Tropical Cyclone Wind Speed Probabilities Products

Updated July 2014

1. Overview

The tropical cyclone surface wind speed probabilities text and graphical products issued by the National Hurricane Center (NHC) have been operational since the beginning of the 2006 hurricane season. The underlying techniques were developed by researchers at NOAA and Colorado State University, while the products themselves were developed by the Technology and Science Branch (TSB) at NHC.

The tropical cyclone surface wind speed probabilities products provide probabilities of sustained (1-minute average) surface (10-meter elevation) wind speeds of at least 34 kt (39 mph, tropical storm force), 50 kt (58 mph), and 64 kt (74 mph, hurricane force) at individual locations in the Atlantic and eastern North Pacific basins. The location-specific probabilities are based on errors during recent years in the official track and intensity forecasts issued by the NHC. Variability in tropical cyclone size (wind radii) is also incorporated into the probabilities.

One separate wind speed probability text product is issued with each advisory package for every active tropical cyclone in the Atlantic and eastern North Pacific basins. The text product provides location-specific probabilities for all three wind speed thresholds (34, 50, and 64 kt). The text products are available at about the same time as the other advisory package text products. Also, NHC issues a set of storm-centered graphical wind speed probability products with each advisory package for each active tropical cyclone in the Atlantic and eastern North Pacific basins. The graphical wind speed probabilities are immediately available as a *preliminary graphic* when the tropical cyclone advisory is issued. These preliminary graphics only contain data for one tropical cyclone. Approximately 15 to 30 minutes after advisory time, a set of basin-wide wind speed probability graphics become available which supercede the preliminary graphics. Although the probability data for each tropical cyclone remains the same, the final graphics illustrate the wind speed probabilities for all tropical cyclones in the area of interest. The delay that occurs between the preliminary and final probability graphics results from the need to wait a few minutes after the advisory release deadline (e.g., 11:00 PM EDT). This pause ensures that all tropical cyclone advisories have been issued.

2. Description of the wind speed probabilities text product

The text wind speed probability product (PWS) contains wind speed probabilities for selected coastal and inland cities, as well as selected island and ocean locations for

each tropical cyclone forecast issued by the NHC. Each wind speed probability text product provides probabilities (in percent) for wind speeds of at least 34 kt (39 mph, tropical storm force), 50 kt (58 mph), or 64 kt (74 mph, hurricane force) at each listed location. Two types of probability values are provided in the text product: cumulative probabilities of occurrence, and onset probabilities.

Cumulative probabilities are provided in the text product for the following time periods: 0-12 hours, 0-24 hours, 0-36 hours, 0-48 hours, 0-72 hours, 0-96 hours, and 0-120 hours (0-5 days). These cumulative probabilities indicate the overall chances that the stated wind speed will occur at each location during the period between hour 0 (the beginning of the forecast) and each listed forecast hour.

Onset probabilities are provided for each of the following time intervals: 0-12 hours, 12-24 hours, 24-36 hours, 36-48 hours, 48-72 hours, 72-96 hours, and 96-120 hours. These onset probabilities indicate the chances that the stated wind speed will start during each individual period at each location. Cumulative probabilities through each forecast time period represent the sum of the onset probabilities up to that time.

In other words, cumulative probabilities tell decision-makers the chances that the event will happen at all. The onset probabilities tell decision-makers when the event is most likely to start.

View a complete example of the tropical cyclone wind speed probability text product.

Probabilities for a particular location and speed are provided only when the 120-hour (5-day) cumulative probability of sustained tropical storm and 50-kt winds is at least 2.5% (rounded to 3%). Hurricane force probabilities are provided when the 120-hour (5-day) cumulative probability is at least 1%. Locations are listed in geographic order, and data for all wind speeds (with high enough probabilities) at one location are grouped together.

