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NUREG/CR-7005

Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants

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Technical Basis for Regulatory Guidance on Design-Basis Hurricane Wind Speeds for Nuclear Power Plants

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ABSTRACT

This report is intended to provide the technical basis for a potential new regulatory guide that will provide licensees and applicants with guidance that the staff of the U.S. Nuclear Regulatory Commission considers acceptable for use in selecting the design-basis hurricane wind speeds to which a nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public in accordance with General Design Criterion 2, “Design Bases for Protection Against Natural Phenomena,” and General Design Criterion 4, “Environmental and Dynamic Effects Design Bases,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to Title 10, Part 50, of the *Code of Federal Regulations*, “Domestic Licensing of Production and Utilization Facilities.”

This report documents the approach and results of an analysis of peak-gust hurricane wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7}. The analysis used a weighted sampling method to enable the simulation of 10 million years of hurricane wind speeds in the contiguous United States. The staff initiated this study because development of new wind speeds for its guidance on design-basis tornadoes (Revision 1 to Regulatory Guide 1.76, “Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants”), which was based on the new Enhanced Fujita scale, resulted in a decrease in the tornado design-basis wind speeds. The design-basis tornado wind speeds presented in Regulatory Guide 1.76 correspond to the exceedance frequency of 10^{-7} per year. The decrease in the design basis tornado wind speeds was large enough to prompt an investigation into whether hurricane wind gusts with an annual exceedance frequency of 10^{-7} would exceed tornado winds at the same annual exceedance frequency. This report considers peak-gust wind speeds for hurricanes that affect the Atlantic and Gulf coasts of the United States.

FORWARD

The Nuclear Regulatory Commission (NRC) has determined that a regulatory guide providing design-basis hurricane wind speeds for nuclear reactors may be needed for the future reactor licensing efforts. This report provides the technical basis for this potential new regulatory guide that will provide licensees and applicants with guidance that the Commission staff considers acceptable for use in determining design-basis hurricane wind speeds that a nuclear power plant design should withstand to prevent undue risk to the health and safety of the public.

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This report documents the approach and results of an analysis of peak-gust hurricane wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7}. The analysis used a weighted sampling method to enable the simulation of 10 million years of hurricane wind speeds in the contiguous United States. The U.S. Nuclear Regulatory Commission initiated the study because the development of new wind speeds for tornadoes, for its guidance on design-basis tornadoes (Revision 1 to Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants"), which was based on the new Enhanced Fujita scale, resulted in a decrease in the tornado design-basis wind speeds. The design-basis tornado wind speeds presented in Regulatory Guide 1.76 correspond to the exceedance frequency of 10^{-7} per year The decrease in the tornado wind speeds was large enough to prompt an investigation into whether or not extreme hurricane wind gusts with an annual exceedance frequency of 10^{-7} would exceed tornado wind speeds at the same annual exceedance frequency. This report considers peak-gust wind speeds for hurricanes that originate in the Atlantic and make landfall along the Atlantic and Gulf coasts of the contiguous United States. It does not include locations outside the contiguous 48 states, and it does not consider hurricanes that originate in the Pacific.

The analysis for this report used the peer-reviewed hurricane simulation model for the development of wind speed maps for Standard ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures*, from the American Society of Civil Engineers (ASCE) and the Structural Engineering Institute (SEI). The model generated peak-gust wind speeds at 3575 grid points in the middle and eastern portions of the United States. A weighted sampling approach facilitated a simulation with an effective length of 10 million years that computed wind speeds for each model hurricane at each affected grid point. In addition to the computation of a deterministic peak-gust wind speed for each model hurricane, the analysis incorporated a wind field modeling error term. The error term includes the inability of the wind model to capture some asymmetries in the underlying model pressure fields, as well as the inability of the model to capture small-scale features such as extreme convective gusts. The inclusion of this error term resulted in an effective maximum peak gust in the range of 1.7 to 1.8 times the mean wind speed.

The range of hurricane parameters in the pre-computed wind fields in the model was extended to cover the smaller and more intense hurricanes that are occasionally simulated in the 10-million-year event set. This analysis used a minimum possible central pressure of 823 hPa (although this limit was not reached) rather than the 863-hPa limit for the ASCE/SEI 7 wind speed maps. Similarly, the analysis used a value of 4 km for the smallest value of the radius to maximum winds of a model hurricane rather than 8 km.

The resulting design-basis hurricane wind speeds are 3-second peak-gust values at a height of 10 m in flat open terrain, which is consistent with the definition of design wind speeds in the ASCE/SEI design standard.

This report provides contour maps of the resultant wind speeds, both as standard contour plots on a map and in a grid format similar to that in the Commission's presentation of design-basis tornado wind speeds. This report uses a 0.1-degree grid instead of the 2-degree grid for the tornado wind speeds. The 0.1-degree grid better captures the strong gradient in hurricane wind speeds that exists near the coast.

The model simulated synthetic hurricanes in the Atlantic Basin, including the Gulf of Mexico. The 10^{-6} exceedance probability wind speeds are higher than those of tornadoes along the entire Gulf of Mexico and Atlantic coastlines. The 10^{-7} exceedance probability wind speeds are higher than those for tornadoes along the coastline south of the border between North Carolina and Virginia. These very high wind speeds are driven to a large extent by the treatment of uncertainty in extreme gusts in the field modeling. The maximum peak-gust wind speed with an exceedance probability of 10^{-7} is about 290 mph (130 m/s). This maximum occurs in the Florida Keys 100 m inland from the coast. Assuming this maximum has a gust factor of about 1.7, the corresponding sustained over-water wind speed is in the range of 200 to 210 mph (90 to 94 m/s).

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ACRONYMS AND ABBREVIATIONS

ASCE	American Society of Civil Engineers
BL	boundary layer
EF	Enhanced Fujita
ESDU	Engineering Sciences Data Unit
hPa	hectoPascal
hr	hour
km	kilometer
kt	knot
m	meter
mbar	millibar
MBL	mean boundary layer
min	minute
mph	miles per hour
mps	meters per second
NCEP	National Centers for Environmental Prediction
NRC	U.S. Nuclear Regulatory Commission
RMW	radius to maximum winds
s	second
SEI	Structural Engineering Institute
SST	sea surface temperature
yr	year

1. INTRODUCTION

1.1 Purpose and Scope

The Nuclear Regulatory Commission (NRC) has determined that a hurricane regulatory guide for nuclear reactors may be needed for future reactor licensing efforts. This potential new regulatory guide will provide licensees and applicants with guidance that the staff of the U.S. NRC considers acceptable for use in selecting the design-basis hurricane wind speeds that a nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public. The NRC initiated this study because the development of new wind speeds for tornadoes, for its guidance on design-basis tornadoes, which was based on the new Enhanced Fujita scale, resulted in a decrease in the tornado design-basis wind speeds. The decrease in the tornado wind speeds was large enough to prompt an investigation into whether or not extreme wind gusts during hurricanes would affect the design-basis hurricane wind speeds. The Enhanced Fujita (EF) scale was introduced in 2006. The EF scale relates damage to wind speed; the National Weather Service adopted it on February 1 2007. The new approach resulted in a reduction of the wind speeds for a given tornado in comparison to the original Fujita scale. The NRC updated its guidance on tornado characteristics for the design of nuclear power plants in Revision 1 of Regulatory Guide 1.76, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*, in March 2007 (NRC 2007). The design-basis tornado wind speeds presented in Regulatory Guide 1.76 correspond to the exceedance frequency of 10^{-7} per year. The revised design-basis tornado regulatory guide reflects the implementation of the EF scale for classification of tornado winds. This update resulted in reduced design-basis wind speeds for tornadoes and prompted a concern that, in the hurricane-prone regions of the United States, hurricane wind gusts might control the design-basis wind speeds at an annual exceedance level of 10^{-7}. The analysis for this report addressed this issue by extending the peer-reviewed hurricane hazard model wind speed design criteria for ASCE/SEI 7-05, *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 2006), from the American Society of Civil Engineers (ASCE) and the Structural Engineering Institute (SEI). This extension allowed estimation of the magnitude of hurricane wind gusts that have annual exceedance probabilities of 10^{-6} and 10^{-7}.

This report considers hurricanes that affect the contiguous United States with landfalls along the Gulf and Atlantic coasts. It does not encompass locations outside the 48 contiguous states such as Hawaii, Puerto Rico, or the U.S. Virgin Islands, and it does not consider hurricanes that originate in the Pacific.

The possibility of a hurricane making landfall along the Pacific Coast and affecting the United States does not require consideration because the current NRC design-basis wind speeds for the Pacific Coast specify that tornado winds of 160 mph (72 m/s) are sufficiently high. The waters off the coast of California are much too cold to support a cyclone of hurricane intensity. The prevailing upper level winds tend to steer the systems westward, away from land, although the region has experienced tropical storm force winds from the remnants of tropical cyclones. An investigation for quantifying wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7} along the Pacific Coast would require the development of a separate model, which is beyond the scope of this document. The omission of hurricane winds in Southern California is consistent with the statement in Regulatory Guide 1.76 that “tornado wind speeds may not bound hurricane wind speeds for certain portions of the Atlantic and Gulf Coasts” (NRC 2007).

Section 1.2 provides the regulatory basis for the NRC staff to develop guidance on design basis hurricane wind speeds. Section 2 provides an overview of the hurricane simulation methodology with information on changes to the model that enable an effective simulation length of 10 million years. Section 3 presents the predicted peak-gust hurricane wind speeds with exceedance probabilities of 10^{-6} and 10^{-7} and compares them to those for tornadoes.

1.2 Regulatory Background

Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50), provides General Design Criteria that require that nuclear power plants be designed to withstand to prevent undue risk to the health and safety of the public. The criteria that apply to this analysis are:

- *Criterion 2—Design bases for protection against natural phenomena. Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.*

- *Criterion 4—Environmental and dynamic effects design bases. Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.*

Criterion 2 includes protection from the effects of natural phenomena including hurricanes, and Criterion 4 includes protection from the dynamic effects of hurricanes, which includes missiles or flying debris as a result of high wind speeds.

2. SIMULATION METHODOLOGY

This section discusses the methodology for the estimation of peak-gust hurricane wind speeds with annual exceedance probabilities in the range of 10^{-6} and 10^{-7}. The methodology is nearly identical to that in Vickery et al. (2009a), but this analysis made some minor improvements to the model. Section 2.1 provides a detailed overview of the simulation methodology, primarily from peer-reviewed papers that describe the model. Section 2.2 describes model improvements, and Section 2.3 describes the modeling of wind field uncertainty. Section 2.4 compares the computed wind speeds of the improved model to those of the model in Vickery et al. (2009a). Section 2.5 discusses the effect of site target size on wind speeds, and Section 2.6 discusses the model's sensitivity to increased hurricane activity.

2.1 Hurricane Simulation Overview

The starting point for the estimation of hurricane peak-gust wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7} is the hurricane simulation model in Vickery et al. (2000a, 2009a). The simulation model in Vickery et al. (2000a) forms the basis of the design-basis wind speeds in the three most recent editions of the ASCE 7 wind loading standards: ASCE 7-98, ASCE 7-02, and ASCE/SEI 7-05 (ASCE/SEI 2006). The Vickery et al. (2009a) model is expected to be adopted in the 2010 edition of ASCE 7. The hurricane simulation model has three key components:

1. A track model that describes the variation of the translation speed and heading of a tropical cyclone as it moves across the water or land.

2. An intensity model that estimates the central pressure of a model tropical cyclone. The intensity model uses a relative intensity approach that ensures that the intensity of a developing hurricane can never exceed its maximum potential intensity as estimated by the Emanuel (1988) method. The intensity of the model tropical cyclone is a function of the mixed sea surface temperature (SST), tropopause temperature, and relative humidity. The model uses the exponential decay models from Vickery (2005) to simulate the decay of the tropical cyclones over land. Additional components of the intensity model include a model to describe the size of the tropical cyclone and a model to describe the shape of the pressure distribution within the cyclone. Vickery and Wadhera (2008) describe the details of modeling the size and shape parameters, which are defined by the radius to maximum winds (RMW) and the Holland B parameter (which, along with the RMW, is used to define the pressure field).

3. A wind field model that, given key hurricane parameters (central pressure, RMW, B, translation speed, and location), estimates the mean wind speed and associated wind directions. The mean wind speeds are converted to peak-gust wind speeds using a gust factor model that accounts for storm duration. For each model tropical cyclone, the model computes wind speeds at each of 3575 grid points across the eastern and southeastern United States are affected by hurricanes. The grid spacing varies from about 4 km close to the coast to about 40 km for inland locations. This model incorporates uncertainties, or errors, in the estimates of the wind speeds. The errors result from comparisons of modeled and observed wind speeds using data from more than 250 anemometer time histories. The introduction of the errors serves both to smooth the wind speed hazard curve and to account for the occurrence of anomalous gusts in hurricanes that the model does not encompass.

The over-water hurricane track simulation occurs in two steps. In the first step, the hurricane position at any point in time is modeled using the approach in Vickery et al. (2000a), which includes all tropical cyclones in the HURDAT database (Jarvinen et al. 1984). In the second step, the relative intensity, *I*, of the hurricane is modeled using the approach in Vickery et al. (2000a), with modification to include the effects of ocean mixing and wind shear. The model then uses the relative intensity to compute the central pressure and subsequently *RMW* and *B*. Figure 2-1 outlines the overall model methodology; it shows two modeled hurricane tracks along with a short narrative on the major steps of moving the simulated storm forward in time. Figure 2-2 is a flow chart that outlines the methodology as a simulated storm moves from one point to the next. Figure 2-3 is a map of the locations of the 3575 grid points at which the model computes wind speeds.

Hurricane intensity, which is defined by central pressure difference, is modeled as a function of the relative intensity and thermodynamic and atmospheric environmental variables, including SST, tropopause temperature, and vertical wind shear. The relative intensity approach is based on the efficiency of a cyclone relative to a Carnot heat engine (Emanuel 1988). The definition of the relative intensity for this analysis is the ratio of the central pressure difference at the center of a cyclone to the maximum possible central pressure difference for the given meteorological conditions. The key parameters that control the relative intensity are the SST, tropopause temperature T_o and the relative humidity, which for this analysis is a constant equal to 0.8.

For each storm in the HURDAT database where central pressure data are available and the storm is over water, the model computes the relative intensity using the central pressure difference, SST, tropopause temperature, and relative humidity. The SST at the storm center is determined from the HadISST dataset (Rayner et al. 2003, 2006), which provides monthly mean SSTs for the period from 1850 to the present on a 1-degree geographical grid. The T_o temperature data were from the National Center for Atmospheric Research reanalysis T_o database (www.cdc.noaa.gov), which provides T_o data on a 2.5-degree geographical grid. A linear two-dimensional interpolation method produces the value of T_o at the storm center.

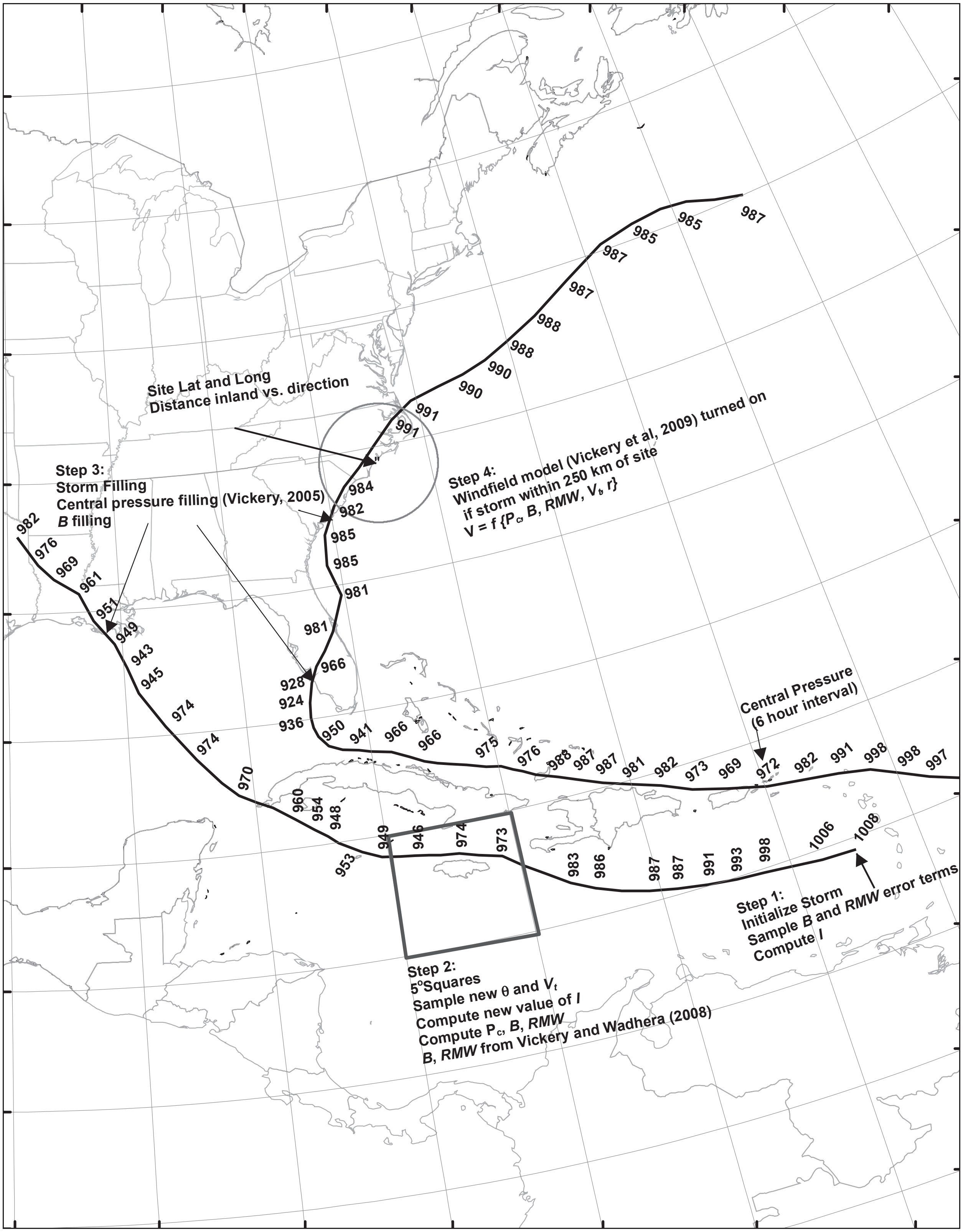

Figure 2-1. Hurricane simulation methodology showing two sample simulated hurricane tracks (Vickery et al. 2009a).

