Developing a Dataset of Wind Gust Factors to Improve Forecasts of Wind Gusts in Tropical Cyclones

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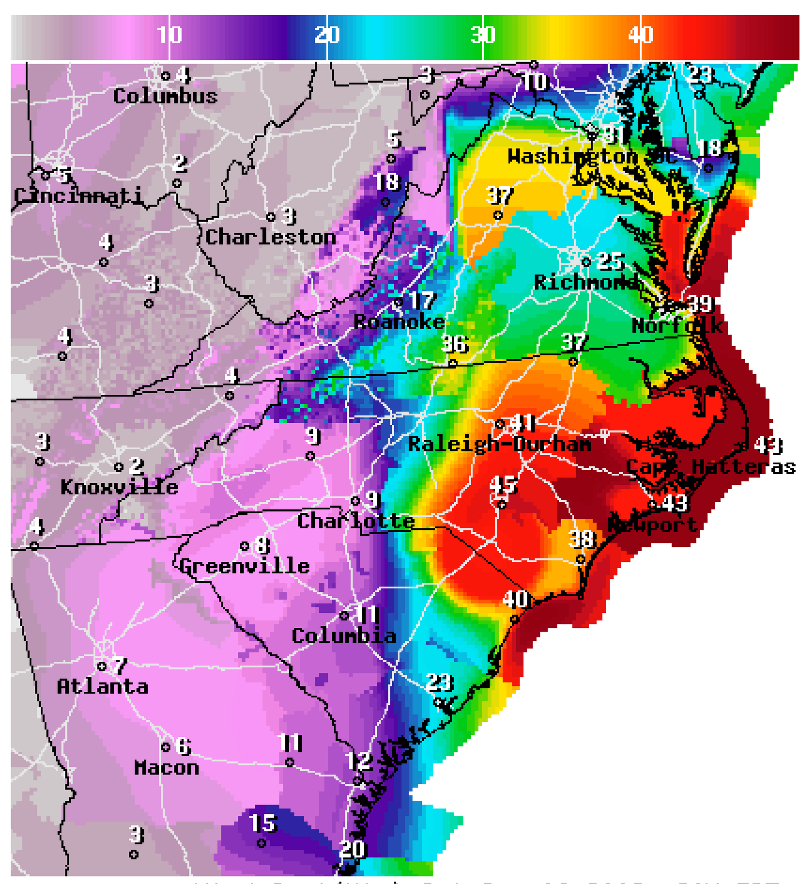
Introduction and Problem

Tropical cyclones (TCs) are a dangerous and high impact weather phenomena which result in numerous forecast and warning challenges for National Weather Service (NWS) forecasters. A survey of 9 NWS Weather Forecast Offices (WFOs) in the Southeast and Mid-Atlantic revealed that the prediction of TC winds and precipitation was a top priority for collaborative research. This project was motivated by this need and was conducted to support a NWS-NC State University Collaborative Science, Technology, and Applied Research (CSTAR) project.

Predicting TC wind gusts are problematic for several reasons:

- There are gaps in our understanding of the spatial and temporal distribution of wind gusts associated with landfalling TCs.
- Wind gust forecasts are typically derived from the sustained wind forecast which can be problematic itself.
- Results from previous studies have not been routinely used by NWS forecasters.
- A survey of forecasters from the CSTAR WFOs revealed that the methods used to develop wind gusts grids during TC events sometimes lack consistency and scientific discipline.
- Most forecasters surveyed suggested using a percentage above the sustained wind speeds to use as a gust factor (GF). These values ranged wildly with large discrepancies even noted within several of the same WFOs.
- Wind gust variations across spatial and temporal scales is difficult using the current methodology.
- The end result is often an inconsistent and poorly collaborated forecast with limited foundation in science that may be inaccurate and is difficult for users to interpret as in this example from Tropical Storm Hanna.



NDFD 48 hour wind gust forecast valid 8AM EDT on 06 September 2008 during Tropical Storm Hanna.