It is important for users to realize that probabilities that may seem relatively small may still be quite significant. The probabilities may indicate there is a chance that a damaging or even an extreme event may occur at your location. This may warrant making preparations to protect lives and property. Users are urged to consider the potentially immense cost (in terms of lives, property, etc.) of not preparing for an extreme event, even if the chances at an individual point are only perhaps 1 in 20 (5%) or 1 in 10 (10%) that the event will occur.

3. Description of the wind speed probabilities graphical products

Each wind speed probabilities graphic provides probabilities (in percent) that wind speeds of at least 34 kt (39 mph, tropical storm force), 50 kt (58 mph), or 64 kt (74 mph, hurricane force) will occur during cumulative time periods at each specific point on the

map. The cumulative periods extend into the 5-day forecast period at 12-hour intervals (that is, 0-12 h, 0-24 h, 0-36 h, …, 0-120 h). An individual graphic is produced for each active tropical cyclone for each cumulative time period and for each wind speed threshold. The capability to animate through the periods is also provided. These cumulative probabilities indicate the overall chances that the indicated wind speed will occur at any specific location on the map during the period between hour 0 and the forecast hour.

In other words, these cumulative probabilities tell decision-makers the chances that the event will happen at any point on the map within the time period stated on each graphic.

The example graphic below (an earlier experimental version) shows the hurricane force (64 kt, 74 mph) wind speed probabilities for Hurricane Charley (2004), based on advisory 14 issued at 5:00 PM Thursday August 12, the day before landfall in southwestern Florida. When this advisory was issued, the hurricane warning was extended northward along the west coast of Florida from Bonita Beach northward to Bayport (to include Fort Myers, Port Charlotte, Sarasota, and Tampa). The cumulative 0-120 hour values are shown here to indicate the overall chances of experiencing hurricane-force winds at any point on the map. While the exact official track forecast for this advisory goes over Tampa, it is clear from this graphic that the chances of experiencing hurricane-force winds from this event are nearly the same (about 30%) over a large portion of the coastline and over many inland areas, including the eventual landfall location at Port Charlotte, FL. This graphic is an excellent example of a situation in which the wind speed probabilities can help users to understand forecast uncertainties, such that they are not surprised by any relatively small changes in the track. This graphic also shows why it is crucial to make proper preparations when a watch or warning is issued for your area, even if the exact track forecast does not go over your area.

An example of a suite of 5-day wind speed probabilities graphics for an advisory package is provided below with explanations that follow. Examples are provided for 34 kt (39 mph, tropical storm force) or greater, 50 kt (58 mph) or greater, and 64 kt (74 mph, hurricane force) or greater.

The example set of probabilities graphics above are based on Hurricane Katrina (2005) advisory number 14, which was issued 18 hours prior to a hurricane watch being issued for southeastern Louisiana and about two and a half days prior to the initial landfall of the center of the hurricane in southeastern Louisiana.

The probabilities show that the hurricane is not a point and has the potential to affect a large area. The probabilities result from uncertainty in the forecast of track, intensity, and size. The Katrina example involves a large and intense hurricane. However, not all storms will produce probabilities this large over as wide an area.

The hurricane-force (64 kt, 74 mph) probabilities are smaller than for tropical storm force (34 kt, 39 mph), primarily because hurricane-force winds do not extend as far out from the center of the hurricane. Note in this example that the probabilities of hurricane-force winds through 5 days (120 hours) are essentially the same for southeastern Louisiana and the western Florida panhandle. Therefore, even though the exact track forecast might go over a particular location on the coastline, there are many other locations that have the same chance of experiencing hurricane conditions during the event. It is important to understand that the probabilities are for specific points on the map. The chances that hurricane-force winds will occur *somewhere* along the Gulf coast in this Katrina case are much larger than the chances at any one point. In other words, in advance of the landfall of Katrina, it was nearly certain that portions of the northern Gulf coast would be impacted by hurricane-force winds, but it was not certainly exactly who would experience those winds. As it turned out, portions of southeastern Louisiana did experience sustained hurricane-force winds, while the western Florida panhandle did not.