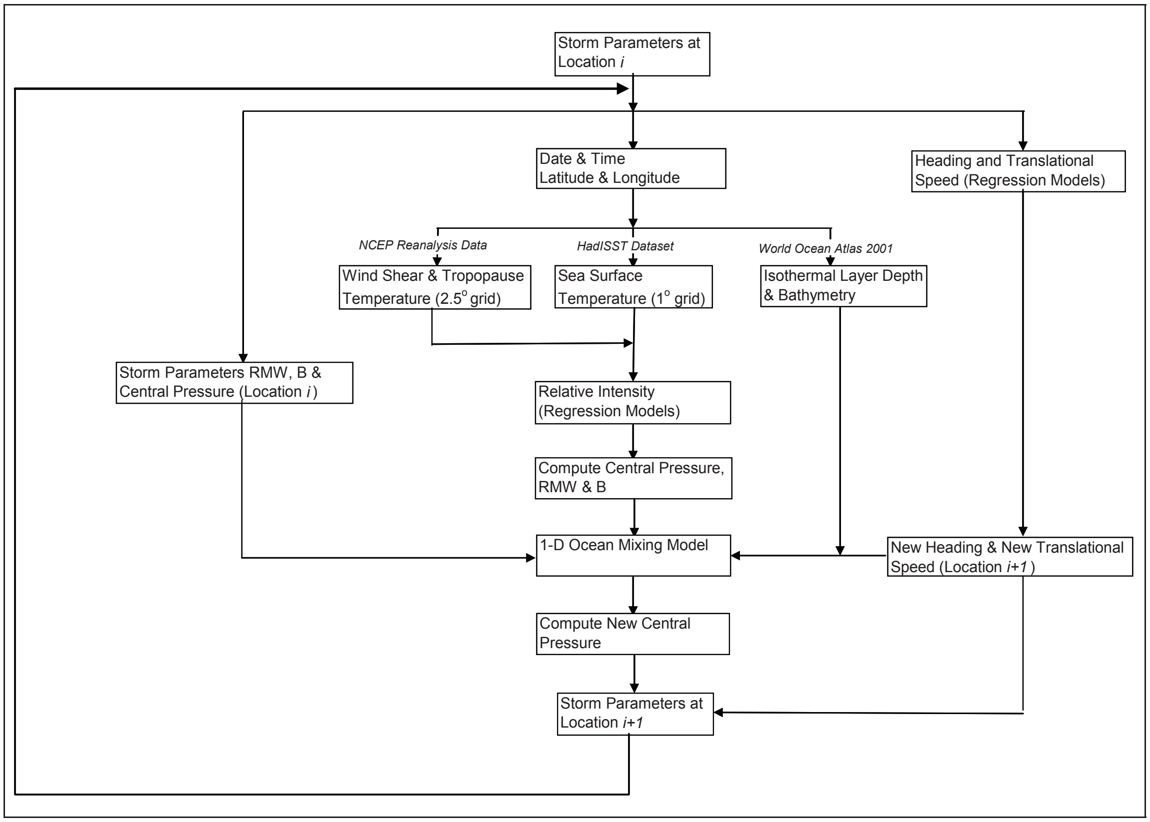

Figure 2-2. Flow chart of simulation methodology.

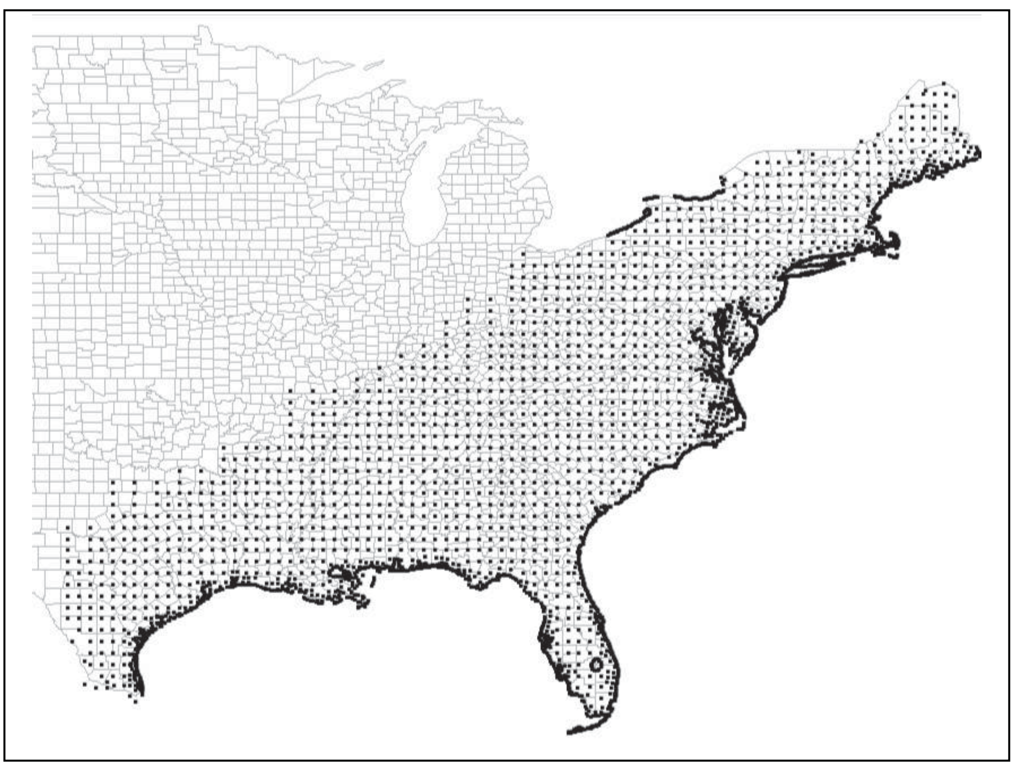

Figure 2-3. Location of 3575 points for wind speed computations.

A simple one-dimensional ocean model, similar to that in Emanuel et al. (2006), simulates the effect of ocean feedback on the relative intensity calculations. The ocean feedback model calculates the mixed-layer depth based on the assumed constancy of a bulk Richardson number, while the mixed-layer momentum is driven by the surface stress and entrainment. The mixed layer momentum equation is integrated over a circular region of 4 times the *RMW*. The ocean mixing model returns an estimate of the mixed-layer depth, which is then used to compute the reduction in SST from the passage of a hurricane. This reduced temperature is used in the relative intensity calculations. The key inputs to the ocean mixing model are the mean wind speed at a height of 10m, which controls the ocean shear stress, the mixed layer or iso-thermal layer depth, the rate of change of water temperature beneath the isothermal layer and the water depth. The iso-thermal later depth is defined as the layer of water near the surface of the ocean where the water temperature is approximately constant. Before mixing, the water temperature within the iso-thermal layer is taken as equal to the un-disturbed sea surface temperature. As the mixed layer depth increases due to the wind stress acting on the surface of the ocean, cooler water beneath the mixed iso-thermal layer is mixed into a new thicker mixed iso-thermal layer near the surface, decreasing the sea surface temperature, and hence resulting in maximum possible storm intensity. In shallow waters where the computed mixed layer depth is greater than the depth of the water, the SST is limited to the value of the depth averaged water temperature. Using the track model, the analysis first simulated 10 million years of hurricanes in the Atlantic basin, which yielded more than 23 million land-falling tropical cyclones. In each simulated year, one historical year of SSTs and tropopause temperature was randomly selected and used in the simulation process for the entire model year. As in Vickery et al. (2000a), the number of storms to be simulated in a model year results from a binomial distribution, and the starting times and positions of the storms come directly from the HURDAT database. The intensity of the first point of a storm is a function of SST and longitude. In the simulation process, hurricanes that make landfall are weakened (filled) with the filling model (Vickery 2005). Ocean mixing is computed using the same simple Holland (1980) wind model as for the model's development.

The model computes the maximum peak-gust wind speed at the time of landfall for each simulated tropical cyclone. It would be computationally prohibitive to calculate the maximum wind speeds at every grid point for every simulated tropical cyclone, so the model uses a weighted sampling approach to reduce the computational effort. Last, the model develops a wind speed hazard curve at each grid point that incorporates wind field modeling uncertainty, a weighted sampling method, and a nonstationary gust factor model. These hazard curves are then used to construct wind speed contours in relation to annual exceedance probabilities of 10^{-6} and 10^{-7}.

Sections 2.1.1 to 2.1.3 present an overview of the three major modeling components; each section summarizes the peer-reviewed papers that describe the submodel and the changes in it to enable estimation of the rare event wind speeds.

2.1.1 Track Modeling

The track model that estimates the wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7} is unchanged from that in Vickery et al. (2009a).

The starting position, date, time, heading, and translation speed of all tropical storms, as given in the HURDAT database, are sampled and used to initiate the simulation. Use of the historical starting positions of the storms (i.e., date and location) ensures that the model incorporates seasonal climatology for the point of storm initiation. Given the initial storm heading, speed, and intensity, the simulation model estimates the new position and speed of the storm based on the changes in the translation speed and storm heading over the 6-hr increments. The changes in the translation speed *c* and storm heading θ between times *i* and *i*+1 are

$$\Delta \ln c = a_1 + a_2\Psi + a_3\lambda + a_4 \ln c_i + a_5\theta_i + \varepsilon \quad (2\text{-}1a)$$

$$\Delta\theta = b_1 + b_2\Psi + b_3\lambda + b_4 c_i + b_5\theta_i + b_6\theta_{i-1} + \varepsilon \quad (2\text{-}1b)$$

where a_1, a_2, etc. are constants, ψ and λare the storm latitude and longitude, respectively; c_i is the storm translation speed at time step *i*; θ_i is the storm heading at time step *i*; θ_{i-1} is the heading of the storm at time step *i*-1; and ε is a random error term. The coefficients a_1, a_2, etc. have been developed using 5- by 5-degree grids over the entire Atlantic basin. A different set of coefficients for easterly and westerly headed storms is used. As the simulated storm moves into a different 5- by 5-degree square, the coefficients that define the changes in heading and speed change accordingly. The error term results from a binormal distribution. Figure 2-4 compares the mean and standard deviations of modeled and historical translation speed and heading of all tropical cyclones that pass within 250 km of the mileposts, which that Figure 2-5 shows. Figure 2-4 also compares the mean modeled and observed occurrence rates and distances of closest approach for those same cyclones. The historic data in Figure 2-4 encompass the period from 1886 to 2006. The comparisons indicate the track model reproduces the variation of the key tropical cyclone track parameters for tropical cyclones that make landfall along the U.S. coastline.

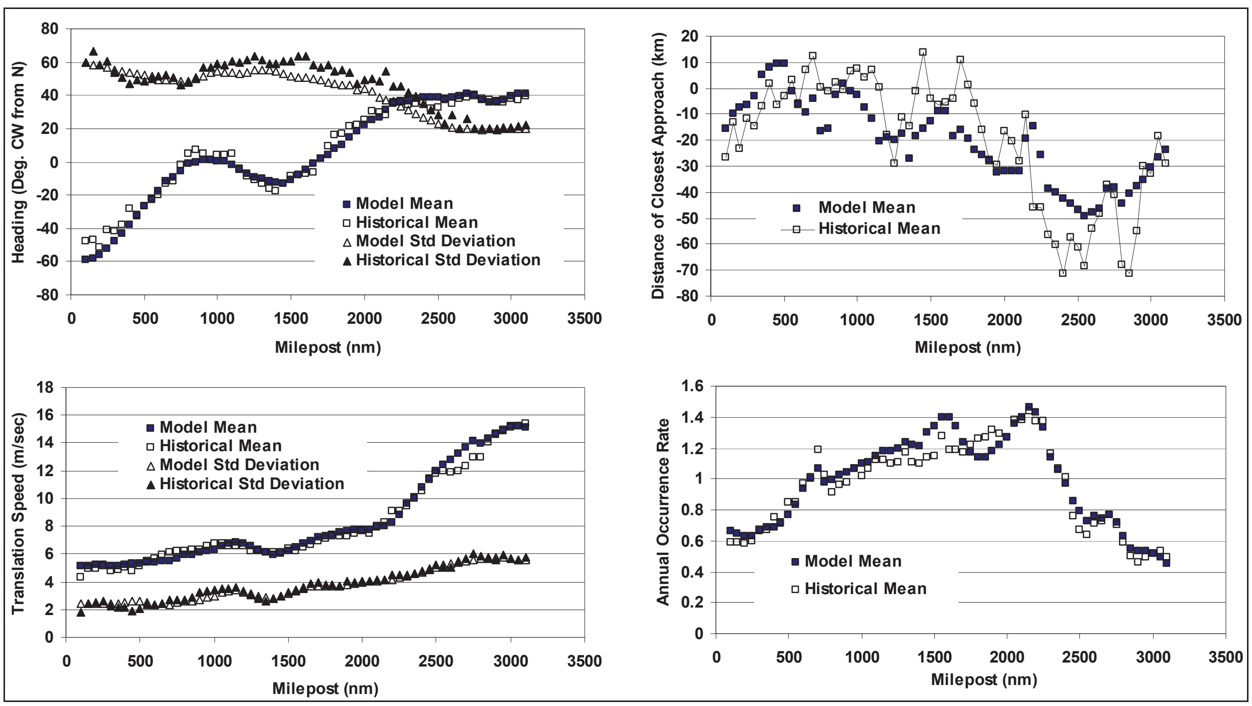

Figure 2-4. Comparison of modeled and historical statistics of heading, translation speed, distance of closest approach, and occurrence rate for all storms passing within 250 km of the indicated milepost.

2.1.2 Intensity Modeling and Size Modeling

The methodology for intensity and size modeling is similar to that in Vickery et al. (2009a).

Central Pressure Modeling. In the simulation model, the relative intensity at any time is a function of relative intensity at the previous three steps and the scaled vertical wind shear V_s (DeMaria and Kaplan 1999) at the storms current location as

$$\ln(I_{i+1}) = c_1 \ln(I_i) + c_2 \ln(I_{i-1}) + c_3 \ln(I_{i-2}) + c_4 V_s + \varepsilon \tag{2-2}$$

where c_1, c_2, etc. are constants that vary with region in the Atlantic Basin, and ε is a random error term. In the development of the dataset of historical values of *I*, the surface-level wind speeds for estimating the *c* vales for the ocean mixing model were obtained using the simple wind field model in Holland (1980), with the surface-level mean wind speed equal to 80 percent of the gradient balance wind speed[1]. The model uses nine different regions to simulate the intensity changes of tropical cyclones in the Atlantic and Gulf of Mexico.

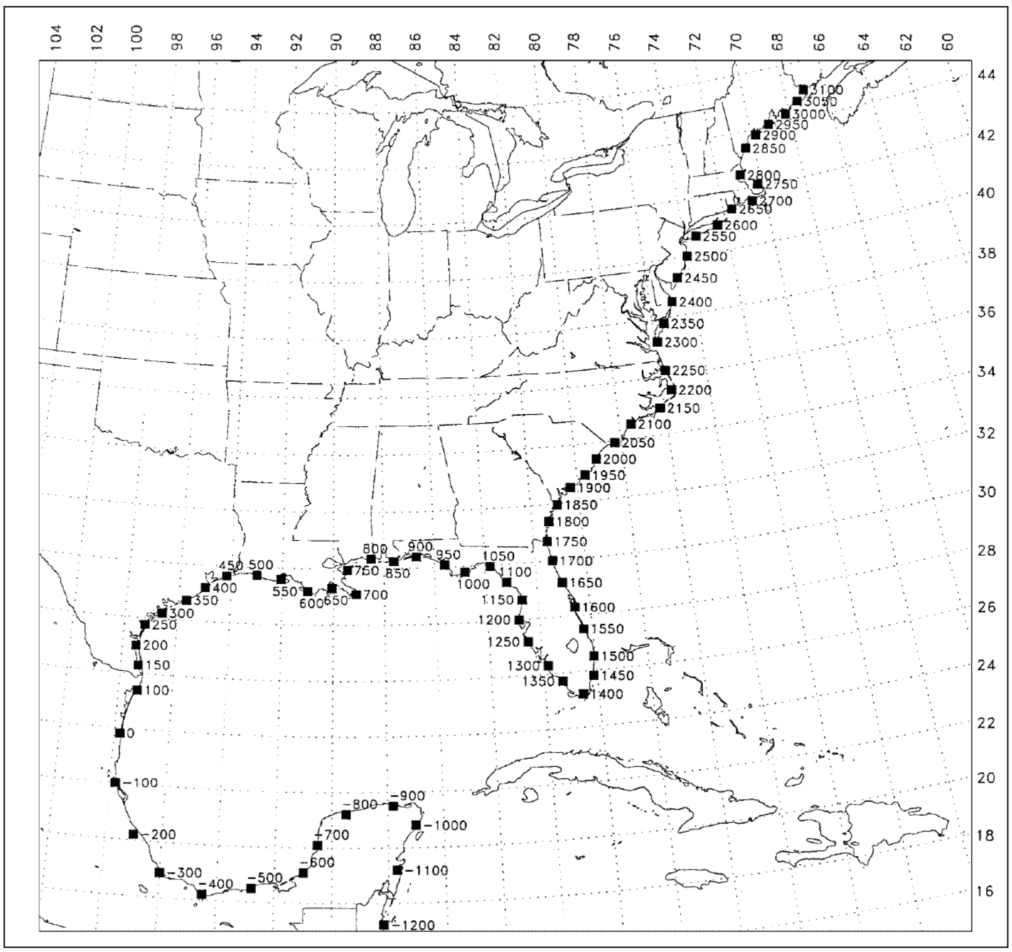

Figure 2-5. Location of mileposts for calculation of track parameters for model validation.

The relationship between relative intensity and central pressure is that from Darling (1991). The relative intensity *I* is

[1] The gradient balance wind speed is steady velocity which is in balance with the pressure gradient force, the Coriolis force and the centrifugal force associated with the curvature of the isobars.

$$I = \frac{p_{da} - (p_c - e_s)}{p_{da} - p_{dc}} = \frac{1013 - p_c + (1 - RH)e_s}{(1 - x)(1013 - RHe_s)} \tag{2-3}$$

where 1013 represents the far-field ambient pressure, expressed in hPa,, p_c is the cyclone central pressure, *RH* is the relative humidity, e_s is the saturation vapor pressure (hPa), p_{da} is the surface value of the partial pressure of dry air, and p_{dc} is the minimum sustainable surface value of the cyclone central pressure (or dry air) for a hurricane given by $p_{dc} = xp_{da}$.

The saturation vapor pressure e_s is:

$$e_s = 6.112 \exp\left[\frac{17.67(SST - 273)}{SST - 29.5}\right] \tag{2-4}$$

where *SST* is the sea surface temperature in Kelvin.

The variable *x* is obtained from the solution of the non-linear equation

$$\ln(x) = -A\left(\frac{1}{x} - B\right) \tag{2-5}$$

$$A = \frac{\in L_v e_s}{SST(1 - \in)R_v p_{da}} \tag{2-6}$$

$$B = RH\left[1 + \frac{e_s \ln(RH)}{p_{da} A}\right] \tag{2-7}$$

where R_v is the gas constant of water vapor (461 in this analysis), L_v is the latent heat of vaporization $(2.5 \times 10^6) - 2320(SST - 273)$, and $\in$ is the efficiency of a cyclone heat engine from

$$\in = \frac{SST - T_0}{SST} \tag{2-8}$$

where T_0 is the tropopause temperature. In the conversion of the relative intensity to pressure, *RH* is a constant equal to 0.8.

As the model overview in Section 2 indicates, the value for *SST* in the model is the mixed SST that accounts for the upwelling of cool water beneath the surface of the ocean.