Methods

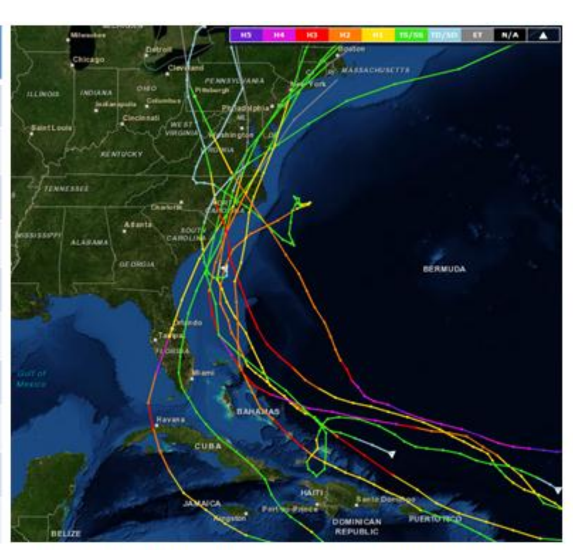
We examined the sustained winds, wind gusts, wave heights, and gust factors for ten tropical cyclones that impacted the Carolinas and Virginia. Only hourly observations with wind speeds of 10 knots of more were included. Data analysis was conducted in two groups: land observations and marine observations. The hourly wind gust factor for each location was computed as the ratio of the wind gust to the sustained wind speed (Vickery and Skerlj 2005).

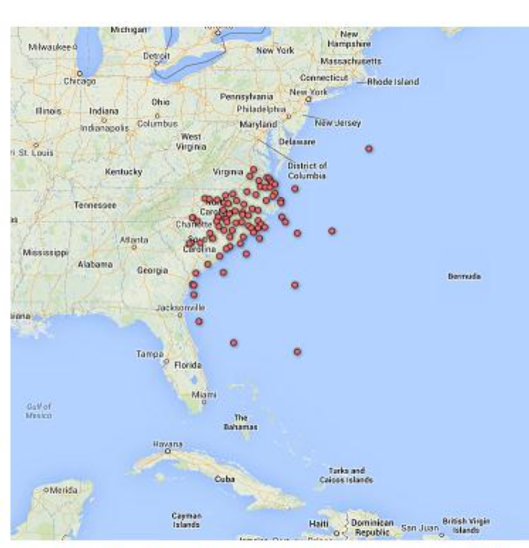
For the land locations, observations from between 21 and 45 ASOS or AWOS METAR locations impacted by the various storms were included. The locations varied for each storm and were selected to capture the variations in the wind field. A total of 14,938 gust factors were computed.

For marine locations, only observations from buoys that have an anemometer height of 5 meters were included to remove any of the variability introduced by different observational heights. Only observations in which the wave heights observed were less than 5 meters were included. This was done to remove any uncertainty in the quality of the wind observations in large waves as high sea states associated with high surface winds can shelter the buoy and reduce the buoy's wind speed observation (Skey et al. 1995). A total of 1,720 marine gust factors were calculated.

Storm Name	Date	Landfall	Winds at Landfall
Irene	27-Aug-11	NC	85 MPH
Hanna	6-Sep-08	NC/SC	70 MPH
Ernesto	30-Aug-06	South FL	70 MPH
Gaston	29-Aug-04	SC	75 MPH
Charley	13-Aug-04	FL	75 MPH
Isabel	18-Sep-03	NC	105 MPH
Floyd	16-Sep-99	NC	105 MPH
Dennis	4-Sep-99	NC	105 MPH
Fran	5-Sep-96	NC	115 MPH
Bertha	12-Jul-96	NC	105 MPH

