Figure 1. Experimental Tropical Cyclone Wind Probability, 64 kt wind, issued for the 12 h period ending at 7 AM CDT 29 August 2005.

2. INITIAL DEVELOPMENT, 2005 - 2007

A continuing emphasis on improving the communication of uncertainty in forecasting (National Research Council, 2006) has increased markedly in tropical cyclone hazards forecasting, given additional momentum from the effects of the 2004 and 2005 Atlantic basin activity. Probabilistic wind forecasts (up to 64 kt) from NHC became official in 2006, and experimental storm surge probabilities were unveiled in 2007. Local WFO's in Miami and Melbourne, FL, began working with this data stream in 2006, and by 2007, a number of coastal offices from the Carolinas through Florida were able to apply an algorithm which incorporated the probabilistic wind forecasts into expressions of uncertainty, in text form, for legacy NWS local zone and marine products (Santos, et. al, 2008).

As probabilistic wind data were gaining a foothold into forecast operations, customers were being introduced to a variety of tropical cyclone hazard graphics. By the 2007 season, a number of coastal offices were issuing color coded impact maps, for the primary tropical hazards of wind, storm surge flooding, inland flooding, and tornadoes (Fig. 2). However, questions arose about the meaning of these graphics: should forecasters predict impacts (Fig. 3), or would it be more prudent to assess *potential* for a range of values to occur that would *create* impact? In other words, “high wind impact” to the mobile home dweller may be “low wind impact” for the resident with concrete block construction and reinforced roofing. However, the *potential* for winds greater than 100 mph may be “high”, resulting in a greater *risk* for widespread damage.

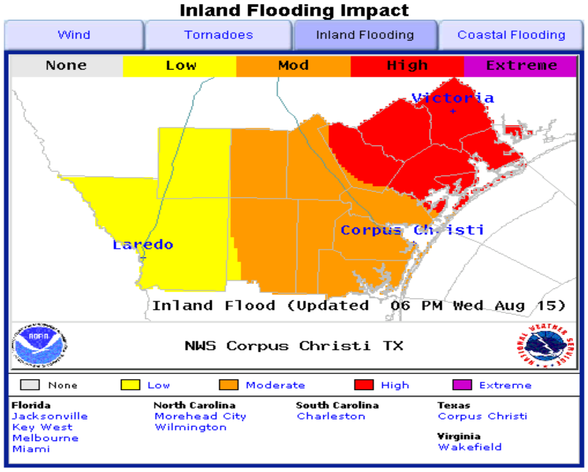

Figure 2. Inland flood impact graphic from WFO Corpus Christi, TX, during Tropical Storm Erin in 2007.

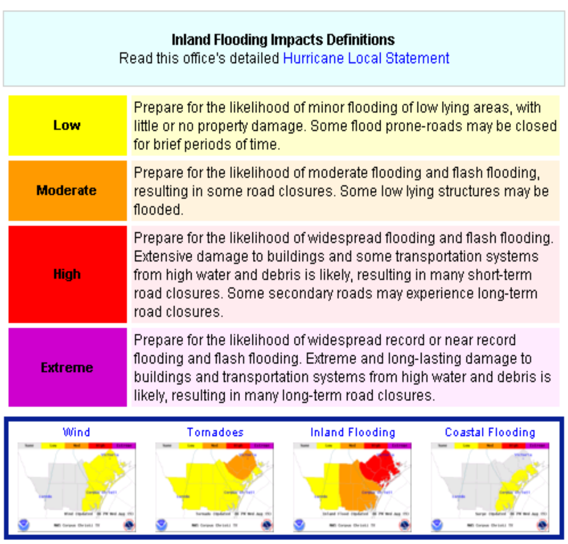

Figure 3. Inland flooding impact definitions, WFO Corpus Christi, TX.

Providing potential for impact levels through risk and threat assessment is an excellent method to use uncertainty information, and lend added scientific heft to the prediction. In 2006 and 2007, WFO’s in Miami and Melbourne used the probabilistic wind data from NHC to enhance their potential impact graphics (Santos, et. al., 2008). For tropical cyclones with the greatest potential for widespread damage, current wind speed probabilities contribute smaller portions of information compared with deterministic forecasts, since, as mentioned prior, there has been no development as of this writing for 100 kt speeds. However, there is hope that with additional data provided by the active 2004 and 2005 seasons, as well as two land-falling major hurricanes in 2007, probabilities for “major” tropical cyclone winds may be available in the not too distant future.

3. ONGOING DEVELOPMENT

The incorporation of uncertainty information for storm surge flooding and inland flooding is now underway, with probabilistic storm surge information scheduled for widespread experimental use for an increasing number of coastal WFO’s during the 2008 season. Tropical cyclone storm surge probabilities, based on a statistical combination of an ensemble of SLOSH model runs, produce data for cumulative probabilities and the probability of exceeding a specific surge value (National Weather Service, 2007). Coastal offices, including Melbourne and Miami, FL, and Charleston, SC, have developed algorithms that incorporate deterministic surge forecasts from the real-time SLOSH data, and probabilistic data from NWS’ Meteorological Development Laboratory (MDL), to produce more robust storm surge threat graphics (Fig. 4).