Holland B Parameter Modeling. The Holland *B* parameter is used to define the pressure field and plays an important role in the risk prediction methodology; see, for example, Vickery et al. (2000a, 2009a) and Powell et al. (2005). Holland (1980) describes the radial distribution of surface pressure in a hurricane in the form

$$p(r) = p_0 + \Delta p \times \exp - \left[\frac{A}{r^B}\right] \tag{2-9}$$

where $p(r)$ is the surface pressure at a distance *r* from the storm center, $p_0$is the central pressure, Δp is the difference between the peripheral pressure and the central pressure, *A* is a size parameter, and B is the Holland's pressure profile parameter. Holland (1980) showed that $RMW = A^{1/B}$. Therefore, Equation 2-9 can be expressed as

$$p(r) = p_0 + \Delta p \times \exp - \left[\frac{RMW}{r} \right]^B \qquad (2\text{-}10)$$

The gradient balance velocity V_G for a stationary storm is therefore

$$V_G = \left[\left(\frac{RMW}{r} \right)^B \frac{B \Delta p \exp \left[- \left(\frac{RMW}{r} \right)^B \right]}{\rho} + \frac{r^2 f^2}{4} \right]^{1/2} - \frac{fr}{2} \qquad (2\text{-}11)$$

where ρ is the density of air, and f is the Coriolis parameter. The maximum wind speed occurs at the *RMW* and is

$$V_{G\max} \approx \sqrt{\frac{B \Delta p}{e \rho}} \qquad (2\text{-}12)$$

where e is the base of natural logarithms.

In parametric hurricane wind field models where the input surface pressure field is defined by two parameters (Δp and a radius), the maximum wind speed in the simulated hurricane is proportional to the square root of Δp, whereas, with the introduction of the additional term B, the maximum wind speed in the simulated hurricane is proportional to the square root of $B\Delta p$. Figure 2-6 shows example pressure profiles and gradient wind speed profiles for Equations 2-9 through 2-11.

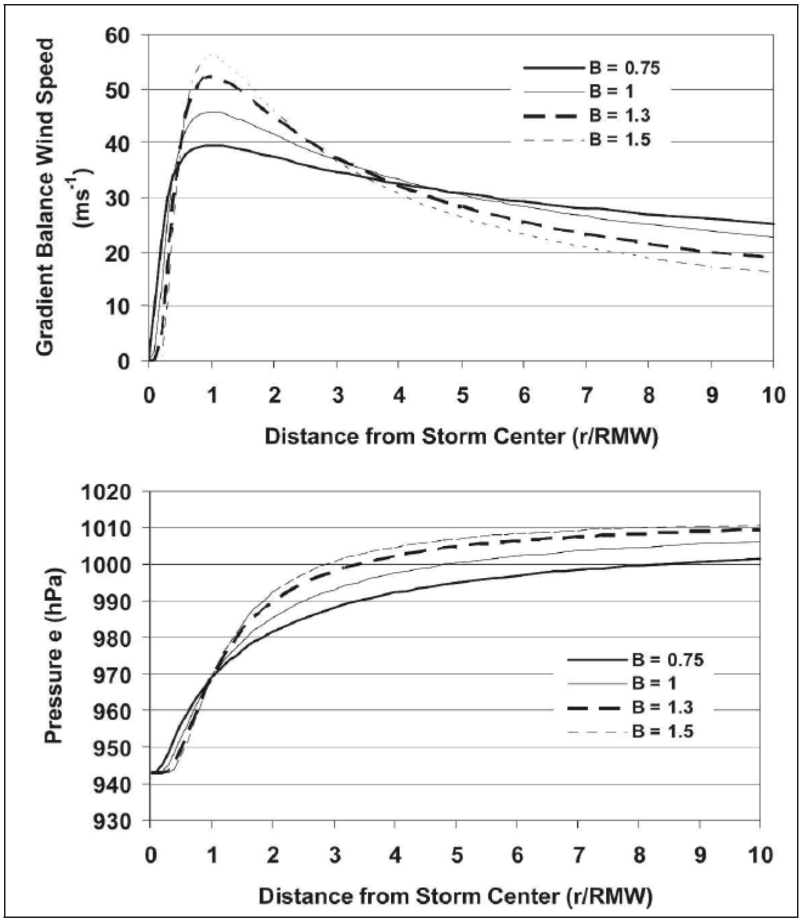

Figure 2-6. Effect of *B* on gradient winds (top) and pressure (bottom) versus distance from storm center (Vickery and Wadhera 2008).

Modeling the surface pressure field using Equation 2-10 is a significant improvement over modeling the pressure field with empirical models that are described by only two parameters. The approach still has limitations (see Thompson and Cardone 1996, Willoughby and Rahn 2004, Willoughby et al. 2006, and Vickery and Wadhera 2008). The use of a single value of *B* (or *RMW*) does not reproduce the azimuthal and radial variations in the pressure fields (and therefore wind fields) that often occur in real hurricanes.

Therefore, while the use of Equation 2-10 has limitations, using the approach in a hurricane simulation model allows for the modeling of storms similar to both Hurricane Katrina (p_0 ~920 hPa, V_{max} ~110 kt) and Hurricane Charley (p_0 ~942 hPa, V_{max} ~125 kt). (V_{max} is the estimated maximum 1-min average wind speed at a height of 10 m over water as defined by the National Hurricane Center.) The omission of *B* does not allow for the variation in the maximum wind speed that occurs in real hurricanes for a given Δp (all else being equal).

Vickery and Wadhera (2008) describe the statistical model for the Holland *B* parameter, in which the value of *B* over open water is

$$B = 1.76 - 1.21\sqrt{A} + \varepsilon \; ; \; r^2 = 0.345, \; \sigma_B = 0.226 \qquad (2\text{-}13)$$

where

$$A = \frac{RMW \times f}{\sqrt{2R_d T_s \times \ln\left(1 + \frac{\Delta p}{p_c e}\right)}} \tag{2-14}$$

and ε is the random error term sampled from a normal distribution with a mean of zero and standard deviation equal to σ_B.

In Equation 2-14 (denoted Equation 2 in Figure 2-7), *RMW* is expressed in meters, , R_d is the gas constant for dry air, T_s is the SST in degrees Celsius, p_c is the central pressure of the tropical cyclone in hectopascals, and Δp is the difference between the p_c and the far field pressure in mbars (taken here as 1013 hPa). Figure 2-7 shows a comparison of modeled and observed values of *B* plotted versus the square root of *A* with the modeled results for *B* computed using both Equation 2-14 and the model in Vickery et al. (2000). The figure shows individual estimates of *B* from 35 hurricanes as plus signs. *B* values from three specific hurricanes are identified with different symbols to show the variability (or lack of) within a hurricane. For Hurricane Andrew in 1992 (boxes) the values of *B* tend to remain high. Hurricane Floyd in 1999 (triangles) has relatively low values of *B*, whereas in the case of Hurricane Georges in 1998 (circles), both high and low values of *B* are evident. The higher values of *B* occurred while Georges was in the open Atlantic, the lower values occurred in the Gulf of Mexico, and the lowest occurred at the time of landfall.

The comparison of the two sets of modeled results shows the higher *B* values that result from the Vickery et al. (2000a) model for values of the square root of *A* are greater than 0.2. The overestimate of *B* from the Vickery et al. (2000a) model increases as the square root of *A* increases. The increasing difference between the two models is primarily the result of the omission of the latitude term in the Vickery et al. (2000a) model. The error term σ_B in Equation 2-13 is much smaller than the value of 0.381 in the Vickery et al. (2000a) model. This smaller error term results in a lower variance in the predicted wind speeds, and therefore a lower slope in the wind speed versus return period hazard curve.

After landfall, *B* is modeled as

$$B(t) = B_0 \exp(at) \tag{2-15a}$$

$$a = 0.0291 - 0.0429 B_0; \; a \leq -0.005 \tag{2-15b}$$

where B_0 is the value of *B* at landfall. The reduction in the magnitude of *B* after landfall results from comparisons of modeled and observed pressures and wind speeds at both coastal and inland stations. In the wind field modeling comparisons (Vickery and Wadhera, 2008), the magnitudes of both *B* and *RMW* (typically decreasing and increasing after landfall, respectively) are estimated along the track of the hurricane until reasonable matches between both the modeled and observed wind speed and pressure traces are obtained. The reduction in the modeled values of *B* after landfall were found to be adequately modeled using Equation 2-15.

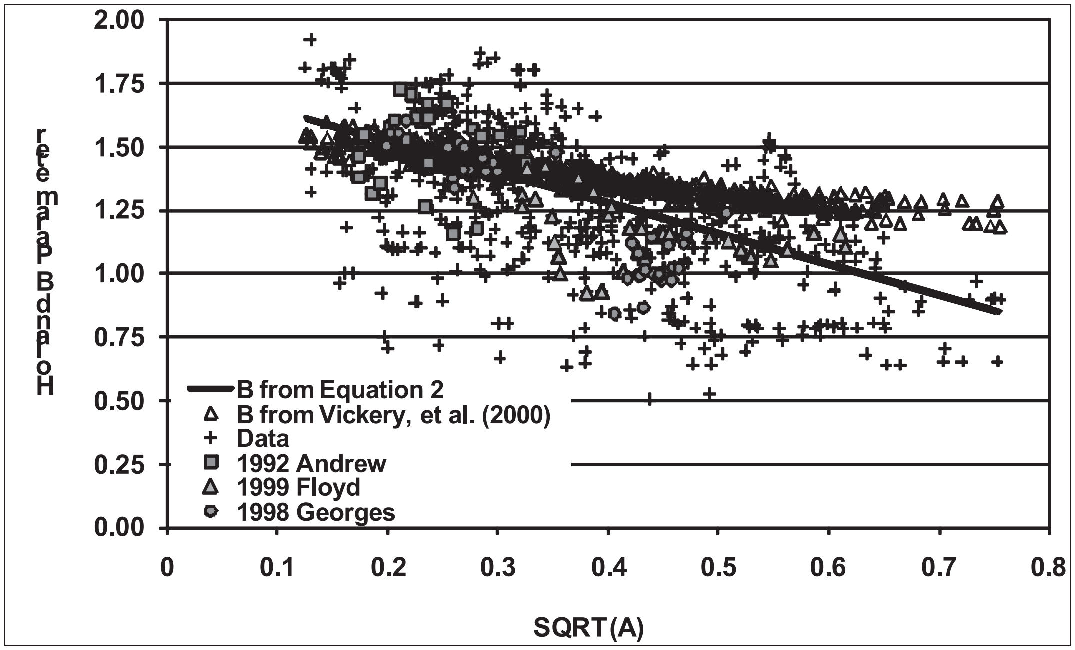

Figure 2-7. Comparison of observed and modeled values of *B* (Vickery et al. 2009a).

Vickery and Wadhera (2008) suggest that, for hurricanes that approach the Gulf Coast, *B* decreases during the last 12 hr before landfall. They also suggest that this reduction in *B* requires further study to determine if this behavior is indicative of most Gulf Coast hurricanes or just those in the sample. The reduction in *B* for Gulf Coast land-falling hurricanes was not modeled here, and the estimates of wind speeds versus return period might therefore be slightly conservative along the Gulf Coast.

RMW *Modeling.* In Vickery and Wadhera (2008), two models are given for the *RMW* (in kilometers), one for Gulf hurricanes and one for all hurricanes. Here, the all-storms *RMW* model was applied to Atlantic hurricanes and the Gulf of Mexico *RMW* model was applied to storms in the Gulf. The models for *RMW* in the simulation are

$$\ln(RMW_{\text{Atlantic}}) = 3.015 - 6.291\times10^{-5}\Delta p^2 + 0.0337\Psi + \varepsilon_{\text{Atlantic}}\ ;\ r^2 = 0.297,\ \sigma_{\ln(RMW)} = 0.441 \quad (2\text{-}16a)$$

$$\ln(RMW_{\text{Gulf}}) = 3.859 - 7.700\times10^{-5}\Delta p^2 + \varepsilon_{\text{Gulf}}\ ;\ r^2 = 0.290,\ \sigma_{\ln(RMW)} = 0.390 \quad (2\text{-}16b)$$

The two statistical models for the *RMW* (Gulf and Atlantic) combine to yield one *RMW* model for each simulated storm:

$$RMW = a_1 RMW_{\text{Atlantic}} + (1 - a_1) RMW_{\text{Gulf}} \quad (2\text{-}17a)$$

$$a_1 = \frac{\sum \Delta p_{\text{Atlantic}}}{\sum \left[\Delta p_{\text{Atlantic}} + \Delta p_{\text{Gulf}}\right]} \quad (2\text{-}17b)$$

where Δp is the central pressure difference and the summation occurs over all 6-hr time steps from storm origination to the current time.

2.1.3 Wind Field Modeling

Vickery et al. (2009b) contains details of the wind field model for estimation of wind speeds under the key hurricane parameters that define the wind field (central pressure, *B*, *RMW*, and translation speed). The model consists of the numerical solution of the equations of motion of a translating hurricane that is used to define the characteristics of the mean boundary layer (MBL) flow. This slab model is coupled with a two-dimensional representation of the variation of wind speed using height to convert the MBL wind speeds to surface-level wind speeds.

Slab Model. This discussion is a brief overview of implementation of the slab model approach. Thompson and Cardone (1996) and Vickery et al. (2000, 2009b) contain details. The model solves the depth-averaged dry equations of horizontal motion, forced by a constant translating pressure field. A finite difference scheme solves the steady-state wind field over a set of nested rectangular grids. The basis of this approach is the assumption that the large-scale structure of the hurricane wind field changes relatively slowly over time. Therefore, at any instant the wind field can be considered to be very nearly at the steady-state conditions it would have if the hurricane was moving over homogeneous terrain at a constant translational speed equivalent to the instantaneous translational speed.

The slab model is based on a formulation that was originally developed by Chow (1971) and is similar to the model in Thompson and Cardone (1996), but was simplified using the Fourier series approach in Vickery et al. (2000). The equation of horizontal motion, vertically averaged through the height of the boundary layer (BL), is written in Earth-fixed coordinates as

$$\frac{d\vec{V}}{dt} + f\left|\vec{k}\times\vec{V}\right| = -\frac{1}{\rho}\nabla p + \nabla\times\left(K_H \nabla \vec{V}\right) - \frac{C_d}{h}\left|\vec{V}\right|\vec{V} \quad \text{(2-18a)}$$

where

$$\frac{d}{dt} = \frac{\partial}{\partial t} + \vec{V}\times\nabla \quad \text{(2-18b)}$$

Here $\vec{V}$ is the vertically averaged horizontal velocity; f is the Coriolis parameter; $\vec{k}$ is the unit vector in the vertical direction; ρ is the air density; K_H is the horizontal eddy viscosity coefficient; C_d is the drag coefficient; and h is the height of the hurricane BL (constant equal to 1000 m in this analysis). It is assumed that the vertical advection of momentum is small in comparison with the horizontal advection of momentum and is ignored.

The pressure gradients dp/dx and dp/dy are prescribed by transforming the following expression for the radial pressure gradient with

$$\frac{\partial p}{\partial r} = \frac{\Delta p B}{r}\left(\frac{RMW}{r}\right)^B \exp\left(-\left(\frac{RMW}{r}\right)^B\right) \quad \text{(2-19)}$$

where *B* and *RMW* are as before, *r* is the distance from the center of the hurricane, and Δp is the central pressure difference. Inputs to the slab model are the pressure gradients (dp/dx and

dp/dy), the surface drag coefficient C_d, and the storm's translational velocity (u_c,v_c). For the over-water case, the drag coefficient is modeled using the truncated version of the model in Large and Pond (1981). In the over-land case, C_d is a constant equal to 0.0047 (open terrain). The solution to the equations of motion is evolved to the steady-state wind field solution by integrating forward until the acceleration is acceptably small. A nested grid system that consists of six concentric rectangular grids is used to solve for the steady-state wind field under a finite difference approach. Each grid consists of the same number of nodes, but the internode distance is halved with each successive grid. The smallest grid size is set as 10 percent of the *RMW* of the simulated storm. Because it is the storm-centered velocity $\vec{V}_s$, which has been calculated, the storm translational velocity $\vec{V}_c$ is added to the results to get the Earth-centered velocity field.

As Vickery et al. (2000b) describes, the model uses precomputed solutions to Equation 2-18 with an interpolation approach to arrive at a solution for the vertically averaged horizontal wind speed for a given set of hurricane parameters. To cover the full range of possible combinations, the wind fields for 14,040 tropical cyclones were precomputed for each of 9 values of *B*, 13 values of *RMW*, 12 values of Δp, and 10 values of translation speed. The minimum value of *RMW* in Vickery et al. (2009b) is 8 km, but this study added two additional *RMW* values of 4 and 6 km. In addition to adding these two *RMW* solutions, the maximum value of Δp was increased from 150 hPa to 190 hPa through the addition of solutions for both the 170-hPa and 190-hPa cases. The total number of precomputed wind fields increased from 14,040 to 18,900. One complete set of hurricanes is generated for the over-water case, and another set for the over-land case. For each storm, cubic splines fitted along the *x* and *y* directions are used to interpolate the *u* and *v* components at points around circular paths concentric with the grid center. These are then transformed into Fourier series with the Fourier coefficients and saved for recall as needed for modeling a given storm. For each modeled storm, the velocities *u* and *v* at some location *x* and *y* are obtained through a combination of interpolation and scaling from the stored results.

In the use of the slab model, the resultant integrated wind speed (mean value throughout the BL) is adjusted to be representative of the maximum wind speed in the BL. The difference between the maximum wind speed and the depth-averaged wind speed is only a few percentage points, and varies dependent on whether averaging is performed over the assumed 1000-m BL height in the slab model or if the averaging height is the modeled BL depth (jet height).

The slab model approach brings out features that are not reproduced in simple gradient balance vortex models or empirical models such as those in Schwerdt et al. (1979) and Holland (1980). A comparison of the jet strength and its variation with azimuth from the two-dimensional slab model with the results of a full three-dimensional model of a translating hurricane from Kepert and Wang (2001) indicate that the two-dimensional slab model is able to produce horizontal variations of the magnitude of the jet characteristics that correspond to a height of ~500 m and that are similar to those from a full three-dimensional model. However, the slab model yields an area of slightly subgradient wind speeds in the right rear quadrant of the hurricane that does not appear in the three-dimensional model results. Furthermore, the variation of the jet height with azimuth is not provided using the slab model.

Variation of Wind Speed with Height. Vickery et al. (2009b) empirically model the variation of the mean wind speed $U(z)$ with height z in the hurricane BL using

$$U(z) = \frac{u_*}{k}\left[\ln(\frac{z}{z_o}) - 0.4(\frac{z}{H^*})^2\right] \tag{2-20}$$

where k is the von Karman coefficient with a value of 0.4, u_* is the friction velocity, z_o is the aerodynamic roughness length, and H^* is a BL height parameter. The BL height parameter H^* in Equation 2-20 decreases with increasing inertial stability according to

$$H^* = 343.7 + 0.260 / I \tag{2-21}$$

The inertial stability I is

$$I = \sqrt{(f + \frac{2V}{r})(f + \frac{V}{r} + \frac{\partial V}{\partial r})} \tag{2-22}$$

where V is the azimuthally averaged tangential gradient wind speed, f is the Coriolis parameter, and r is the radial distance from the center of the storm. The BL model in Vickery et al. (2009b) represents an azimuthally averaged model and ignores the variation in the shape of the hurricane BL as a function of azimuth in the hurricane that Kepert (2001) predicted.