In the above example, the hurricane-force wind speed probabilities are relatively small (less than 25%) in magnitude at points along the northern Gulf of Mexico coastline through the 5-day forecast period. ***It is important for users to realize that probabilities that may seem relatively small may still be quite significant.*** The probabilities may indicate there is a chance that a damaging or even an extreme event may occur at your location. As a storm gets closer to land, relatively small probabilities may warrant making preparations to protect lives and property. Users are urged to consider the potentially immense cost (in terms of lives, property, etc.) of not preparing for an extreme event, even if the chances at an individual point are only perhaps 1 in 20 (5%) or 1 in 10 (10%) that the event will occur.

While separate graphics are centered on each individual tropical cyclone, probabilities resulting from more than one active tropical cyclone may be seen on each graphic (example below). The tropical cyclone on which the graphic is centered is labeled with a diamond, which represents the location of the center of the tropical cyclone at the beginning of the forecast period.

4. Description of the NDFD wind speed probabilities products

Cumulative – These values tell you the overall probability the event will occur sometime during the specified cumulative forecast period (0-6 hours, 0-12, 0-18, etc.) at each specific point. These values are provided in both the text and graphical formats. In the text product, the numbers are in parentheses. The graphical products depict only cumulative values. The text product is transmitted to users via normal NWS dissemination methods. The graphic is available on the internet from the National Hurricane Center and the Central Pacific Hurricane Center.

Incremental – These values tell you the probability the event will occur sometime during the specified forecast period (0-6 hours, 6-12, 12-18, etc.) at each specific point. These

values are incremental since they can increase in value by accounting for the possibility the event might start in an earlier period and still be occurring in the specified period. These values are not currently provided in the official operational text or graphical NHC products.

5. Potential advantages as compared to previous products

The NHC has been issuing other products intended to convey the uncertainties in the track forecast. However, those products do not account for the uncertainties that also exist in the forecast of the cyclone's intensity and size.

The discontinued strike probabilities text product was a statement about the "close" approach of the center of a tropical cyclone. However, the wind speed probabilities products are about the ***weather.*** That is, the wind speed probabilities provide the chances of wind speeds equal to or exceeding familiar thresholds (for example, tropical storm force and hurricane force) at individual locations. Therefore, these probabilities likely have more direct meaning and impact to users. Also, while the previously available strike probabilities only provided forecast information out to three days for just the Atlantic basin, the wind speed probabilities provide information out to five days for both the Atlantic and Eastern Pacific basins.

NHC also continues to provide a watch/warning graphic that also displays the forecast track and a "cone of uncertainty". The cone represents the probably track of the center of a tropical cyclone, and is formed by enclosing the area swept out by a set of circles along the forecast track. The size of each circle is set so that two-thirds of historical official forecast errors over a 5-year sample fall within the circle. It is important to remember that the effects of a tropical cyclone can be experienced well away from the center of the cyclone and well outside of the cone of uncertainty, since the actual path of the center does not always stay within the cone, and since tropical cyclones vary in intensity and size. The wind speed probabilities provide more direct information about what wind conditions could be experienced at specific locations both inside and outside of the cone.

6. Method for computing the wind speed probabilities

The calculation of the wind speed probabilities is accomplished by creating a large set of alternative but plausible tracks and intensities roughly centered on the current official forecast. The alternative tracks are created using a Monte Carlo method that takes into account the uncertainty of the track forecasts on a case-by-case basis (DeMaria et.al. 2013). This is accomplished using the spread of the dynamical model guidance. When the spread of the guidance is large (small), the NHC forecasts typically exhibit larger (smaller) forecast errors than average. In cases in which there is a large (small) spread