Table of the tropical cyclones included

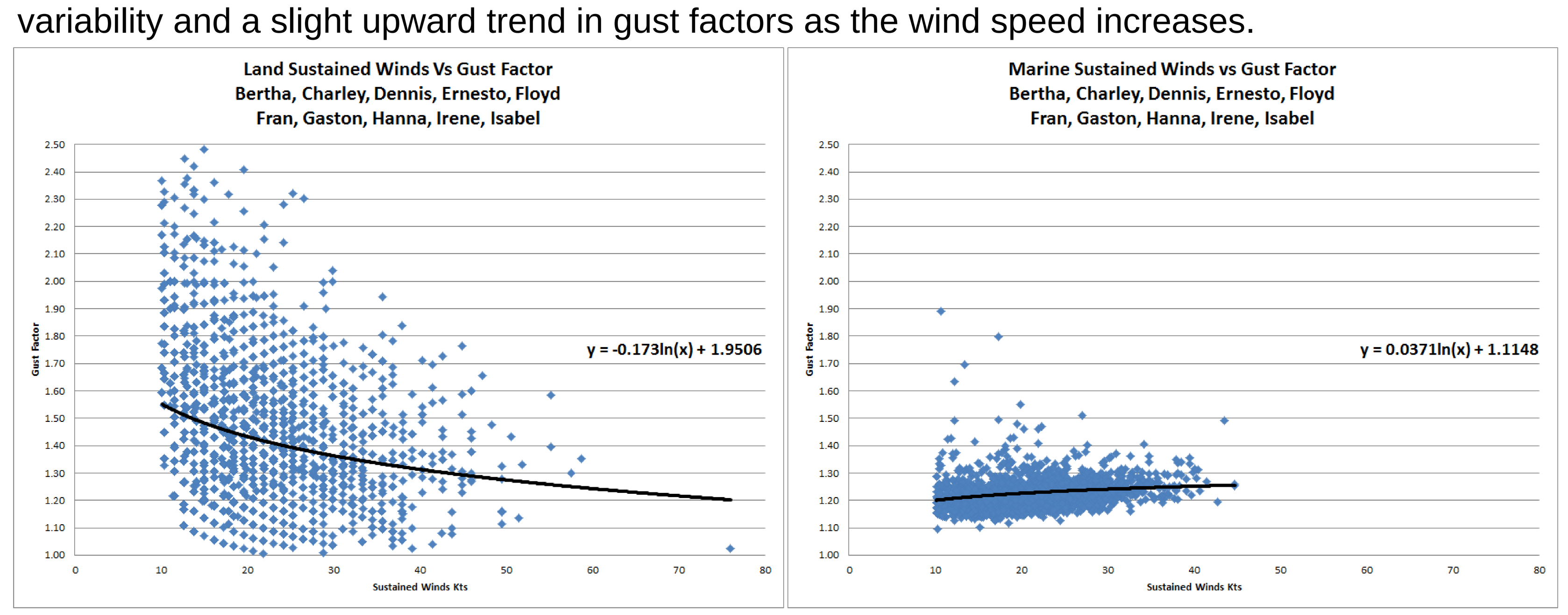

Tracks of the tropical cyclones examined


Locations of the METARs and buoys examined

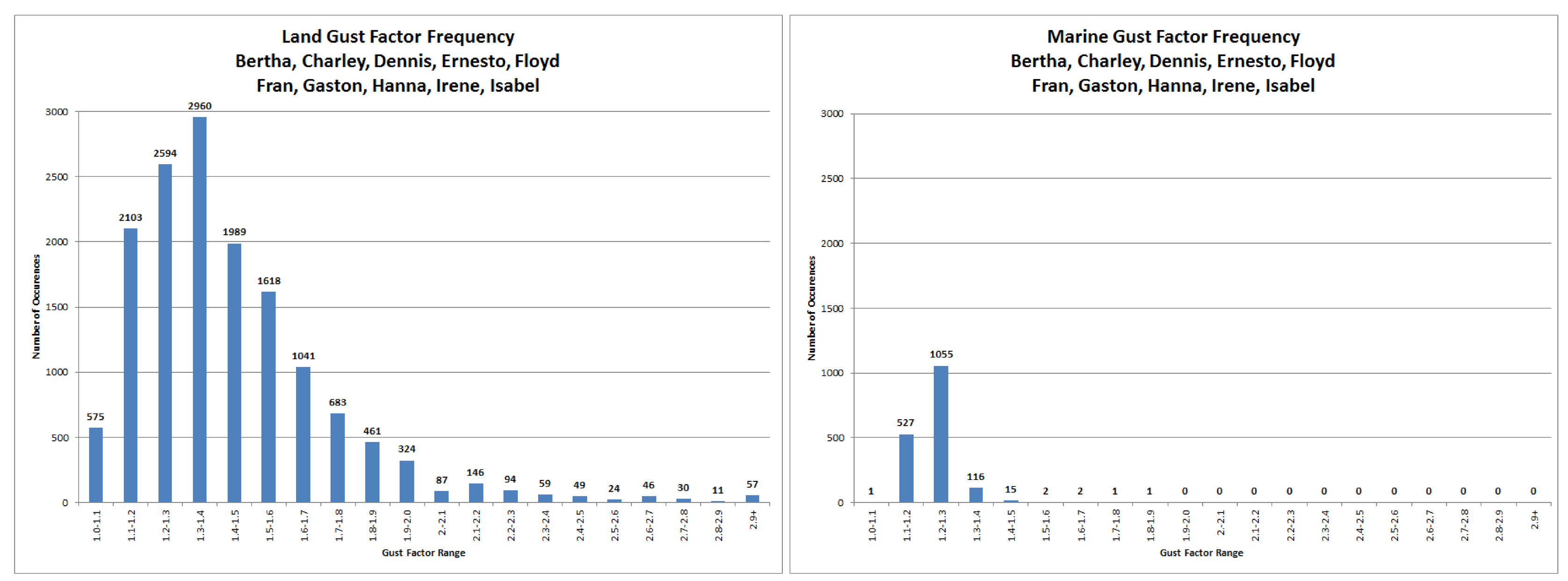
Results

	Number of Gust Factors	Average Gust Factor	Standard Deviation	Max Sustained Wind	Max Wind Gust
Land	14,938	1.47	0.30	76 kts	88 kts
Marine	1,720	1.23	0.06	45 kts	65 kts

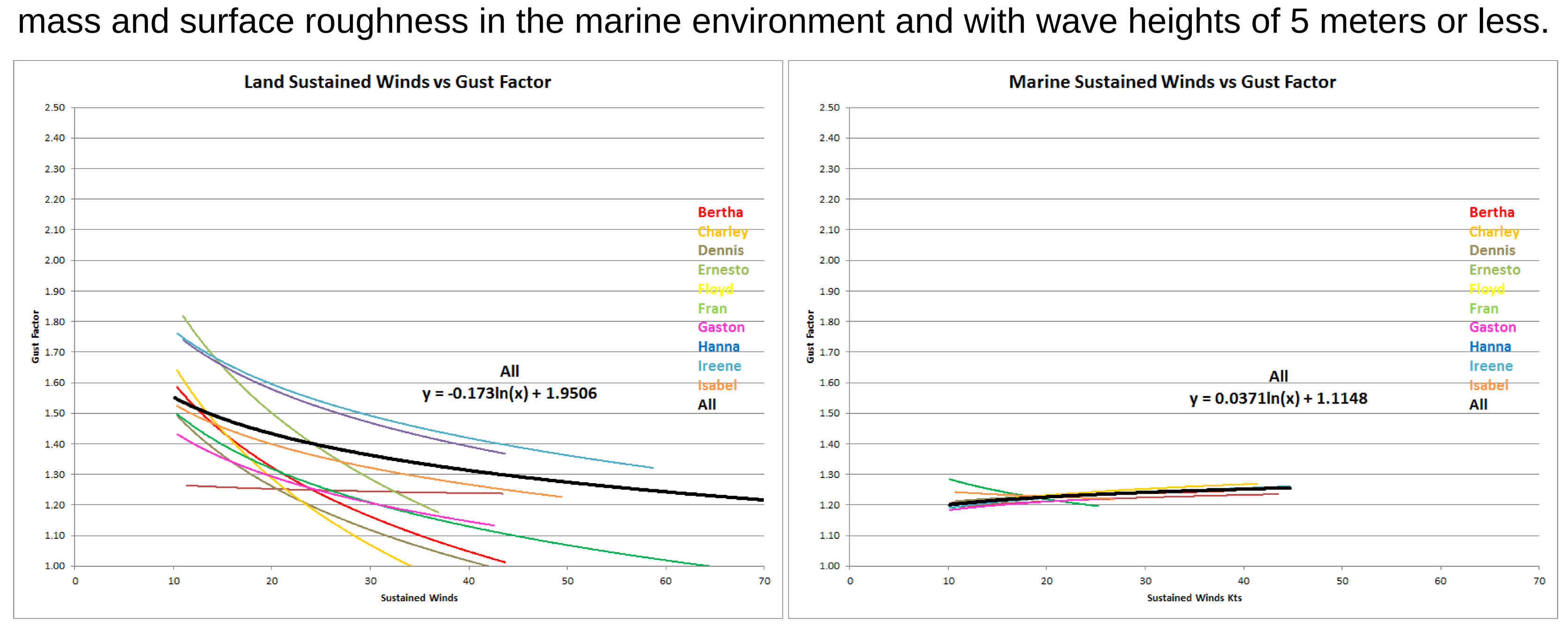
The charts below are scatter plots of the sustained winds versus gust factors for all 10 storms for land locations (left) and marine locations (right) along with a best fit regression curve. Note the greater variation in gust factors for the land locations which show an inverse relationship between the wind speed and gust factor as well as a decrease in the variability of observations as wind speeds increase. The marine locations depict a much more compact distribution with less variability and a slight upward trend in gust factors as the wind speed increases.