As in Powell et al. (2003), the sea surface drag coefficient derived from the dropsondes in Vickery et al., (2009b) initially increases with wind speed in a fashion similar to that in Large and Pond (1980) and then reaches a maximum value and levels off or decreases (Figure 2-8). The mean wind speed at 10 m (U_{10}) at which the sea surface drag coefficient reaches this maximum is only about 25 m/s [i.e., less than the 40 m/s in Powell et al. (2003)] but varies with storm radius. This lower wind speed threshold is consistent with the value Black et al. (2007) estimate of about 23 m/s, although in Black et al. (2007) had limited measurements at wind speeds above 25 m/s. The combination of the empirical BL model and the variable cap on the sea surface drag coefficient yields ratios of V_{10}/V_G over the ocean of about 0.67 to 0.74, varying with both storm size and intensity.

Figure 2-9 compares the modeled and observed marine wind speed profiles that were computed using the drag coefficients in Figure 2-8, and the BL model in Equations 2-20 through 2-22, with the only input to the model consisting of the maximum (gradient) wind speed and distance from the center of the storm.

Dropsonde data are unfortunately very limited for velocity profiles over land, and there is therefore more reliance on models to estimate the characteristics of the hurricane BL over land. The standard engineering approach to modeling terrain-change effects is to assume that the wind speed at the top of the boundary-layer (BL)remains unchanged (but the BL height is free to change) and to adjust the winds beneath the BL height to be representative of those that are associated with the new roughness length. Vickery et al. (2009b), estimated the change in the BL height using the Kepert (2001) linear BL theory, but further increased the BL height increase that the Kepert model predicted so that the reduction in the surface-level winds the model predicted matched the Engineering Sciences Data Unit (ESDU) values for large BL height (ESDU 1982). The net result of the Vickery et al. (2009b) approach is increases in estimated BL height (from marine to open terrain) in the range of 60 to 100 percent, which indicates overland BL heights in the range of ~800 to ~1500 m dependent on wind speed and *RMW.* Powell et al. (2005) used a 100-percent increase in the BL height as the wind transitioned from sea to land.

Figure 2-10 shows the results of the BL height increase in Vickery et al. (2009b) as a comparison of the reduction in the surface-level winds that is brought about by the combined effects of increased BL height and increased surface roughness as wind transitions from marine to open over land terrain. The upper curve denotes cyclonic flow, and the lower curve shows the reduction in the wind speed under the Kepert (2001) BL height method under the assumption that there is no change in the mean wind speed at the top of the BL.

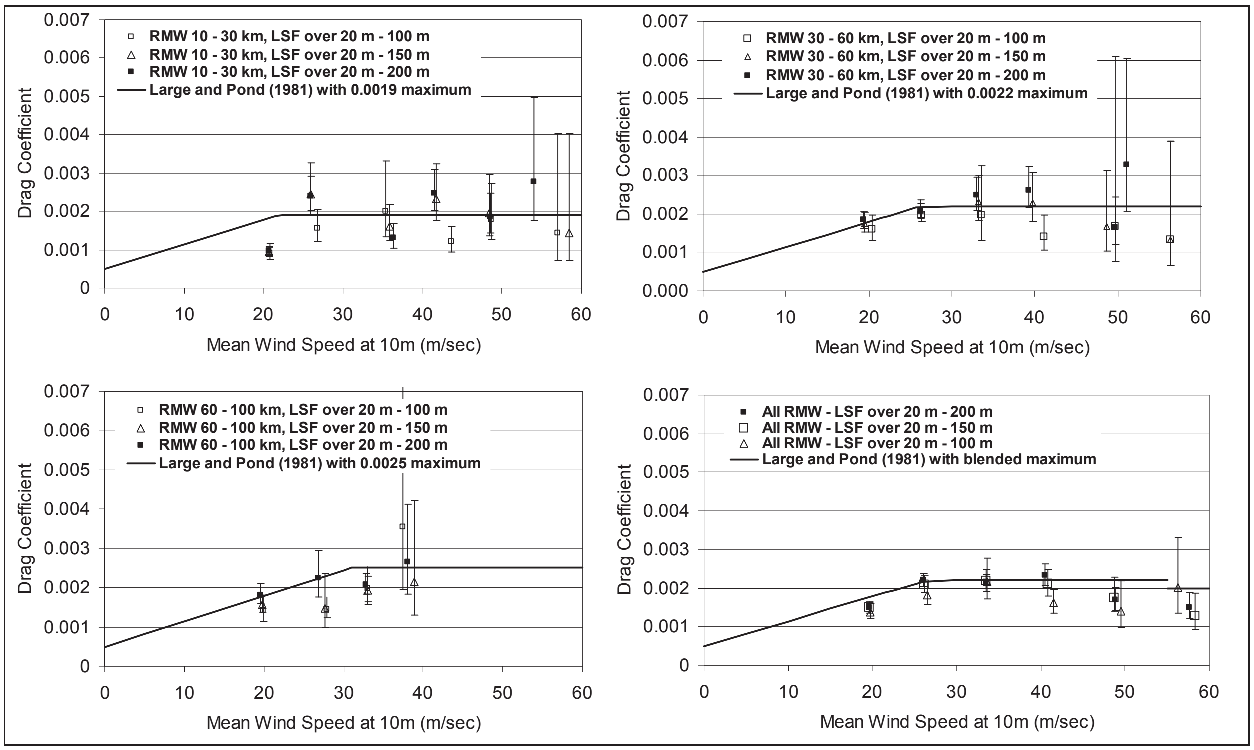

Figure 2-8. Variation of the sea surface drag coefficient with U_{10} near *RMW (LSF=Least Squares fit)*.

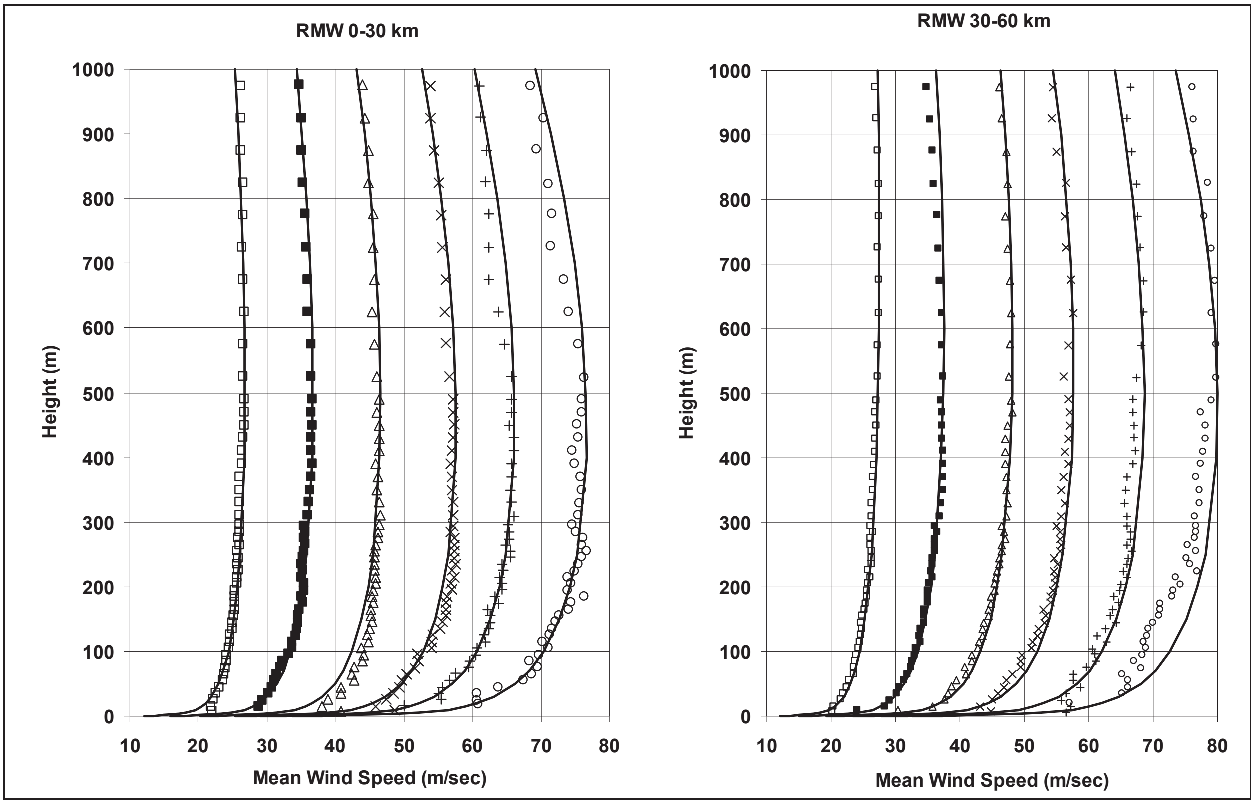

Figure 2-9. Modeled and observed hurricane mean velocity profiles over the open ocean for a range of wind speeds (points represent data).

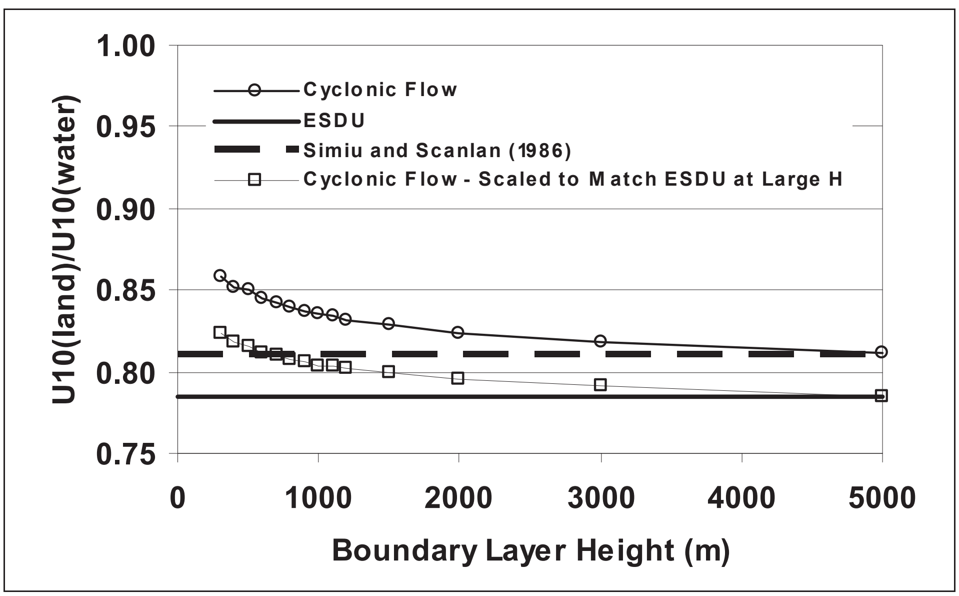

Figure 2-10. Ratio of the fully transitioned mean wind speed over land (z_o = 0.03 m) to the mean wind speed over water (z_o = 0.0013 m) as a function of BL height.

Sea-Land Transition. As the wind moves from the sea to land, the value of the maximum wind speed at a given height in the new rougher terrain asymptotically approaches the fully transitioned value over some fetch distance *F*. Published estimates of the fetch length vary widely, ranging from a few kilometers (e.g., Melbourne 1992) to in excess of 100 km (ESDU 1982; Deaves 1981). Powell et al. (1996) suggest that wind measurements at a height of 10 m taken as far as 20 to 30 km inland are still influenced by the upstream marine roughness. For modeling the transition from sea to land, the ESDU model is used but the limiting fetch distance is reduced to 20 km from the ~100 km used in ESDU (1982). The use of the smaller fetch distance is consistent with the lower BL heights of tropical cyclones (~600 m) in comparison with much larger values (~3000 m) used in ESDU where H scales as u_*/f rather than the square root of $(2K/I)$.

The ESDU transition model was chosen because it provides a means to transition the wind speeds that are associated with an arbitrary averaging time (i.e., hourly mean, 10 min mean, peak gust, etc.). Figure 2-11 shows a comparison of the original and modified ESDU transition functions for the gust and hourly mean wind speeds. In either model it is evident that, at a distance of about 1 km, approximately 60 percent of the transition (or wind speed reduction) has already occurred. An exact value of F is difficult if not impossible to verify, and an inspection of Figure 2-11 indicates that the error in the predicted wind speed is not particularly sensitive to the exact value of F (for F > 10 km). For example, the difference between the model estimates of the degree to which the wind speed has reached equilibrium at 10 km, [approximately where the difference between the ESDU, (F ~ 100 km) and the modified ESDU, (F = 20 km] function reaches a maximum) is about 10 percent. Figure 2-10 shows that the maximum reduction in the mean wind speed using the ESDU model is about 17 percent; therefore, the magnitude of the wind speed error for the assumed fetch length at this location is about 10 percent of 17 percent, or ~1.7 percent.

Wind Field Model Validation. The final wind field model is evaluated through comparisons of modeled and measured wind speeds for hurricanes that make landfall in the United States. In the verification process all measured gust wind speeds have been adjusted to be representative of 3-s gust speeds at a height of 10 m, in either open terrain (z_o = 0.03 m) or marine conditions. In the case of marine wind speed measurements from 3-m discus buoys, the measured wind speeds in high wind cases have been

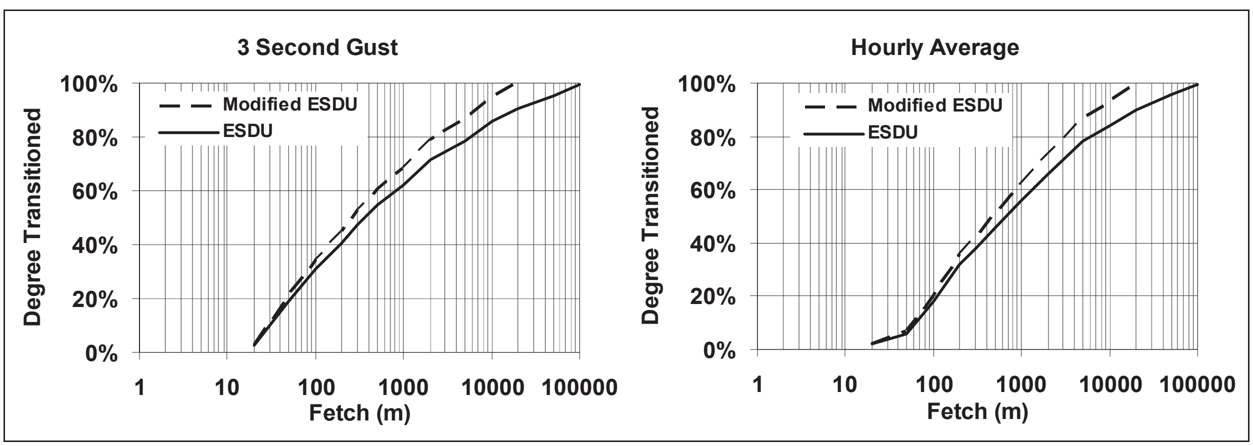

Figure 2-11. ESDU and modified ESDU wind speed transition functions at 10-m elevation.

increased by 10 percent to account for the underestimates in the measured wind speeds as Gilhousen (2006) describes.

Each hurricane is modeled using information on the hurricane track (position and central pressure) from the National Hurricane Center coupled with estimates of the RMW and the

Holland *B* parameter (Holland 1980). The modeled pressure field is axisymmetric, but varies with time. The initial estimate of the *RMW* is usually obtained from H*Wind dataset snapshots of the hurricane wind field at or near the time of landfall. The final estimates of *B* and the *RMW* and their variation with time after landfall are obtained through an iterative approach by reproducing the overall shapes of the wind speed and direction traces and surface pressure traces from as many ground stations as possible. Figures 2-12 and 2-13 are examples of comparison of wind speed and pressure data from stations near the point of landfall for different hurricanes. The assignment of *RMW* and *B* is performed with the objective of describing the overall shape of the wind speed and pressure time histories, rather than matching the individual station maximum wind speeds. The modeling of the hurricane wind field using a symmetric pressure field is a simplification of real world hurricanes, which often are characterized by *RMW* and *B* values that vary with both azimuth and radius. However, as will be shown later, in most cases the model provides a reasonably accurate representation of the overall hurricane wind field, particularly in areas that experience the strongest winds (i.e., near the *RMW*). An example of a hurricane where modeling the wind field with a single value of *B* and *RMW* fails to adequately model the surface level winds is Hurricane Wilma in South Florida.

An extensive set of validation studies has been performed using the hurricane wind field/BL model described in this section through comparisons of modeled and observed wind speed and pressure data for 24 land-falling hurricanes since 1985 (Figure 2-14). In each validation study, estimates of *RMW*, *B*, and their variations in time were obtained using the iterative approach described earlier, with the final selection of the values of *B* and *RMW* that were used to define the hurricane being subjective rather than objective. The number of anemometer stations with either complete continuous records of wind speeds, or records where the maximum wind speed during the storm was measured, was 258. In many cases, additional incomplete records of wind speeds and pressures were used to assist in estimating the variation in both *RMW* and *B*. Figure 2-14 presents individual storm summary x-y plots comparing modeled and observed peak gust wind speeds from twenty four different landfalling hurricanes. Figure 2-15 shows scatter plots that summarize the comparisons of modeled and observed maximum peak gust wind speeds the storms produce. Each plot gives the slope and r^2 values from a linear regression analysis (where the regression line is forced to pass through the origin). In all but one case (Hurricane Wilma), the regression slope is within 4 percent of unity.

The differences between the modeled and observed wind speeds in Figure 2-15 are used to define the wind field model uncertainty, which is used in the estimation of the wind speed hazard curves. The comparisons of modeled and observed peak-gust wind speed indicate that the coefficient of variation of the model error is about 11 percent. Figure 2-15 presents a comparison of modeled and observed peak gust wind speeds obtained from 26 different hurricanes, and includes a total of 227 measurements where the maximum wind speed at a site was recorded. For model gust wind speeds greater than 30 m/sec, the coefficient of variation reduces to 10%.