in the model guidance, the Monte Carlo method samples an error distribution containing larger (smaller) errors. When the model spread is small (large), the wind speed probabilities close to the official forecast track tend to increase (decrease), but decrease (increase) away from the track. The alternate intensity forecasts consider whether each alternate track is over land or water, and the alternate intensity forecasts are adjusted accordingly. The size of the tropical cyclone (set of wind radii) for each alternate track is determined by a climatology and persistence (CLIPER) model and its error components. This CLIPER model takes into account the size of the cyclone at that start of the forecast period as well as typical changes in size that occur as a cyclone experiences changes in strength, forward motion, and other factors. An adjustment is made, for purposes of calculating the probabilities, so that the wind radii represent the average, rather than the maximum, extent of winds in each quadrant. This process results in probabilities of actually experiencing certain wind speeds, not probabilities of falling within the traditional forecast wind radii that indicate the maximum extent of winds from the center. Swaths of particular wind speeds are then computed for each alternate forecast. Probabilities are computed on a 0.5x0.5 degree latitude-longitude grid by counting the fraction of alternate forecasts in which each point falls within a given wind swath (34, 50, or 64 kt). This output is then processed and expressed in text or graphical format via the products being produced by the NHC.

7. References

DeMaria, Mark, John A. Knaff, Richard Knabb, Chris Lauer, Charles R. Sampson, Robert T. DeMaria, 2009: A New Method for Estimating Tropical Cyclone Wind Speed Probabilities. *Wea. Forecasting*, **24**, 1573–1591.

DeMaria, Mark, and Coauthors, 2013: Improvements to the Operational Tropical Cyclone Wind Speed Probability Model. *Wea. Forecasting*, **28**, 586–602.

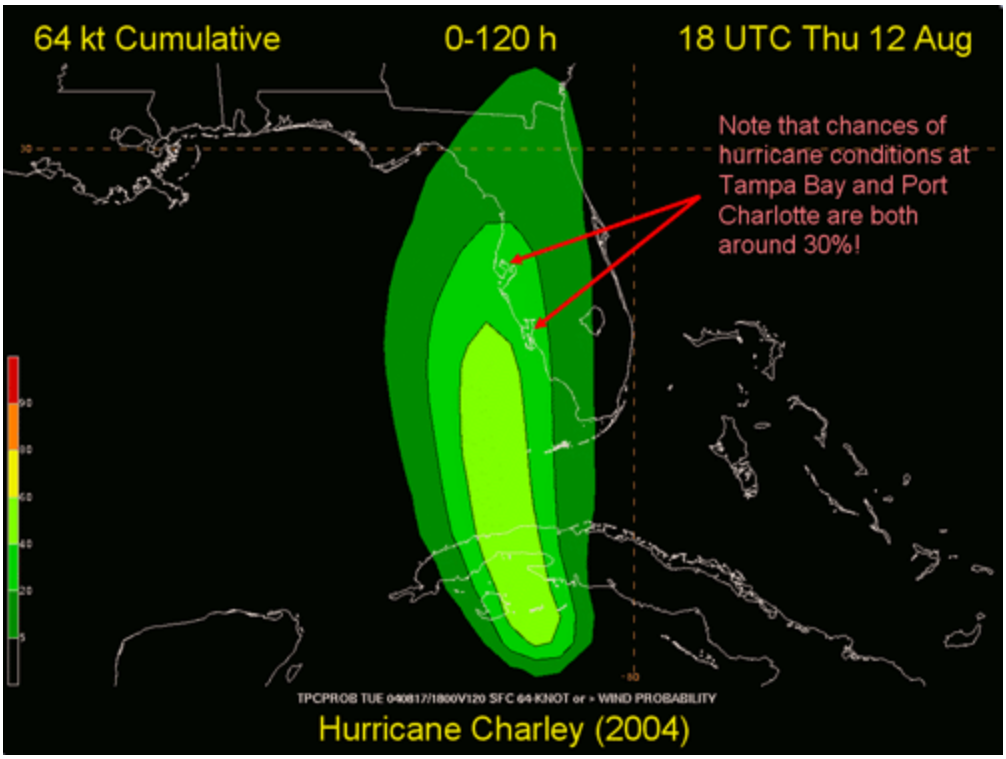

Fig. 1 Plot of probabilities (in percent) of experiencing wind speeds of at least 64 knots (74 mph, hurricane force) during the 120 hours (5 days) starting at 1800 UTC (2:00 PM EDT) on Thursday, August 12, 2004.