Histograms of the frequency of gust factors are shown below for land locations (left) and marine locations (right). For the land observations, note the large number of observations with a large distribution and considerable spread. This results in a standard deviation of 0.30 around the mean of 1.47 with the most frequent land GF ranging between 1.3 and 1.4. The GF for the marine locations indicate a much smaller number and range of GF. The marine GF is most frequently located between 1.2 and 1.3 with 1,055 of the total 1,720 gust factors (61%) ranging between 1.2 and 1.3. The marine observations contain a standard deviation of 0.055 around the mean of 1.23.



Regression equations for each of the storms are shown individually in colors below with a combined curve, merged for all storms, shown in black for land locations (left) and marine locations (right). The land observations show large variations but a similarly shaped curve likely indicating the variations in gust factors driven by air mass, terrain, roughness and other factors. The marine locations show a great deal of consistency which is not surprising given the similar air mass and surface roughness in the marine environment and with wave heights of 5 meters or less.



Transitioning Research to a New Methodology

The distribution of gust factors and the mean values for both land and marine locations in our results were similar to other studies giving us confidence in our empirical data set.

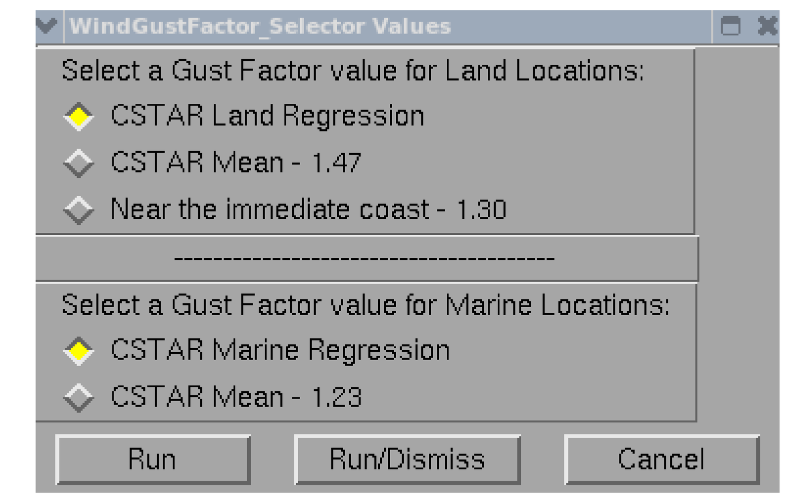
We experimented with several iterations of tools for the Gridded Forecast Editor (GFE) that used the regression equations built from both the land and marine data sets.