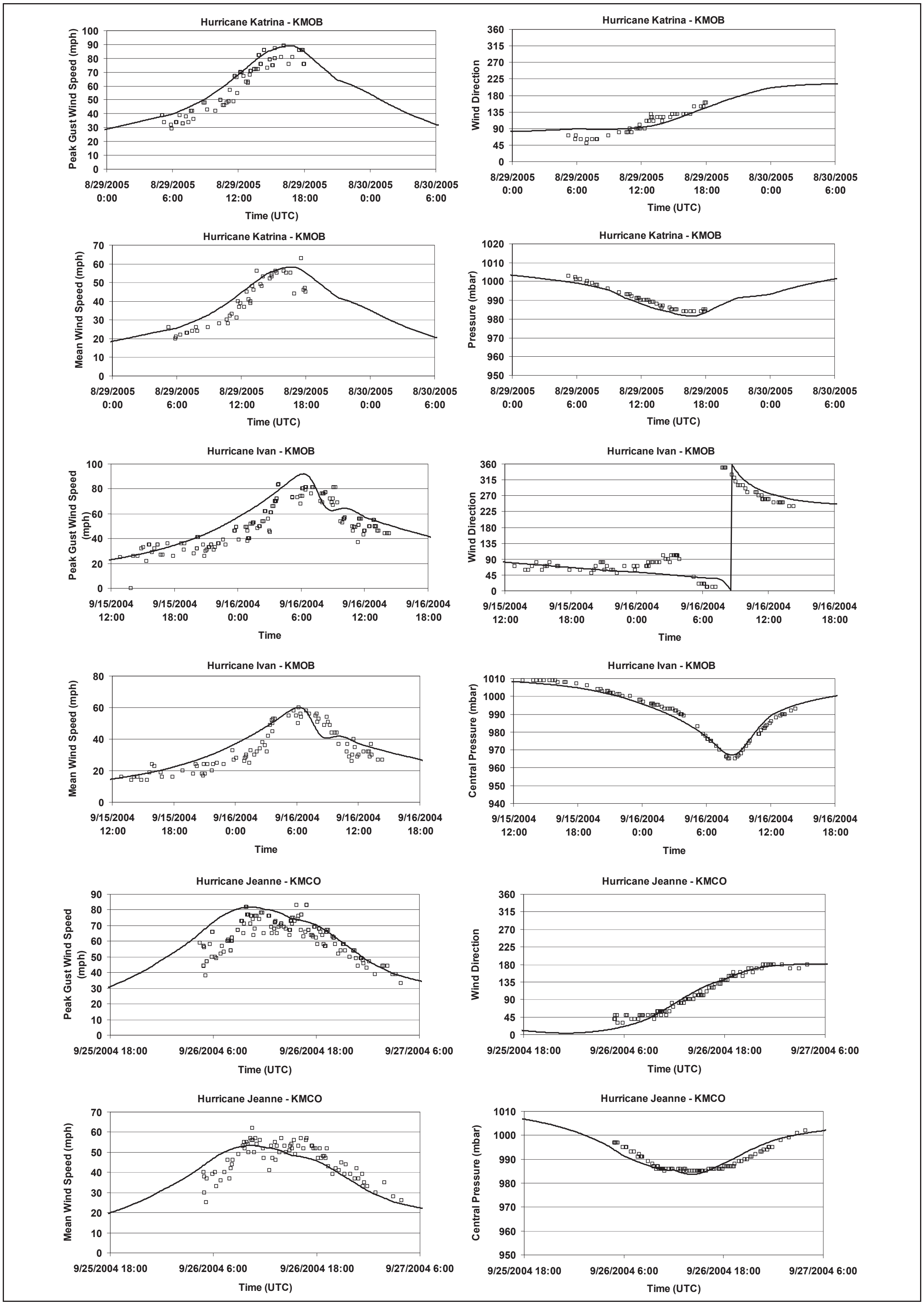

Figure 2-12. Comparison of modeled and observed wind speeds, wind directions, and pressures at inland locations.

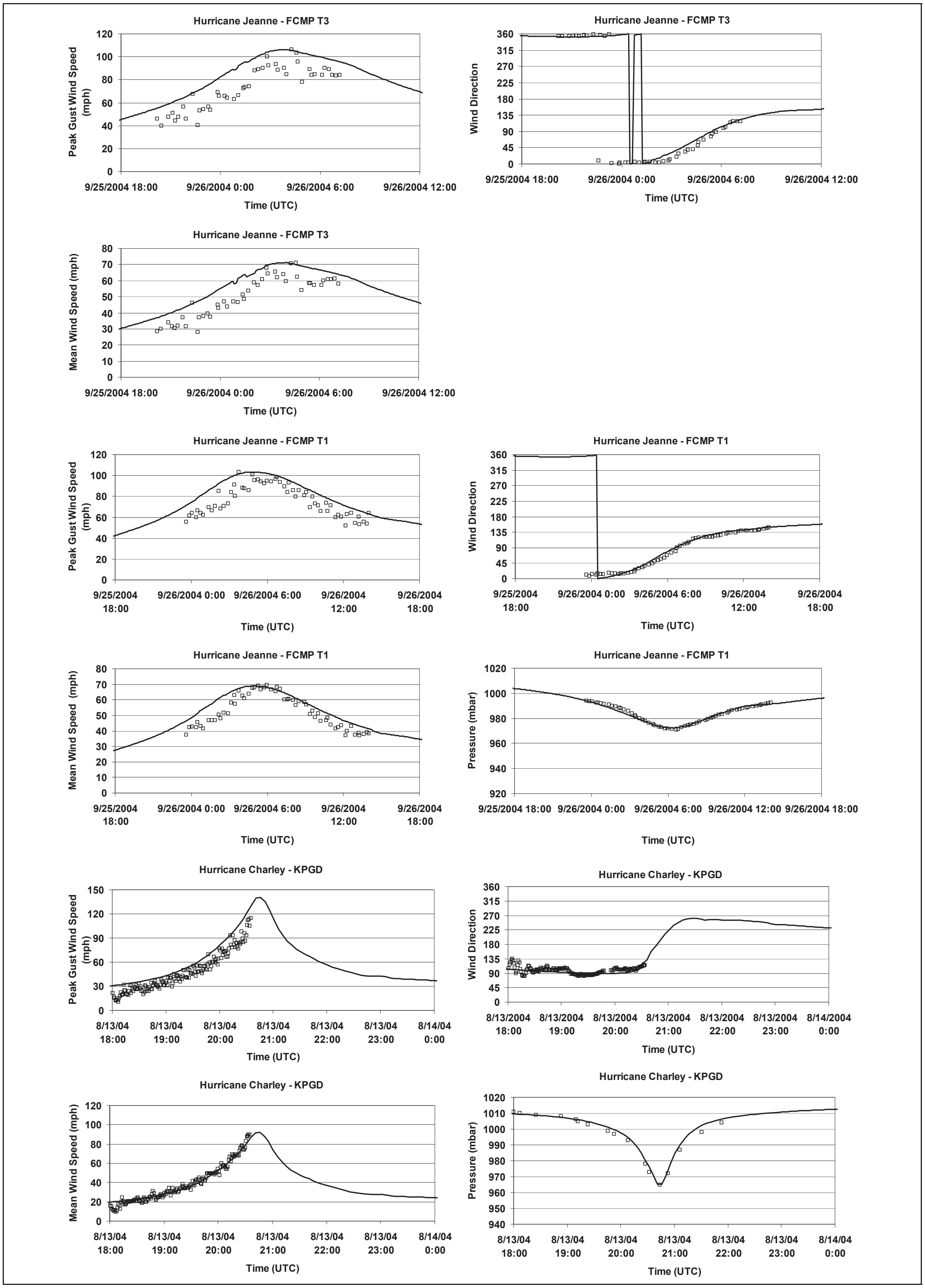

Figure 2-13a. Comparison of modeled and observed wind speeds, wind directions, and pressures at coastal and near-coastal locations.

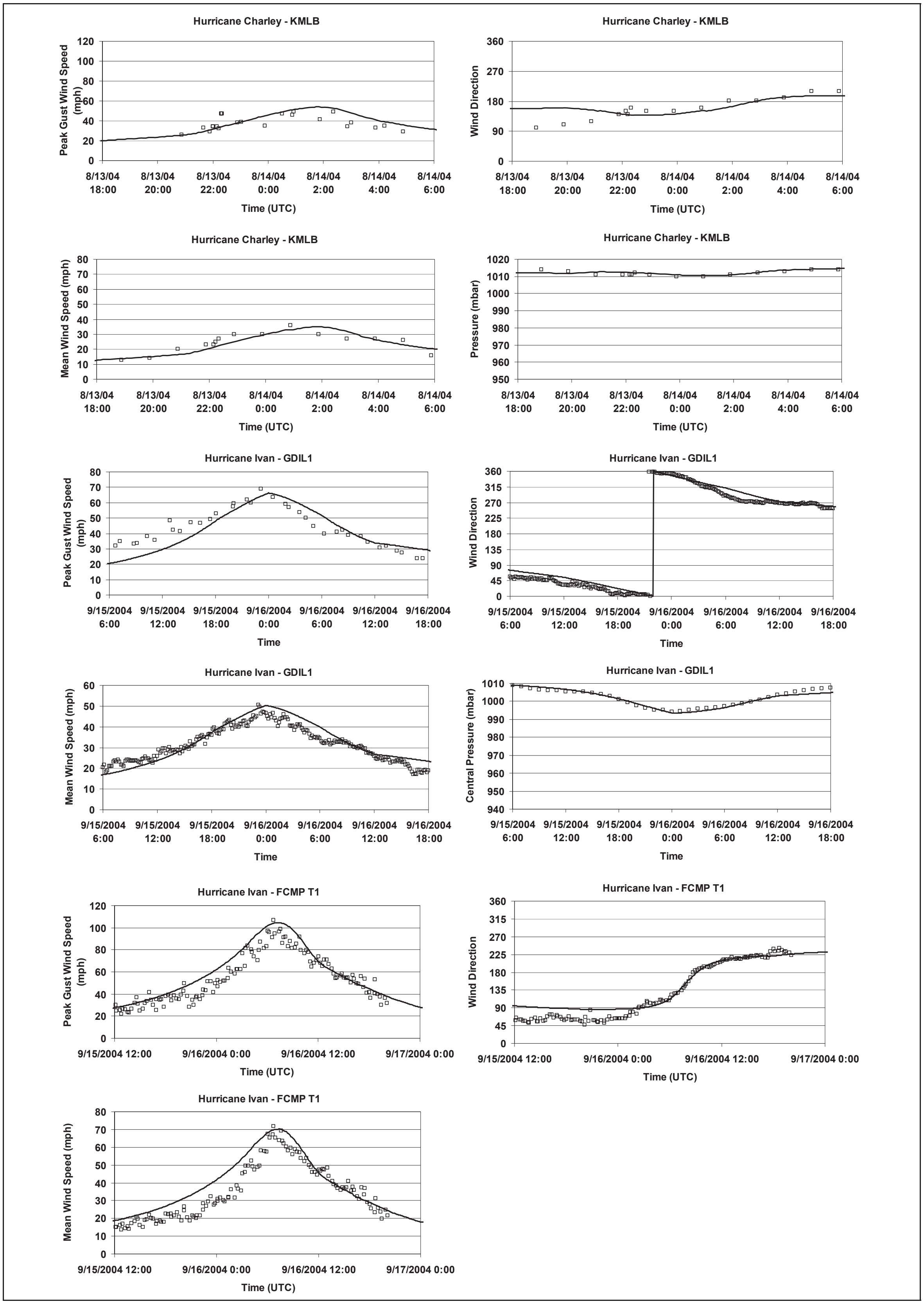

Figure 2-13b. Comparison of modeled and observed wind speeds, wind directions, and pressures at coastal and near coastal locations.

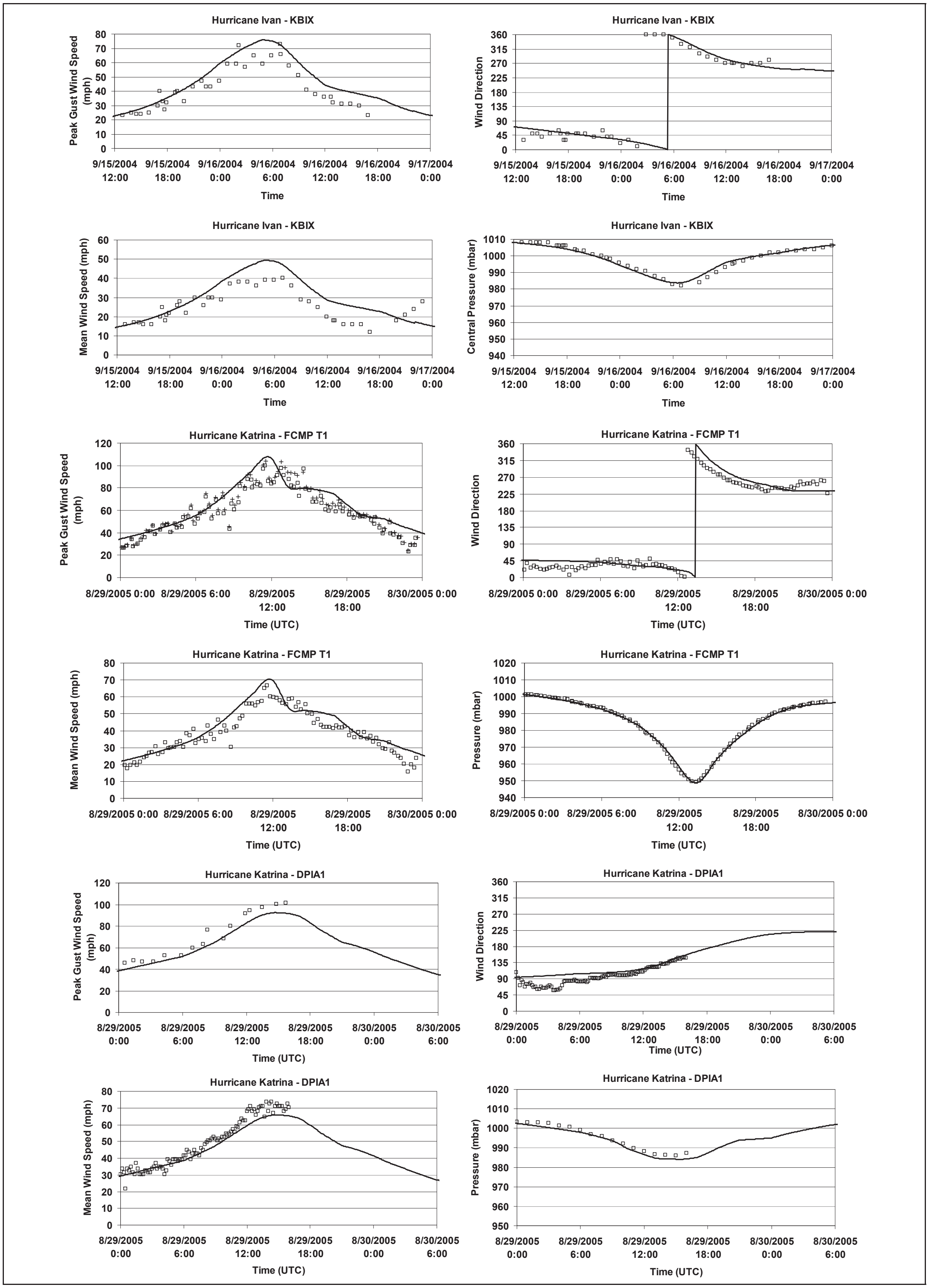

Figure 2-13c. Comparison of modeled and observed wind speeds, wind directions, and pressures at coastal and near coastal locations.

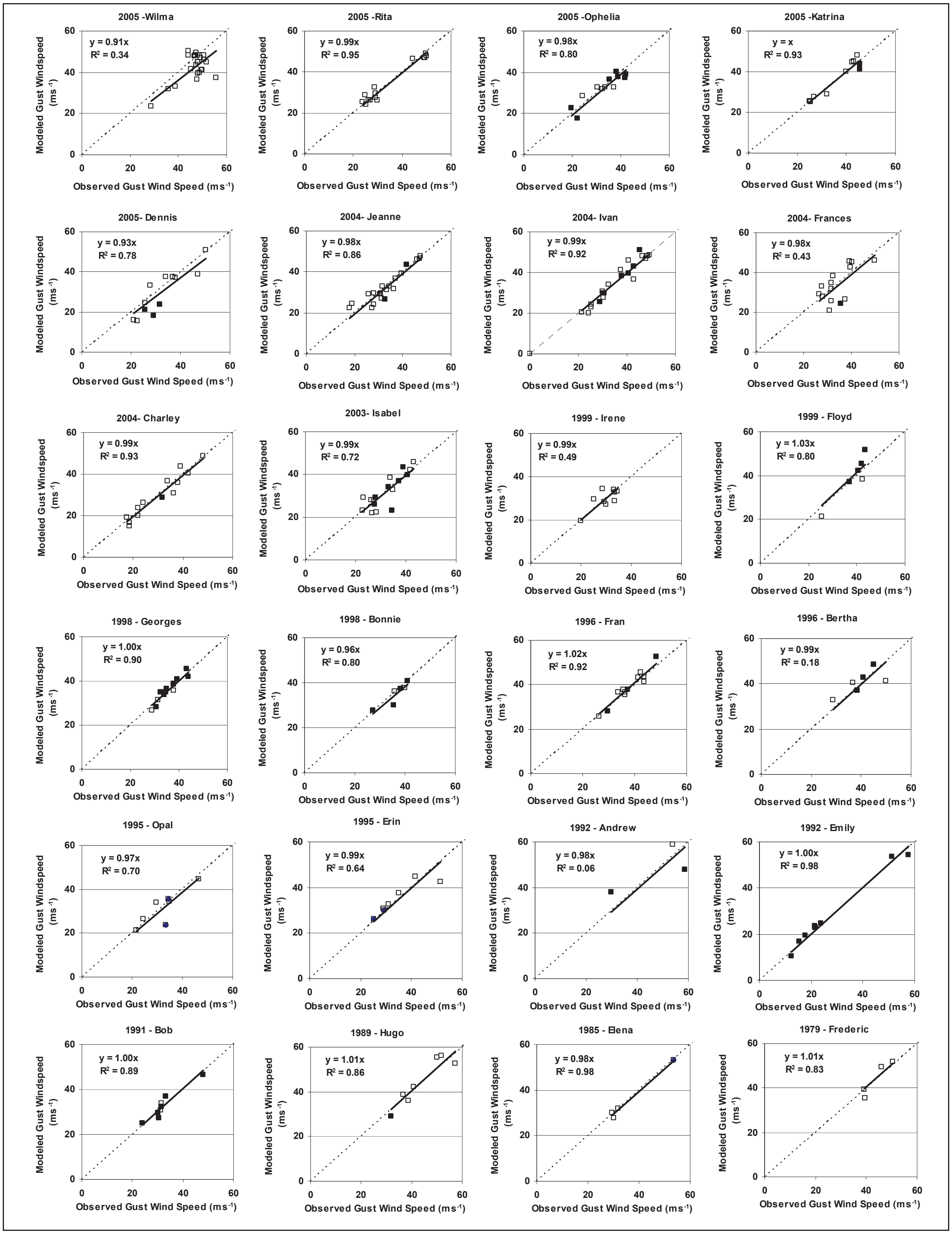

Figure 2-14. Comparison of modeled and observed maximum peak-gust wind speeds for 24 land-falling hurricanes. Open squares represent land-based measurements; solid squares represent marine-based measurements. All wind speeds are at a height of 10 m in either open terrain or marine conditions.