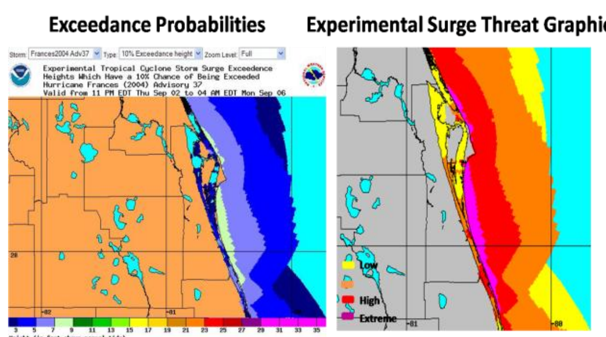

Figure 4. NWS MDL Exceedance Probabilities (left), and experimental storm surge threat graphic from WFO Melbourne, FL (images courtesy of Dave Sharp).

For inland flooding and tornadoes, incorporation of uncertainty information has begun, but was only in the early stages of development in comparison to wind, followed by storm surge. For inland flooding, a promising algorithm combines probabilistic forecasts of excessive rainfall potential issued by the NWS Hydro-meteorological Prediction Center, with deterministic forecasts of precipitation amount and flash flood guidance, resulting in a graphical depiction of threat from inland flooding (Fig. 5). For tornadoes, plans are in place to include probabilities generated by the Storm Prediction Center, then perhaps layering probabilities for the strongest tornado, to produce a tornado threat graphic.

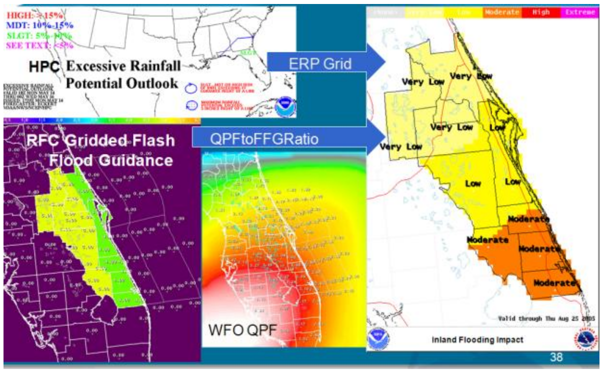

Figure 5. Example of process that would include deterministic (WFO QPF), probabilistic (Excessive Rainfall Potential, or ERP), and guidance (Flash Flood exceedance values). Images courtesy of Dave Sharp.

4. INNOVATIONS AND THE FUTURE

The development of more scientifically-sound tropical cyclone hazard forecasts through the blending of deterministic and probabilistic data offers great promise during a time of rapid information technological change. From the homeowner needing to make an evacuation decision on a deterministic forecast of storm surge, to the emergency manager tasked with assessing forecast uncertainty to determine where, when, and how long to deploy first responders prior to a storm surge event, sufficient, sound data will be available. Newer and cheaper gadgets, such as lightning fast mobile communication devices with Global Positioning System (GPS) receivers and high resolution Geographical Information System (GIS) capability, will allow end users to consider a spectrum of potential impacts wherever they may be located. Digital television may become an interactive receiver during natural or man-made hazards that provides specific impact information to the location of the box.

The following scenario may well be happening, soon, in any prone coastal location: Prior to the onset of tropical cyclone season, a resident may wish to evaluate a number of storm surge scenarios specific to his house. The resident may be asked by a relative to evaluate their home, which sits at a lower elevation. Probabilistic information could be used by the resident to determine the risk to his home from any number of values by combining the elevation with the chances that a specific surge value could occur, based on a number of factors, from historical cyclone data to the potential for a location-specific steering pattern to create a worst-case scenario.

When a storm is actually forecast to impact his residence, he can view data in a variety of ways, including deterministic surge values, or the potential impact from the particular storm. A case where a flooding surge is forecast for his location *and* potential impact is extreme could be the confidence he needs to evacuate both him and his relative.

Forecast confidence, often built into a deterministic forecast through subjective means, would become more objective by including improved uncertainty data. In practice, one might be able to view a storm surge potential impact in reference to the forecast surge, which *itself* is generated by combining deterministic and probabilistic data! Fig. 6 shows what such a forecast might look like for a neighborhood.

Figure 6. Example of GIS-based storm surge inundation based on specific values and potential impact. Here, magenta denotes extreme potential and red denotes high potential. (Satellite map courtesy of Google Earth).

5. SUMMARY AND CONCLUSIONS

The use of uncertainty information in assessing the potential for tropical cyclone impacts will improve the value of the forecasts by providing an objective level of confidence that, until recently, had eluded the weather enterprise. Impact statements used to rouse a large community prior to Hurricane Katrina could become viewed as hype if the situation does not materialize as stated. Conversely, impact statements falling short of the eventual outcome may draw blame from a surprised community that is devastated. It is interesting to note that the impact statements used prior to Katrina were largely based on the determination that winds in excess of 69 ms^{-1} (135 kt) would strike the Louisiana and Mississippi coast and nearby communities, when in reality, highest winds in hardest-hit areas of Mississippi were substantially lower, between 54 and 60 ms^{-1} (105 and 117 kt), and even lower in populated southeastern Louisiana, between 51 and 55 ms^{-1} (99 and 107 kt) (Knabb, et. al., 2005).

The addition of uncertainty information to assessment of potential impacts should ensure more consistent outcomes, in the hope that the increased confidence in the forecast translates to increased trust in the forecast by end users. If increased trust elicits life-saving actions from those in harm's way, society benefits.

6. ACKNOWLEDGEMENTS

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