We settled on a more mature methodology that includes a new GFE element called the WindGustFactor (WGF) grid which is the ratio between the wind gust and the sustained wind speed for a specific period of time.

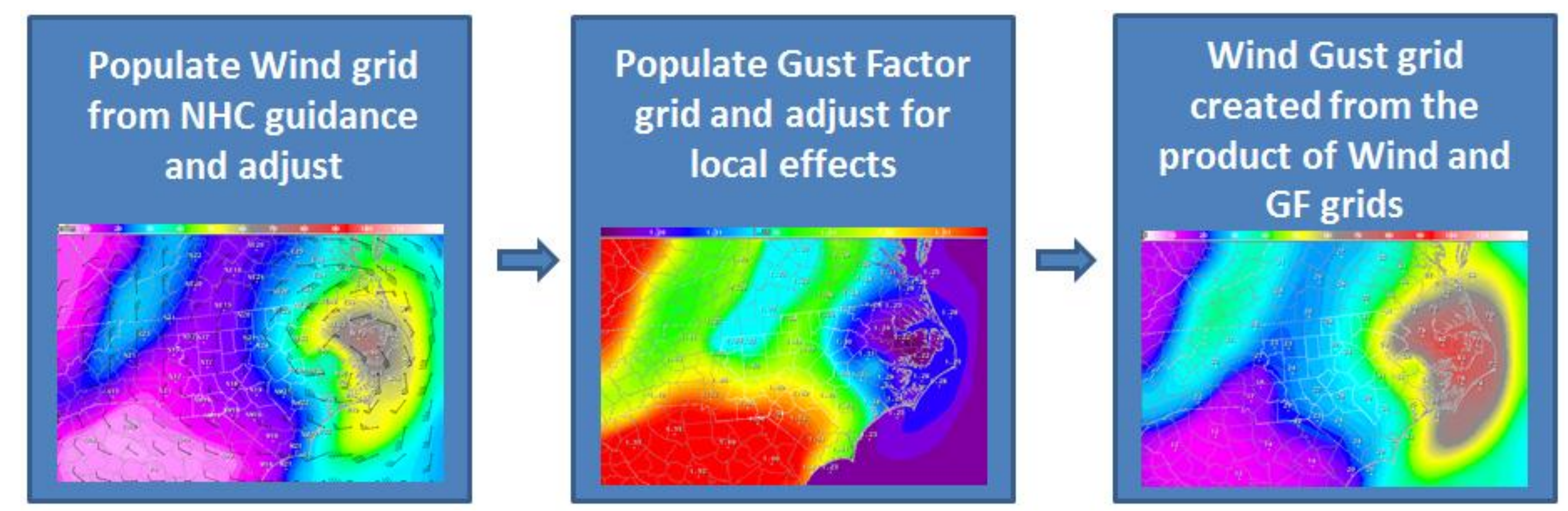
The WGF is initially populated via a GFE tool that uses the sustained winds as an input into the regression equation and produces the WGF grid.

After the WGF grid is initially created, forecasters can spatially and temporally edit the WGF grid for a variety of meteorological and topographical features.

In addition, the WGF grid allows forecasters to collaborate with other WFOs much more efficiently.



The primary steps in this new methodology are shown below. New tools have been developed for the second step (*WindGustFactor_Selector* tool) and the third step (*WindGust_from_WindGustFactor tool*).



Advantages

- A more science-based and consistent process is provided to forecasters which should result in improved wind gust forecast.
- Forecasters can more efficiently integrate the impacts of boundary layer stability, friction, exposure, etc. into the forecast process.
- The gust factor grids can be edited spatially and temporally across the GFE domain.
- Forecasters can visually collaborate with other WFOs in GFE.

Conclusions

- We have created an experimental GFE methodology that uses the empirical data in this study to populate grids of wind gust factors that are used to derive the wind gusts grids.
- This methodology has many advantages that should result in a more consistent, accurate, and science-based forecast.
- This methodology is being evaluated by several WFOs with encouraging results noted during its use with Tropical Storm Andrea in May 2013.
- Results from this project are being incorporated into the NWS Tropical Weather training professional development series.

Acknowledgements

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