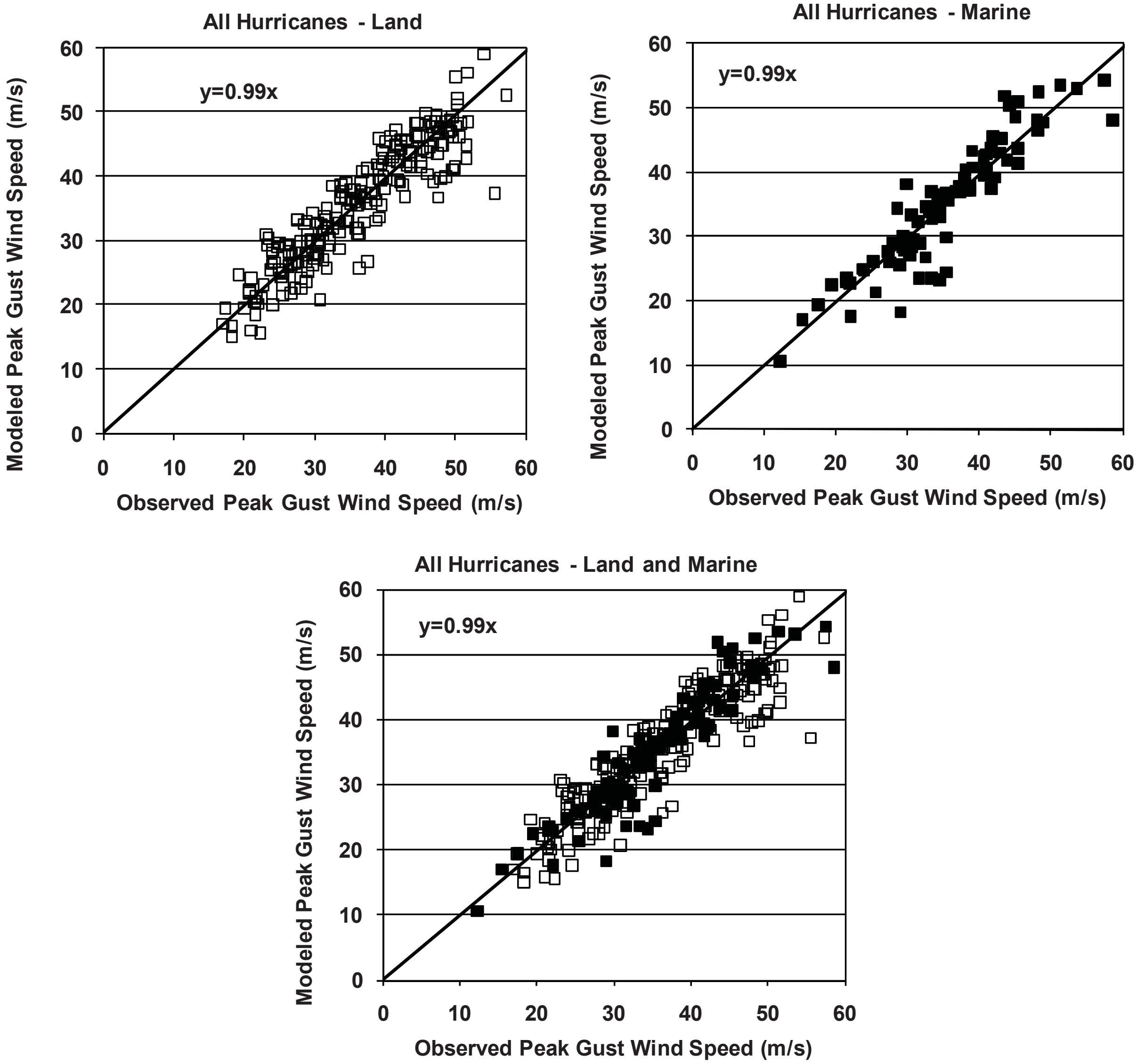

Figure 2-15. Example comparisons of modeled and predicted maximum surface level peak-gust wind speeds in open terrain from land-falling hurricanes. Wind speeds measured on land are given for open terrain (open squares) and wind speeds measured over water are given for marine terrain (filled squares).

2.2 Model Updates and Improvements

In the development of the wind speed contours for annual exceedance probabilities of 10^{-6} and 10^{-7}, this analysis made three changes to the modeling approach. The first change was to the simulation methodology in which a weighted sampling method replaced the full Monte Carlo simulation technique of Vickery et al. (2009a); this enabled more efficient simulation of millions of years of hurricanes. The other two changes are changes in the estimation of gust wind speeds under a set of hurricane parameters (i.e., changes to the wind field model).

2.2.1 Weighted Sampling

This analysis could not use the direct Monte Carlo methodology in Vickery et al. (2009a) for development of the wind speed hazard curves at each of the 3575 sites for annual exceedance probabilities as low 10^{-6} and 10^{-7} because the required computing time is prohibitive. Using the model described in the previous sections, a ten million year hurricane simulation was performed. In this simulation the hurricane tracks and landfall characteristics of all storms are retained, but no wind speeds other than the computation of the maximum wind speed at the time of landfall are computed. Table 2-1 presents a summary of the simulation results where the annual probability of landfall of hurricanes by region and Saffir-Simpson category are presented. The landfall categories are presented as those categorized by the central pressure at the time of landfall and those categorized by the modeled maximum one minute wind speed at a height of 10 m over water at the time of landfall. Note that no category five hurricanes (categorized by either pressure or wind speed) make landfall north of the North Carolina-Virginia border. This ten million year storm set, defined by the full simulated tracks and the landfall wind speeds is used in the weighted sampling method described below to reduce the number of detailed wind model simulations needed at each grid point to develop the hurricane hazard maps.

Table 2-1 Modeled annual hurricane landfall frequency by Saffir-Simpson scale and landfall region.

Landfall Region	Saffir-Simpson Category by Pressure					Saffir-Simpson Category by Wind Speed				
	CAT-1	CAT-2	CAT-3	CAT-4	CAT-5	CAT-1	CAT-2	CAT-3	CAT-4	CAT-5
Texas	0.0204	0.0617	0.1228	0.0482	0.0006	0.0994	0.0776	0.0640	0.0122	0.0007
Louisiana	0.0294	0.0738	0.0710	0.0346	0.0075	0.1075	0.0524	0.0390	0.0149	0.0026
MS/AL	0.0167	0.0323	0.0410	0.0230	0.0061	0.0505	0.0301	0.0251	0.0112	0.0021
NW FL	0.0482	0.0628	0.0551	0.0090	0.0009	0.1019	0.0433	0.0253	0.0050	0.0004
SW FL	0.0299	0.0220	0.0604	0.0229	0.0109	0.0510	0.0335	0.0398	0.0168	0.0051
SE FL	0.0218	0.0356	0.0848	0.0436	0.0137	0.0697	0.0547	0.0487	0.0217	0.0047
NE FL	0.0080	0.0171	0.0098	0.0022	0.0002	0.0247	0.0080	0.0036	0.0009	0.0001
GA/SC	0.0212	0.0363	0.0236	0.0125	0.0020	0.0570	0.0209	0.0126	0.0045	0.0006
NC	0.0208	0.0395	0.0715	0.0104	0.0004	0.0781	0.0395	0.0211	0.0036	0.0002
VA/MD/NJ	0.0032	0.0059	0.0126	0.0010	0.0000	0.0137	0.0061	0.0027	0.0003	0.0000
NY/NE	0.0142	0.0214	0.0416	0.0035	0.0000	0.0433	0.0213	0.0136	0.0026	0.0000

In the weighted sampling approach, the analysis assumed that the wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7} are from land-falling hurricanes. This assumption implies that the peak winds of by-passing hurricanes do not contribute to the high wind speed exceedance probabilities. This is a reasonable assumption in that the strongest winds are located in the eyewall on the right hand side of the model hurricane and near to the radius to maximum winds. In the case by-passing hurricanes, the land will not be affected by the portion of the hurricane having the strongest winds. Figure 2-16 shows the number of storms that make landfall that produce a peak-gust wind speed within the indicated wind speed range. The wind speed bin width in Figure 2-16 is 5 mph (2.2 m/s).

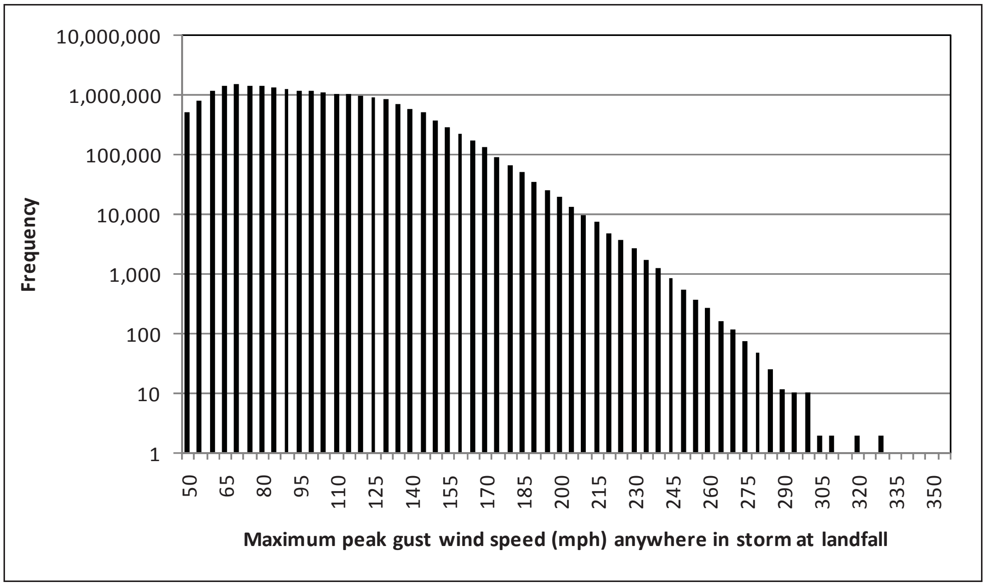

Figure 2-16. Number of hurricanes producing a peak-gust wind speed (anywhere within the model hurricane at a height of 10m, over water) with the indicated wind speed (indicated wind speeds represent the lower value of the bin having a width of 5 mph).

Each event Figure 2-16 depicts has a probability of occurrence of 1/*N* where *N* is the total number of land-falling hurricanes. Hurricanes that make landfall with a maximum peak-gust wind speed of less than 170 mph (76 m/s) (at a height of 10m, over water, anywhere within the storm) are not going to contribute significantly to the wind speed hazard curve for rare events. This 170 mph (76 m/s) marine wind speed is equivalent to an open terrain peak gust wind speed of about 150 mph (67 m/s), but this value varies with storm radius. To speed up the computational effort a weighted sampling approach is employed. Using the weighted sampling approach, only a fraction of the model hurricanes that produce a wind speed indicated by a given wind speed bin are retained. Each hurricane that is retained is assigned a statistical weight w_i where

$$w_i = \frac{N_{p_i}}{N_{R_i}} \tag{2-23}$$

and where N_{p_i} is the total number of hurricanes that produce a peak-gust wind speed within the wind speed bin *i*, and N_{R_i} is the number of hurricanes that produce a wind speed within the wind speed that are retained for use in the development of the hazard curve. For example, if from the full storm set 1,000,000 hurricanes have a maximum wind speed between 100 (45 m/s) and 105 mph (47 m/s) at the time of landfall, but only 2,000 of these storms are retained in the reduced storm set, when performing the full wind speed simulations for each grid point, the weight, or relative frequency of each of these simulated storms is equal to 500 times that of a single storm. In other words, the contribution to the wind speed exceedance probability at each location where the simulated storm produces a wind speed is increased by a factor of 500.

Figure 2-17 shows the fraction of retained storms (1/w_i) as a function of wind speed bin, and shows that all storms having wind speeds greater than 170 mph (67 m/s) (peak gust at a height of 10m over water) at the time of land fall are retained A total of just over 3.5 million storms were retained for development of the hurricane wind speed hazard curves.

The probability that the tropical cyclone wind speed (independent of direction) is exceeded during time period *t* is

$$P_t(v > V) = 1 - \sum_{x=0}^{\infty} P(v < V \mid x)\, p_t(x) \qquad (2\text{-}24)$$

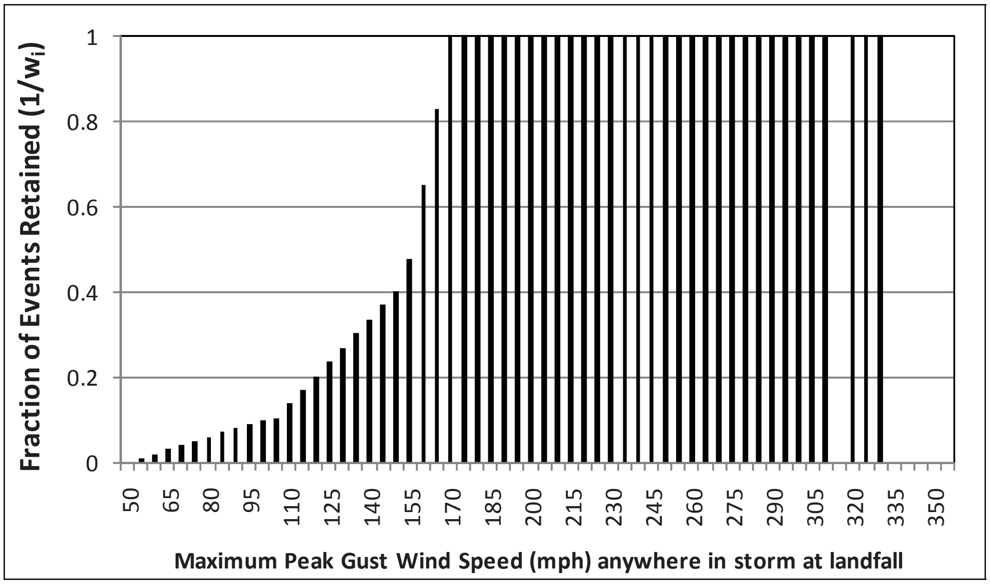

Figure 2-17. Fraction of retained storms versus maximum peak-gust wind speed at a height of 10m over water at the time of landfall (indicated wind speeds represent the lower value of the bin having a width of 5 mph (2.2 m/s)).

where $P(v < V \mid x)$ is the probability that velocity *v* is less than *V* when *x* storms occur, and $p_t(x)$ is the probability of *x* storms occurring during period *t*. From Equation 2-24, defining $p_t(x)$ as Poisson and *t* as 1 year, the annual probability P_a of exceeding a given wind speed is

$$P_a(v > V) = 1 - \exp[-\upsilon P(v > V)] \qquad (2\text{-}25)$$

where υ represents the average annual number of storms that produce a wind speed at a location (i.e., the annual occurrence rate) and $P(v > V)$ is the probability that the wind speed of the tropical cyclone at the location of interest is greater than *V*. Using the weighted storm set, $P(v > V)$ is computed from

$$P(v > V) = 1 - \frac{\sum_{i=1}^{N_{vi}} w_i}{\sum_{i=1}^{N_{Ri}} w_i} \qquad (2\text{-}26)$$

where the summation in the numerator includes the weights of all storms that produce a wind speed less than *v*. The summation in the denominator includes all retained weights and is equal to *N*, which is the total number of storms that produce a wind speed at the location of interest.

To examine the effect of the weighted sampling method on the wind speed hazard curve, the hazard curve was derived at three locations with and without the use of the weighted sampling approach. The locations are Miami, New York Area, and coastal Maine. The similarity of the curves in Figure 2-18 for All Storms and for the reduced storm set demonstrates that the weighted sampling approach is valid. Furthermore, the full storm set used to generate the wind speed hazard curves shown in Figure 2-18 includes by-passing hurricanes, indicating that the omission of by-passing hurricanes in the reduced storm set has a negligible effect on the rare event wind speeds.

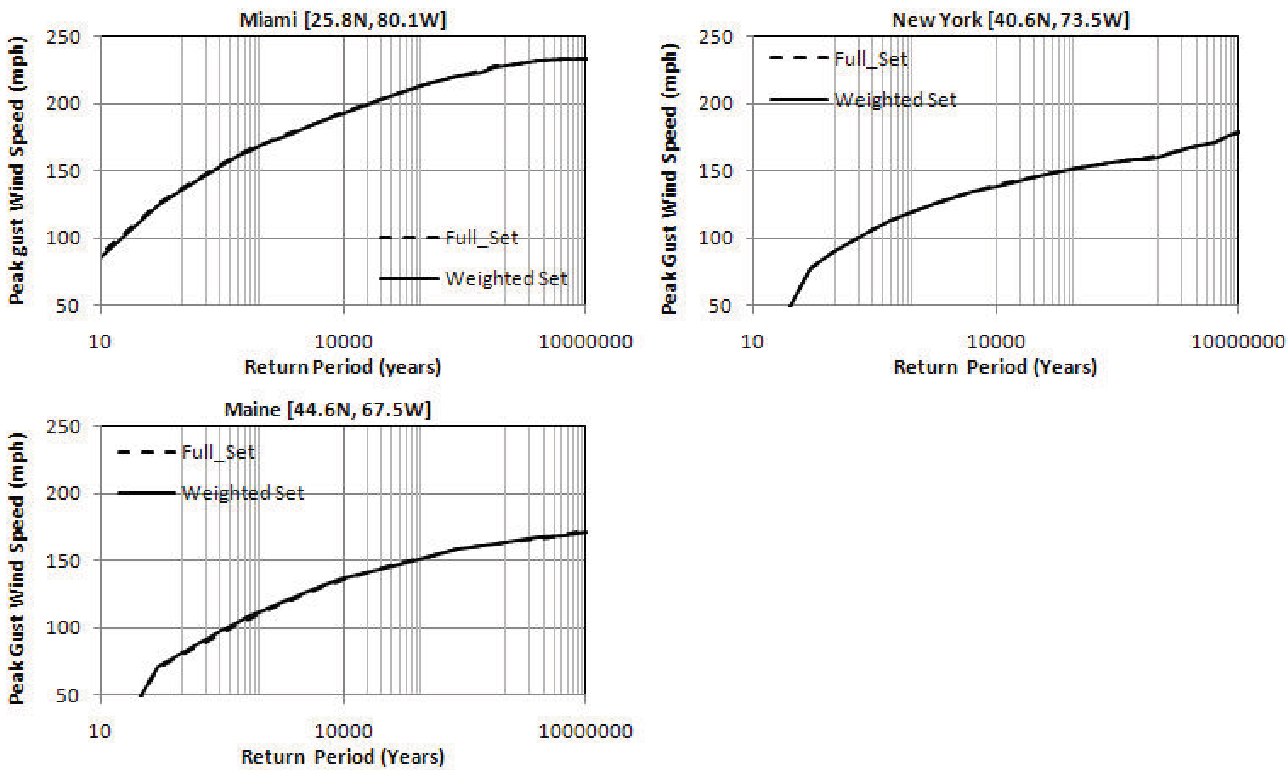

Figure 2-18. Effect of weighted sampling on wind speed hazard curves.

2.2.2 Non-Stationary Gust Factor Modeling

In the development of the wind speed maps in ASCE/SEI 7 (ASCE/SEI 2006), and those in Vickery et al. (2000a, 2009a), the wind field model produces the peak-gust wind speeds by multiplying the mean wind speed from the hurricane wind field model by a gust factor. The gust factor model is based on the ESDU (1982, 1983) models for atmospheric turbulence near the ground. As Vickery and Skerlj (2005) describe, the ESDU models are suitable for estimating the peak-gust wind speeds in a hurricane. As implemented in the Vickery et al. (2000a, 2009a) simulation models, the gust factor is assumed to be associated with a hurricane wind speed where the strongest winds have duration of about 1 hr. This duration assumption is reasonable for most hurricanes, and Vickery et al. (2000b, 2009b) used it in all of their wind field model validation examples. However, for small fast-moving hurricanes such as those likely responsible for the extremely rare winds under investigation here this 1-hr assumption might not be appropriate. To model the effect of storm duration on the peak gust better, the analysis revisited the formulation for the gust factor.

The formulation for the peak-gust wind speed for a hurricane this analysis used extends the approach for a stationary wind speed in Davenport (1964) by assuming the model hurricane wind trace consists of a series of piecewise stationary segments (Figure 2-19).

Using the approach in Davenport (1964), the distribution of the maximum wind speed within each segment shown in Figure 2-19 is computed. Each of the distributions is then combined as independent distributions to obtain one distribution for the maximum gust wind speed. This distribution is then integrated to compute the mean, or expected, maximum gust over the duration of the hurricane.