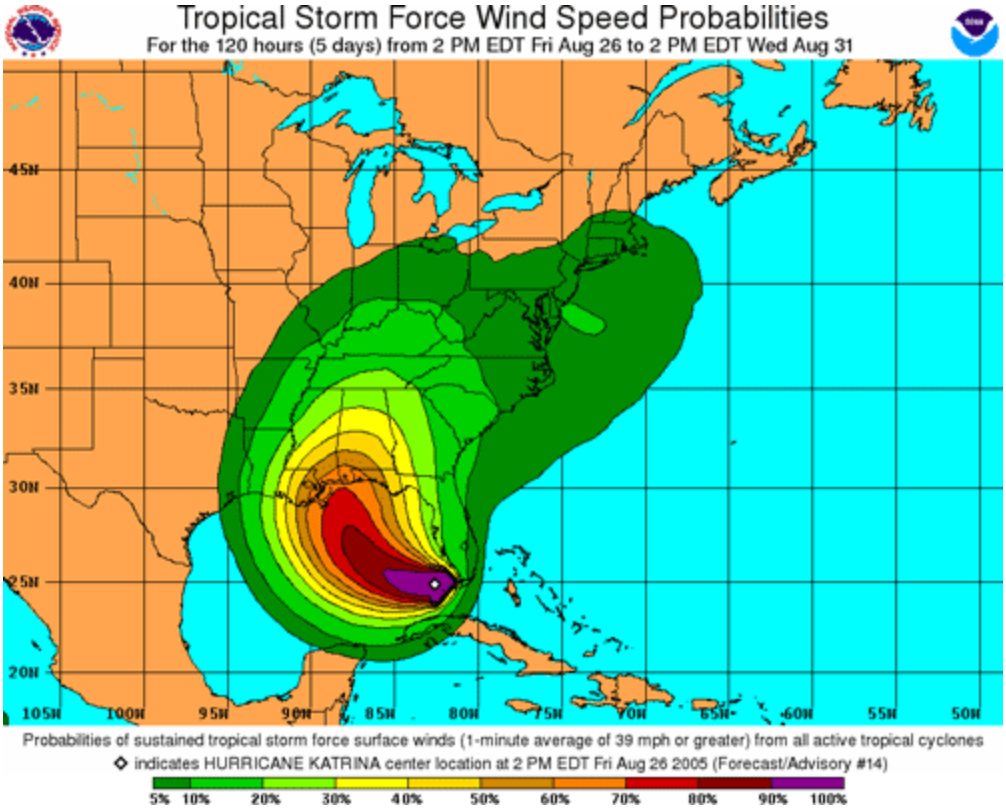

Fig. 2 Wind speed probabilities graphics for Hurricane Katrina (2005) advisory #14. Graphics show cumulative probabilities of wind speeds of at least 34 kt (39 mph, tropical storm force) occurring at any point on the map during the 5-day period beginning 2:00 PM EDT August 26.