Following Davenport (1964), a nondimensional variable η is defined as

$$\eta = \frac{u - \bar{u}}{\sigma(u)} \tag{2-27}$$

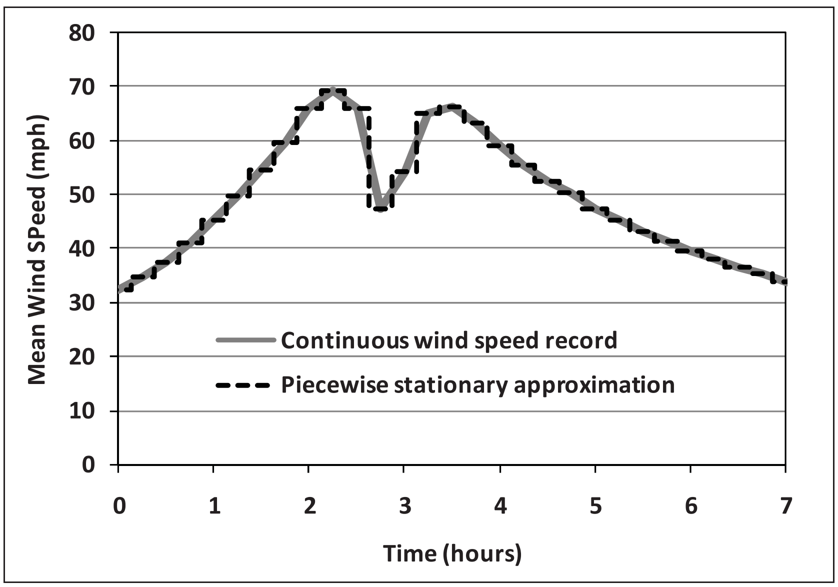

Figure 2-19. Piecewise linear approximation of hurricane wind speed trace for computation of the nonstationary gust factor.

where $\bar{u}$ and $\sigma(u)$ are the mean and standard deviation of the wind speed, which is assumed to be a stationary process with normal distribution.

Davenport (1964) shows that the cumulative density function for the largest maxima within a segment *i* is

$$P_{\max_i}(\eta) = \exp\left[-\nu T \exp\left(-\frac{\eta^2}{2}\right)\right] \tag{2-28}$$

where *T* is the duration of the segment and υ is the cycling rate of the wind speed.

The cumulative density for the peak-gust wind speed $P_{\max}(u)$ within segment *i* is

$$P_{\max_i}(u) = \exp\left[-vT\exp\left(-\frac{1}{2}\left(\frac{u-\overline{u}}{\sigma(u)}\right)^2\right)\right] \tag{2-29}$$

In the case of multiple segments, the cumulative density function over the entire wind speed trace is

$$P_{\max}(u) = \prod_{i=1}^{N} P_{\max_i}(u) \tag{2-30}$$

where *N* is the total number of 15-min segments in the interval.

The mean value of the peak-gust wind speed *û* is

$$\hat{u} = \int_0^\infty u p_{\max(u)du} \tag{2-31}$$

Where, as given in Davenport (1964) $p_{\max}(u)$ is the probability density function for the peak-gust wind speed from

$$p_{\max}(u) = \frac{dP_{\max}}{du} \tag{2-32}$$

Davenport (1964) shows that the solution to Equation 2-31 for a single segment stationary process is

$$\hat{u} = u + g\sigma(u) \tag{2-33}$$

where the peak factor *g* is

$$g = \sqrt{2\ln vT} + \frac{0.577}{\sqrt{2\ln vT}} + \ldots \tag{2-34}$$

The higher order terms in Equation 2-34 are generally ignored, and Equations 2-33 and 2-34 are routinely used in wind engineering applications to estimate a peak-gust wind speed (and other peak responses for normally distributed processes) assuming *T* is equal to 1 hr. For estimating the peak-gust wind speed, Equations 2-29 through 2-32 are solved for each simulated hurricane to compute a peak-gust wind speed that accounts for storm duration.

Using the wind speed trace in Figure 2-19 as an example, the estimated peak-gust wind speed using the nonstationary gust factor model is 105 mph (46.7 m/s), whereas the peak-gust wind speed using the traditional approach (a single gust factor that is computed using *T* equal to 1 hr and applied to the largest mean wind speed in the record) is 106.0 mph (47.4 m/s), a difference of less than one percent. Figure 2-20 shows the effect of the nonstationary gust factor on the predicted peak-gust wind speeds at two sites plotted versus annual exceedance probability. From Figure 2-20 it is evident that the effect of the nonstationary gust factor increases with decreasing exceedance probability and serves to decrease the predicted gust wind speed. The effect of the nonstationary gust factor is more pronounced as the exceedance probability decreases because these rarer events are produced by small fast-moving storms that are more sensitive to duration than the more common typical hurricanes. The effect of the nonstationary gust factor modeling is negligible for annual exceedance probabilities greater than about 10^{-3} (i.e., return periods less than 1000 years).

2.2.3 Modeling Translation Speed Effects in Rapidly Moving Hurricanes

As discussed, the wind field model here and in Vickery et al. (2000b, 2009b) for hurricane wind speeds is based on the numerical solution to the equations of motion for a translating hurricane. This model includes the full translation speed effect. The use of the full translation speed in the model differs from the approach in some simpler wind field models, such as that described in Batts et al. (1980), which only used half of the storm translation speed. Emanuel et al. (2006) used a simple slab model but also use a reduced value of the translation speed (60 percent) in the wind speed computations. While the wind field model has been extensively validated through comparisons of modeled and observed wind speeds, none of these detailed comparisons has been for very fast-moving hurricanes.

A qualitative comparison of the estimated maximum wind speeds of the 1938 New York hurricane (Myers and Jordan 1956) suggests that the version of the wind field model that uses the full translation speed overestimates the maximum wind speeds by about 10 percent. The 1938 hurricane was moving north at a speed of about 20 m/s at the time it crossed the coast of Long Island. To reduce the overestimation of the translation speed effect on rapidly moving hurricanes, this analysis used a reduced translation speed so that the effective translation speed c_{eff} was defined by

$$
\begin{aligned}
c_{\text{eff}} &= c, && c < 15 \text{ m/s} \\
c_{\text{eff}} &= 15 + \frac{c-15}{3}, && 15 < c < 30 \text{ m/s} \\
c_{\text{eff}} &= 20, && c > 30 \text{ m/s}
\end{aligned}
$$

where c is the original translation speed.

The introduction of the modified translation speed eliminated the overestimate of the wind speeds that were evident in the simulation of the 1938 hurricane, which reduced the hourly mean wind speeds from over 100 mph(45 m/s) to 90 mph (40 m/s), which is consistent with the analysis in Myers and Jordan (1956).

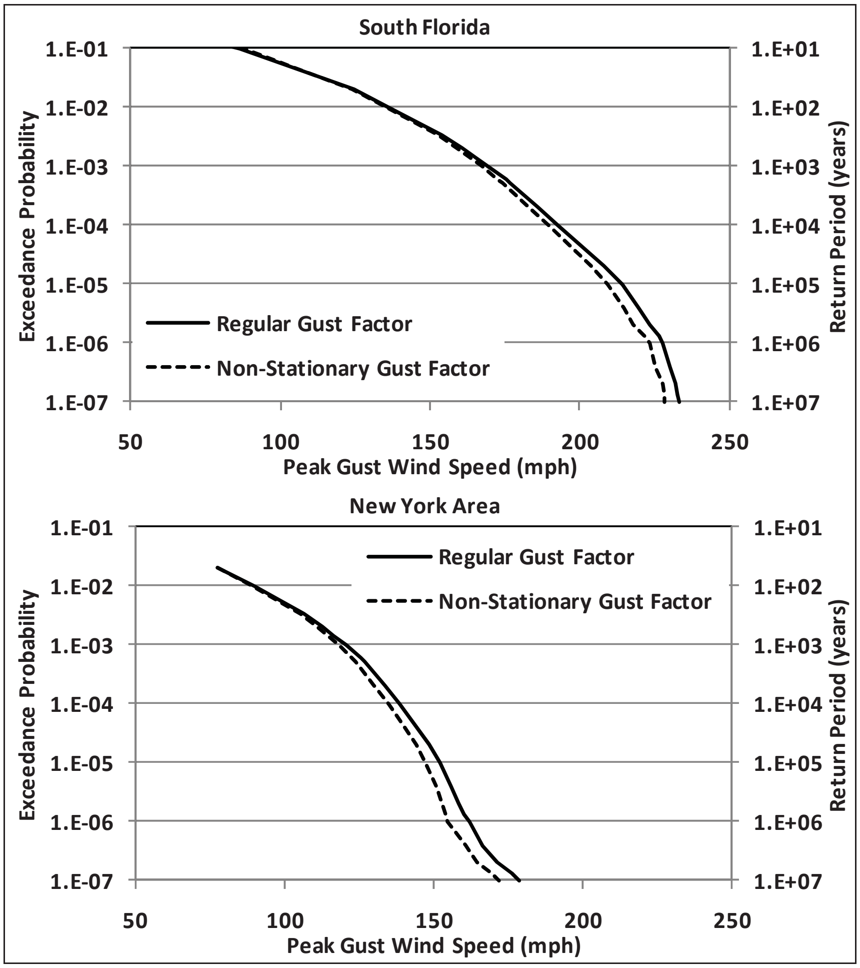

Figure 2-20. Effect of nonstationary gust factor modeling on predicted peak-gust wind speeds as a function of annual exceedance probability.

2.3 Modeling Wind Field Model Uncertainty

As Vickery et al. (2009b) demonstrated, the wind field model for the peak-gust wind speeds in a land-falling hurricane produces unbiased estimates of the peak-gust wind speed using the hurricane parameters in the wind field model. The meteorological parameters in both the wind field model validation studies and in the stochastic hurricane simulation model, are the central pressure, *RMW*, *B*, and the translation speed. The primary nonmeteorological parameter that influences the comparisons of modeled and observed wind speed is the estimate of the surface roughness. As previously indicated in Figure 2-15, the comparisons of modeled and observed peak-gust wind speed indicate that the coefficient of variation of the model error is about 11 percent. A number of factors contribute to the wind field modeling error including measurement error, error in the estimation of the surface roughness, errors in the estimation of the wind field model input parameters, and errors that relate to true deficiencies of the wind field model. These deficiencies include but are not limited to the inability of the gust factor model to capture convective gusts and the inability of an axisymmetric pressure field model with spatially invariant values of *B* and *RMW* to reproduce the more complex pressure fields that occur in nature. Recall that the wind field model uses a single deterministic value of the gust factor, defined as the mean.

Figure 2-21 presents eight examples of actual gust factors plotted vs. mean wind speeds. The gust factor data was obtained from continuous traces of mean and gust wind speeds from some recent land falling hurricanes. All examples are for cases where the anemometer was located in an approximately homogeneous open terrain. The examples are presented to show the variation in true gust factor on a segment-by-segment basis. In the case of the Florida Coastal Monitoring Program (FCMP) examples, the segment length is ten minutes and in the case of the South Florida Water Management District (SFWMD) data the segment length is fifteen minutes. In the eight examples, the coefficient of variation of the gust facto ranges between 4.5% and 7.5% with a mean of 6%, or approximately half of the total coefficient of variation indicated in Figure 2-21, suggesting that about half of the difference between the modeled and observed winds is attributable to the variation in the gust factor.

Figure 2-22 presents examples of modeled and measured radial transects of wind speeds and pressures. The measured data were obtained from NOAA aircraft flights through hurricanes. The comparisons of the modeled and observed wind and pressure data indicate that the basic form of the model used to represent the model hurricanes is good, but clearly not perfect.

The data presented in Figures 2-21 and 2-22 present examples of the potential contribution of gust factor modeling limitations (single deterministic gust factor) and pressure profile parameter, (or shape parameter) to the overall wind field modeling errors. These two simple examples are given to demonstrate that the errors (differences between modeled and observed wind speeds) occur not only at the lower wind speeds but also near the maximum wind speeds.

In accounting for the wind field model uncertainty, the contributions to the wind field model errors that relate to the errors in the estimation of the key hurricane parameters and the surface roughness are ignored, and the entire modeling uncertainty is assigned to the wind field model and gust factor model limitations. This assumption may be conservative but it is consistent with the Vickery et al. (2009b) approach to development of the wind speed maps that the ASCE and SEI will use in the next revision of ASCE/SEI 7. The omission of the wind field modeling uncertainty, or error term, will result in an underestimate of the long return period gust wind speeds.

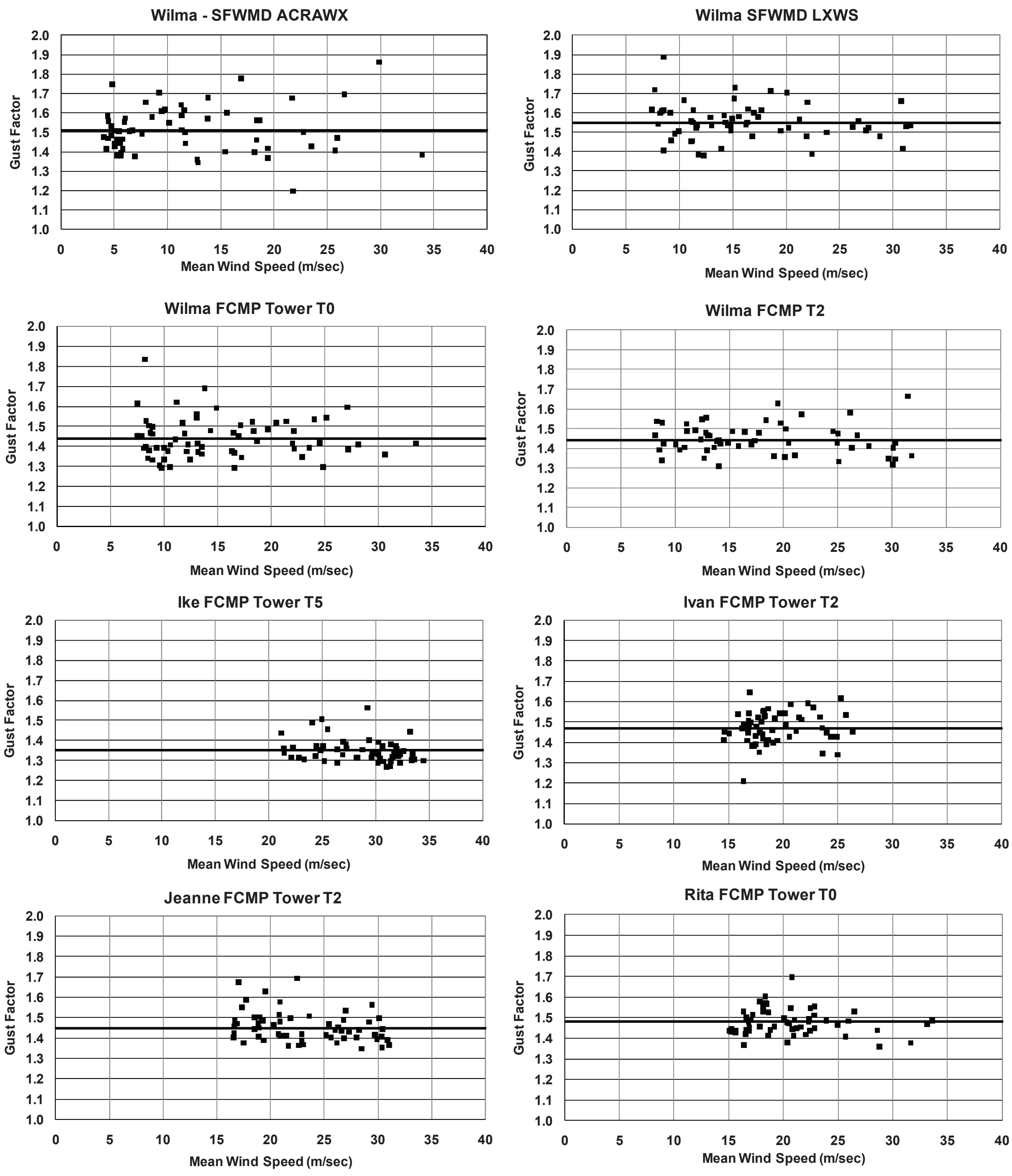

Figure 2-21. Variation of gust factor as a function of mean wind speeds obtained from some recent land falling hurricanes. Solid horizontal line represents the mean value. The gust factors are defined as the 3 second gust wind speed divided by the fifteen minute average wind speed.

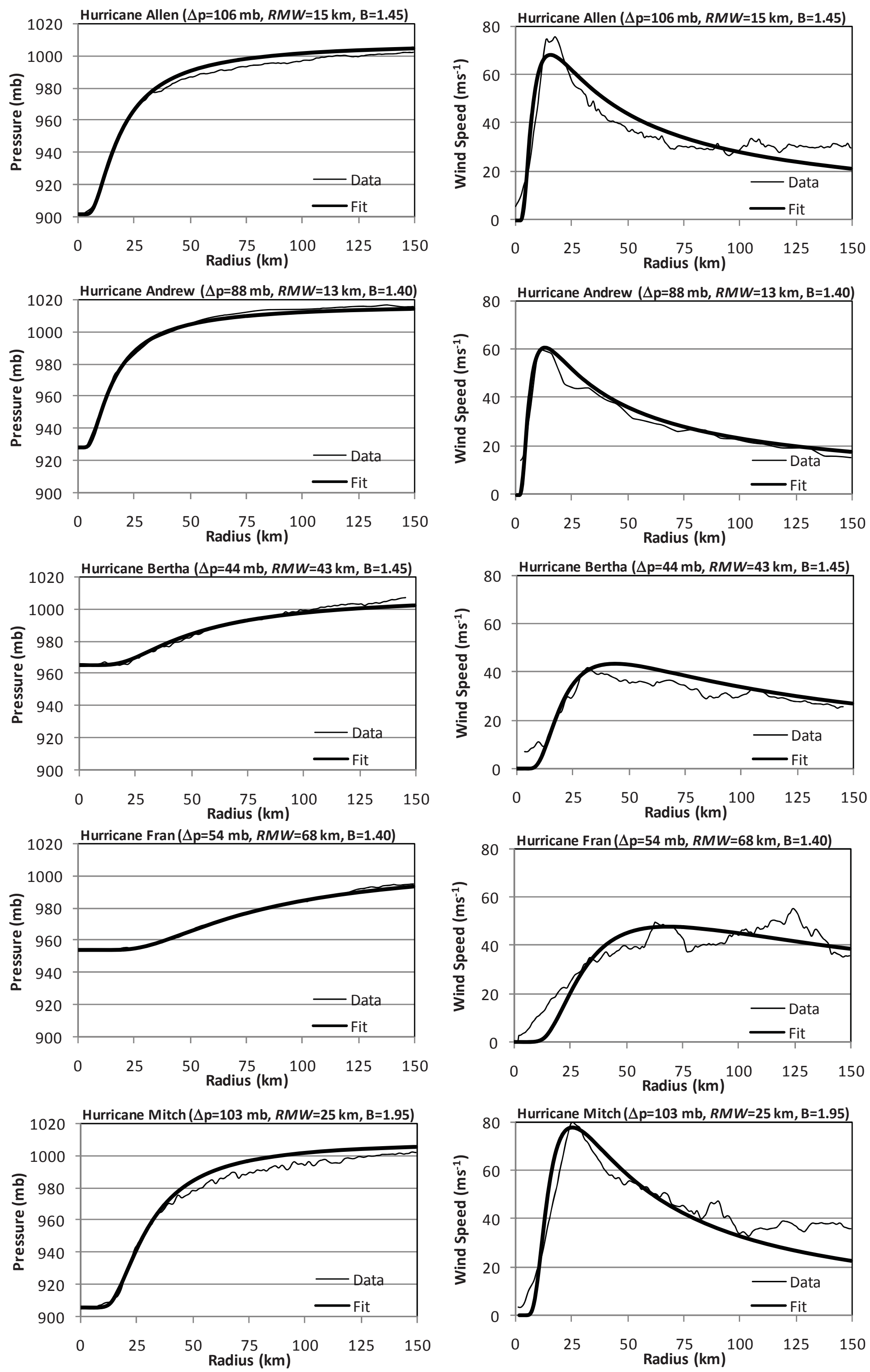

Figure 2-22. Example modeled and observed pressure profiles (left hand plots), corresponding computed gradient balance wind speeds and measured wind speeds (right hand plots).