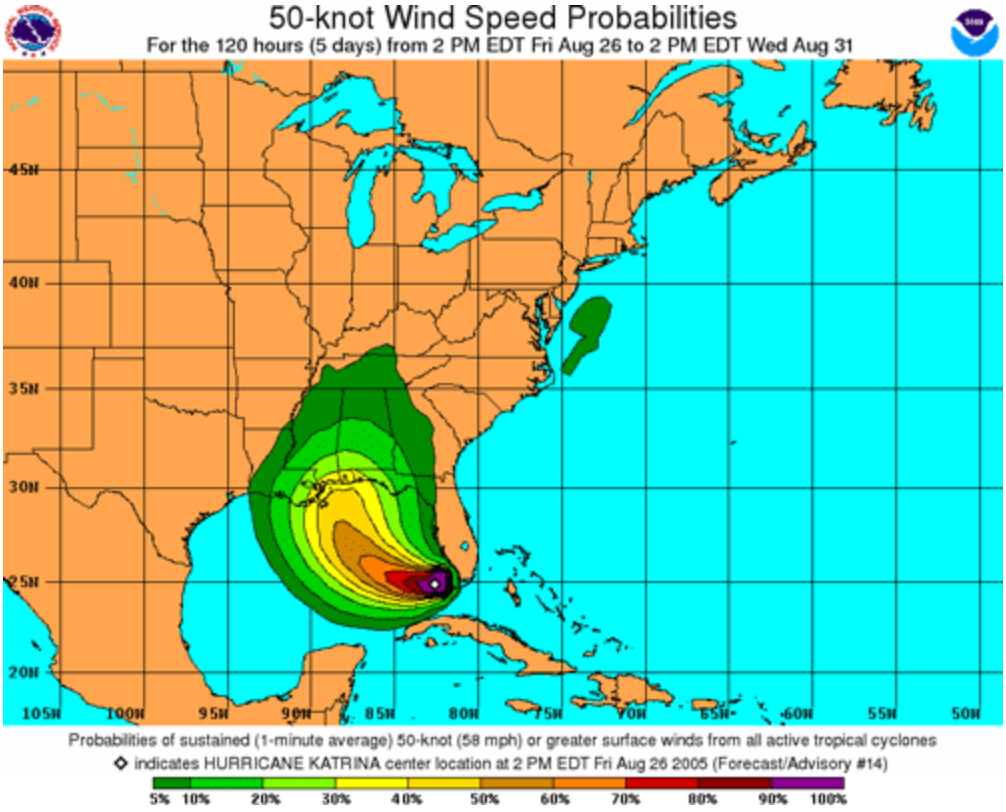

Fig. 3 Wind speed probabilities graphics for Hurricane Katrina (2005) advisory #14. Graphics show cumulative probabilities of wind speeds of at least 50 kt (58 mph) occurring at any point on the map during the 5-day period beginning 2:00 PM EDT August 26.

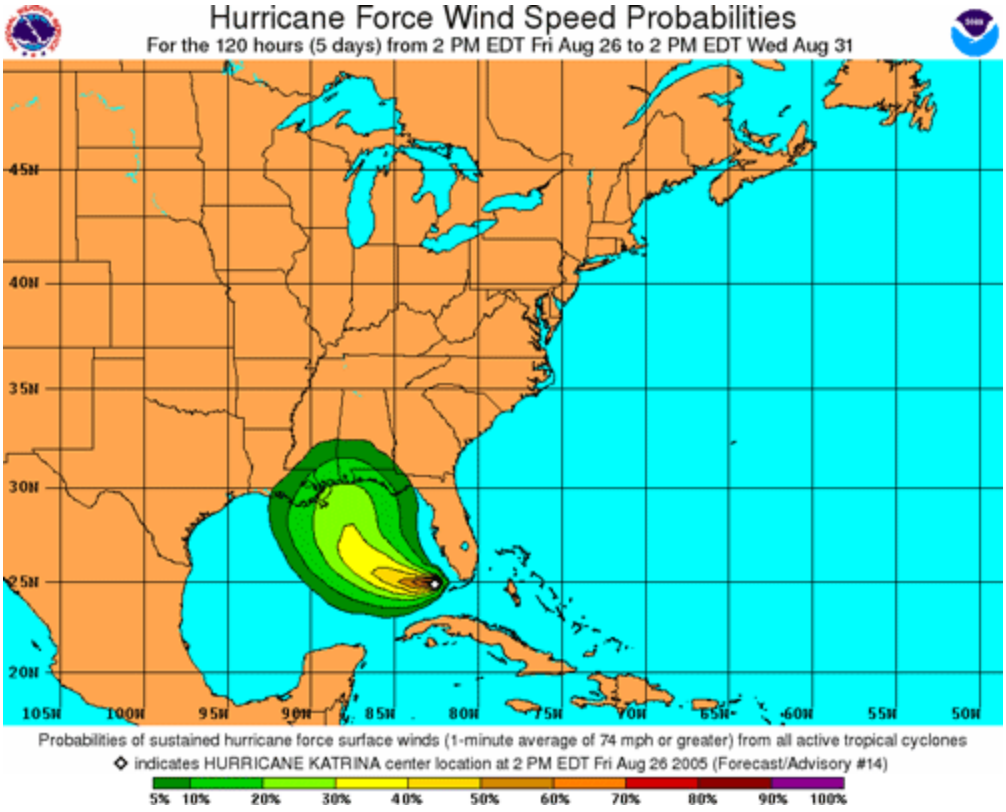

Fig. 4 Wind speed probabilities graphics for Hurricane Katrina (2005) advisory #14. Graphics show cumulative probabilities of wind speeds of at least 64 kt (74 mph, hurricane force) occurring at any point on the map during the 5-day period beginning 2:00 PM EDT August 26.

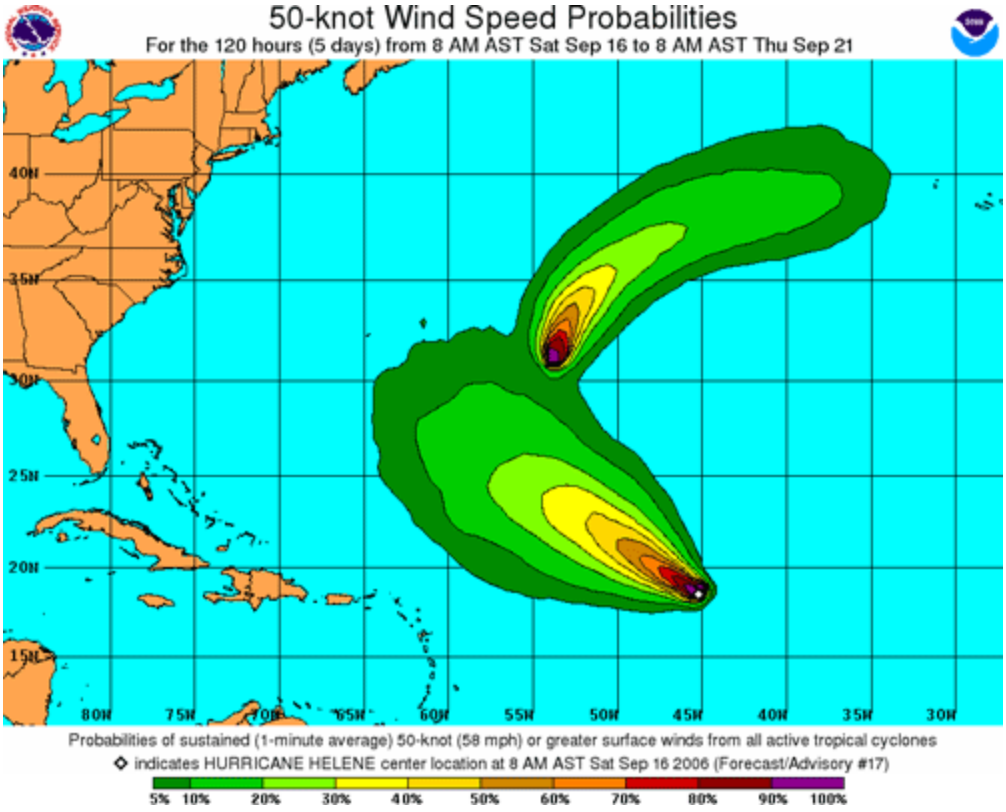

Fig. 5 Wind speed probabilities graphics for Hurricane Helene (2006) advisory #17. Graphics show probabilities of wind speeds of at least 50 kt (58 mph) occurring at any point on the map during the 5-day period beginning 8 AM AST September 16. Note that Hurricane Gordon, located to the north of Hurricane Helene, is generating additional wind speed probabilities on this graphic.