Figure 2-23 demonstrates the effect of the wind field modeling uncertainty on the gust wind speed hazard curve for the same two locations for demonstration of the effect of the nonstationary gust factor. The results show that in the South Florida case the effect of uncertainty is to increase the estimate of the peak-gust wind speed with an annual exceedance probability of 10^{-7} of about 29 mph (13 m/s) or 12 percent of the value that was estimated without the consideration of uncertainty. In the New York case, the inclusion of the wind field modeling uncertainty increases the 10^{-7} annual exceedance probability wind speed by about 14 mph (6 m/s) or 8 percent of the value without consideration of uncertainty.

2.4 Comparison of Model Results

Figure 2-24 shows contour plots of the 100- and 1000-yr return period peak-gust wind speeds at a height of 10 m in flat open terrain from the updated version of the hurricane simulation model. The contours in Figure 2-24 include the effects of changes in the simulation model methodology, which includes the effects of the nonstationary gust factor, removal of the 863-hPa limit on central pressure, the introduction of the weighted sampling approach, and the reduction in the translation speed effect in the wind field modeling. A comparison of the contours of the 100- and 1000-yr return period winds with those in Vickery et al. (2009a) (Figure 2-25) indicates only minor differences between the two sets of wind speed contours.

In the case of the 1000-yr return period peak-gust wind speeds at a height of 10 m in flat open terrain, the comparison of the wind speed contours indicate the updated model produces wind speeds that are marginally less than those from the Vickery et al. (2009a) model. The results of the upgrade appear to provide a better estimate of the long-return period wind speeds.

2.5 Effect of Site Target Size

To examine the effect of target size—the area of the site—the full time series of wind speeds and directions for two sites 0.8 km (0.5 mile) apart were used to simulate the hurricane hazard risk that is defined by the maximum wind speed at either location from each storm and the wind speed at one

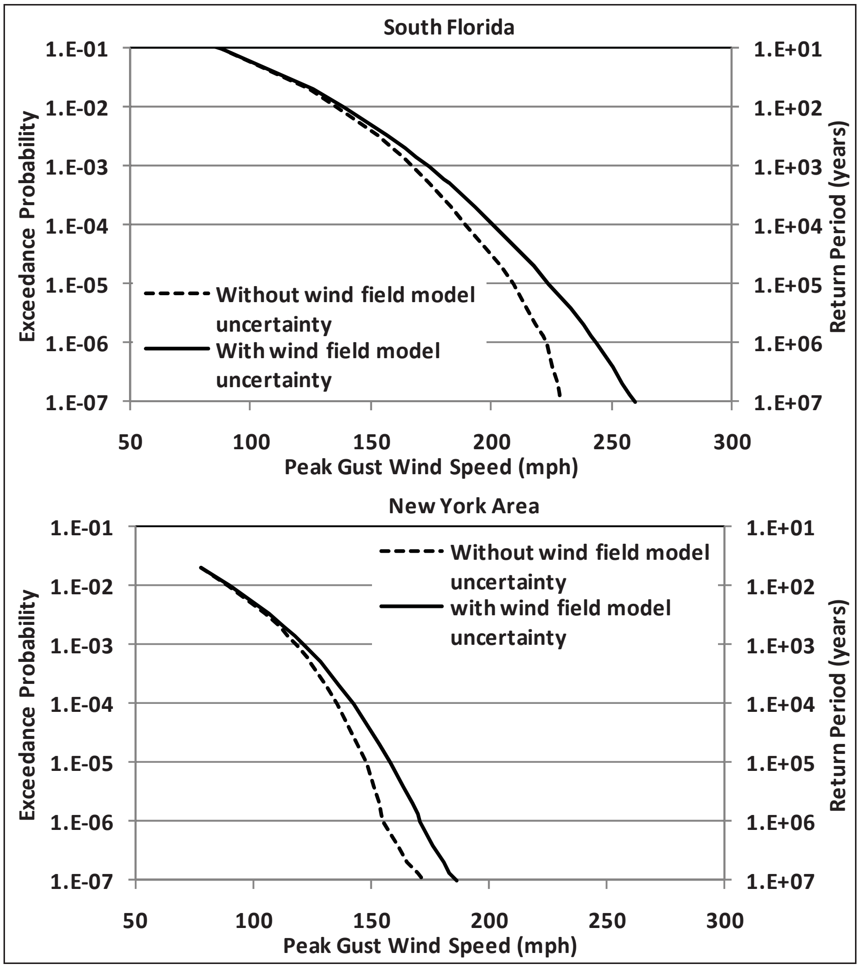

Figure 2-23. Effect of wind field modeling uncertainty on predicted peak-gust wind speeds.

location (a standard point-probability approach). Figure 2-26 presents wind speeds plotted versus annual exceedance probabilities that are due to the effect of target size. Results are for sites in New York and Miami. The target size study results do not include wind field modeling uncertainty. As the figure shows, the effect of target size is negligible; the largest difference is less than 1 percent.

2.6 Sensitivity to Increased Hurricane Frequency

This study used a sensitivity analysis to assess the possible effect of increased hurricane frequency in the future. This approach considers a doubling of the landfall rate of all hurricanes. For this sensitivity, an estimate of the increase in the wind speed with an annual exceedance probability of 1.0×10^{-6} can be obtained by computing the ratio of the wind speeds with an annual exceedance probability of 0.5×10^{-6} to that with an annual exceedance probability of 1.0×10^{-6}. The mean and standard deviation of this ratio over the 3575 points are 1.03 and 0.008, respectively, which suggests that a factor of 2 increase in hurricane frequency would result in only a 3-percent increase in the wind speed with an exceedance probability of 1.0×10^{-6}. The effect of a potential doubling in hurricane frequency on the 1×10^{-7} year exceedance probability winds was obtained by taking the ratio of the wind speeds associated with annual exceedance probabilities of 1.0×10^{-7} and 0.5×10^{-7}. The mean and standard deviation of this ratio over the 3575 points are 1.015 and 0.007, respectively, which suggests that a factor of 2 increase in hurricane frequency would result in less than a 2-percent increase in the wind speed with an exceedance probability of 1.0×10^{-7}.

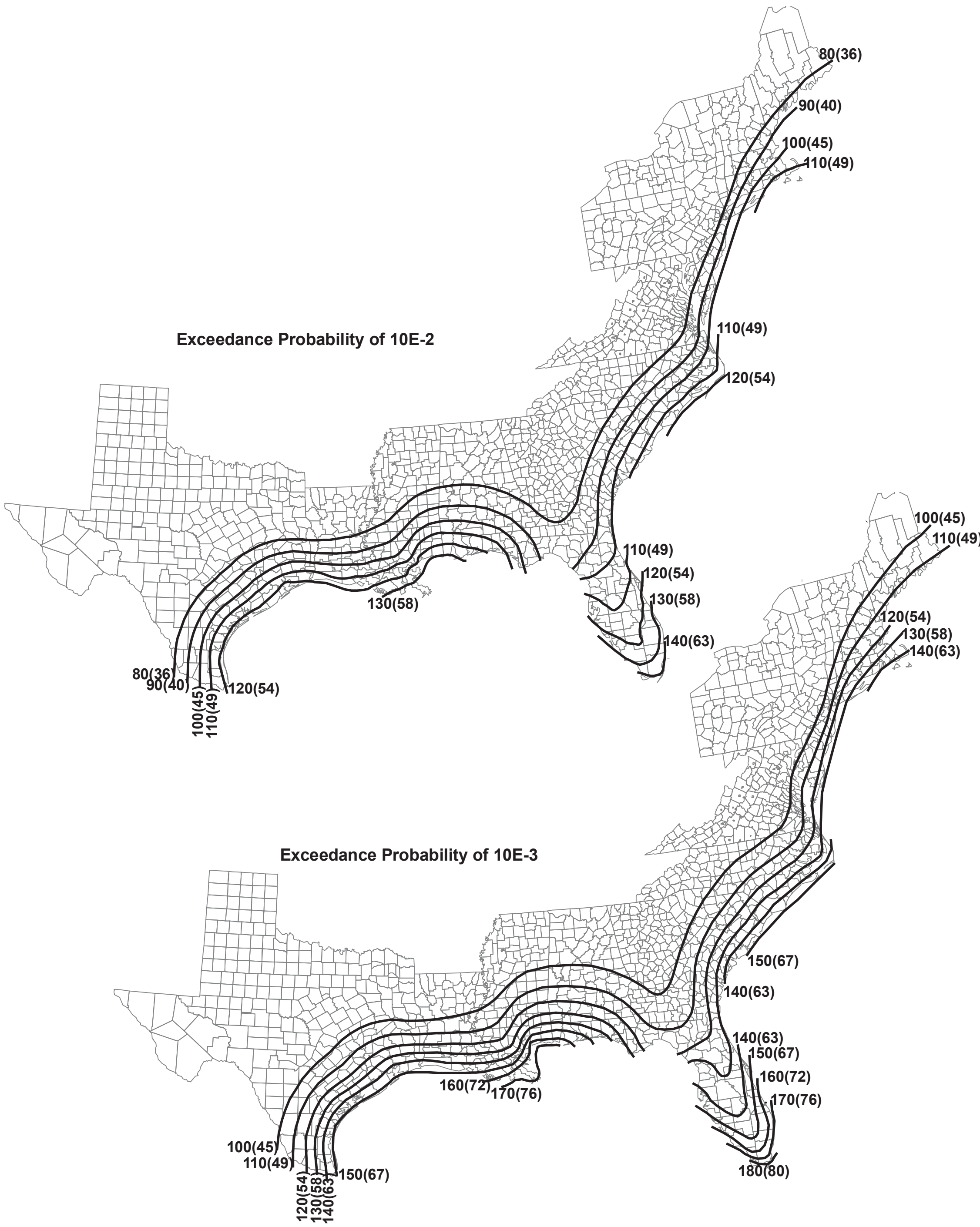

Figure 2-24. Predicted peak-gust wind speeds at 10-m height in open terrain from updated model, annual exceedance probabilities of 10^{-2} and 10^{-3}.

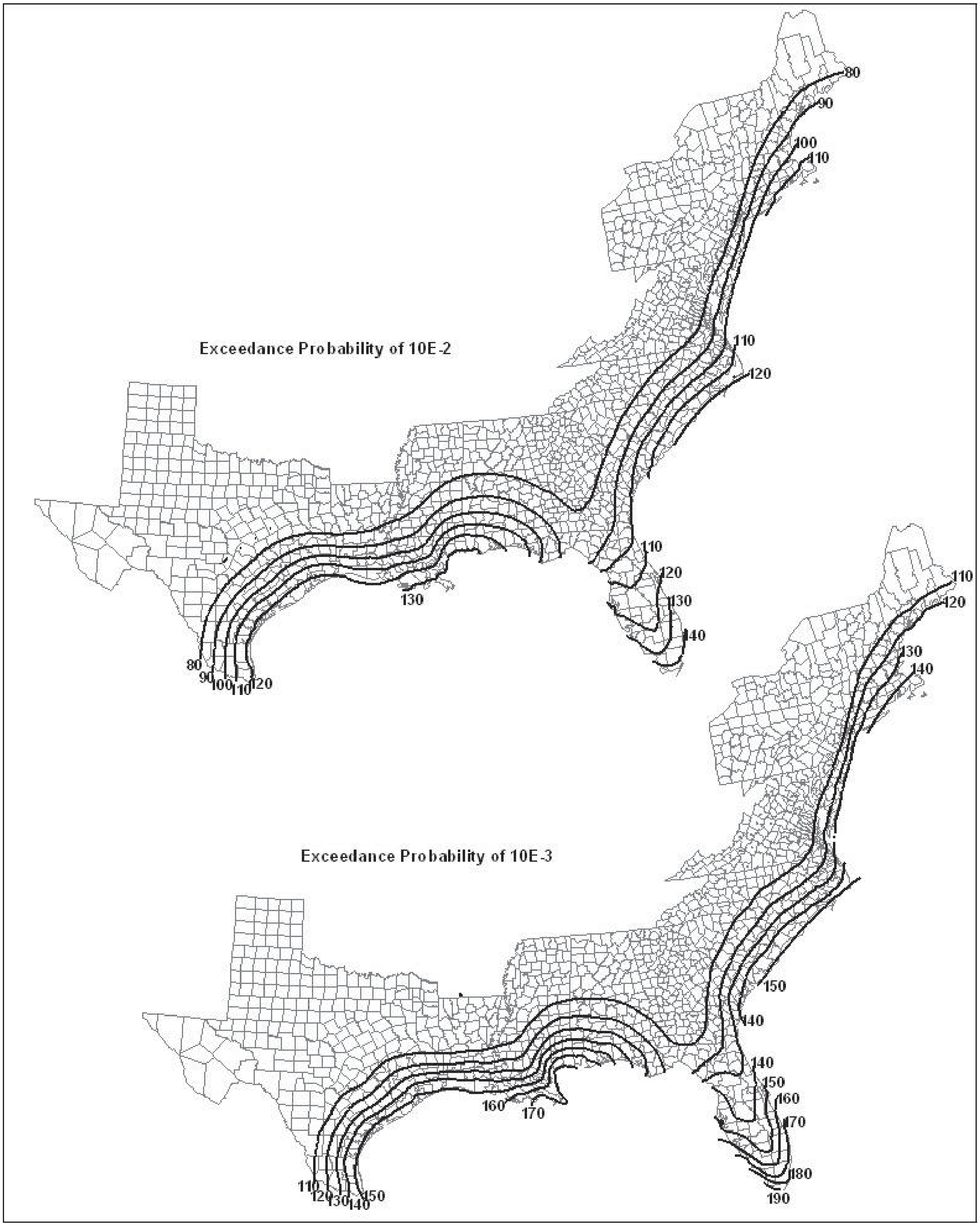

Figure 2-25. Predicted peak-gust wind speeds at 10 m height in open terrain from Vickery et al. (2009a), annual exceedance probabilities of 10^{-2} and 10^{-3}.

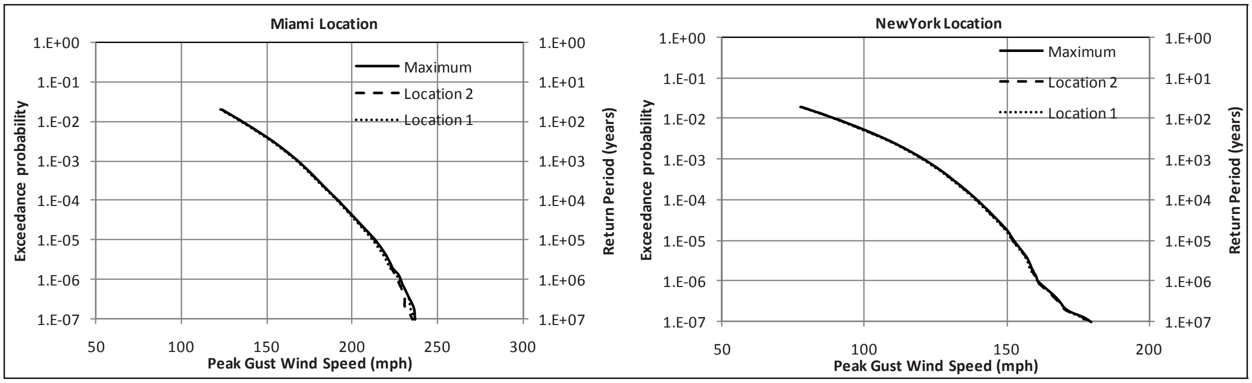

Figure 2-26. Effect of site target size (area) on predicted wind speeds.

3. RESULTS

The analysis for this report used the results from the simulations Section 2 describes to produce wind speed hazard curves for each of the 3575 points and to construct contours of hurricane wind speeds with annual exceedance probabilities of 10^{-6} and 10^{-7}. Contours lines represent 10-mph (4.5 m/s) increments. All wind speeds are representative of a 3-s peak-gust wind speed at a height of 10 m above ground in flat open terrain, which is consistent with the definition of Exposure C in ASCE/SEI 7 (ASCE/SEI 2006). In addition to the standard contour plots, this section shows stylized maps in which the wind speed within each 0.1- by 0.1-degree square is assigned to largest value within the square and rounded up to the nearest 10 mph (4.5 m/s).

Figures 3-1 and 3-2 show the contour plots for annual exceedance probabilities of 10^{-6} and 10^{-7}, respectively, and Figures 3-3 and 3-4 show the stylized maps. Along the coastline, the hurricane-induced wind gusts are often higher than the regionalized gusts tornadoes produce.

Figures 3-5 and 3-6 show the 0.1- by 0.1-degree squares that have hurricane wind speeds higher than the recommended design-basis tornado wind speeds. It is important to recall that the wind field modeling uncertainty (error modeling) increases the rare-event wind speeds by more than 10 percent, and this plays a significant role in the number of locations where the wind speeds are higher than those for tornadoes. The wind model errors are assumed to account for anomalous gusts within hurricanes that are not modeled with the current wind field model.

Appendix A contains the wind speed data given in Figure 3-3 for all points where the indicated wind speeds are greater than those produced by tornadoes. Appendix B contains the wind speed data given in Figure 3-4 for all points where the indicated wind speeds are greater than those produced by tornadoes.

Figure 3-7 shows 24 example locations the analysis used for plotting the change in predicted wind speed as a function of annual exceedance probability. Figure 3-8 shows plots of the change in the predicted wind speed as a function of annual exceedance probability. For example, the increase in wind speed as the annual exceedance probability is reduced from 10^{-2} to 10^{-3} is plotted at 10^{-3}. At Location 1, this difference amounts to a 35-mph (16 m/s) increase in peak gust as the return period increases from 100 to 1000 years. As the return period increases from 1,000 to 10,000 years, the peak-gust wind speeds increase another 27 mph (12 m/s), and so forth; this produces the curves for each location. These plots show that the rate of increase in the design-basis wind speeds decreases with decreasing annual exceedance probability (or increasing return period) for each location. Inland locations generally have a flatter slope in these plots than coastal locations.

The maximum peak gust wind speed associated with an exceedance probability of 10^{-7} is about 290 mph (130 m/s). This maximum occurs in the Florida Keys, at a point located about 100 m from the coast. Assuming this maximum is associated with a gust factor of about 1.7, the corresponding sustained wind speed (over water) is in the range 200 to 210 mph (90 to 94 m/s).

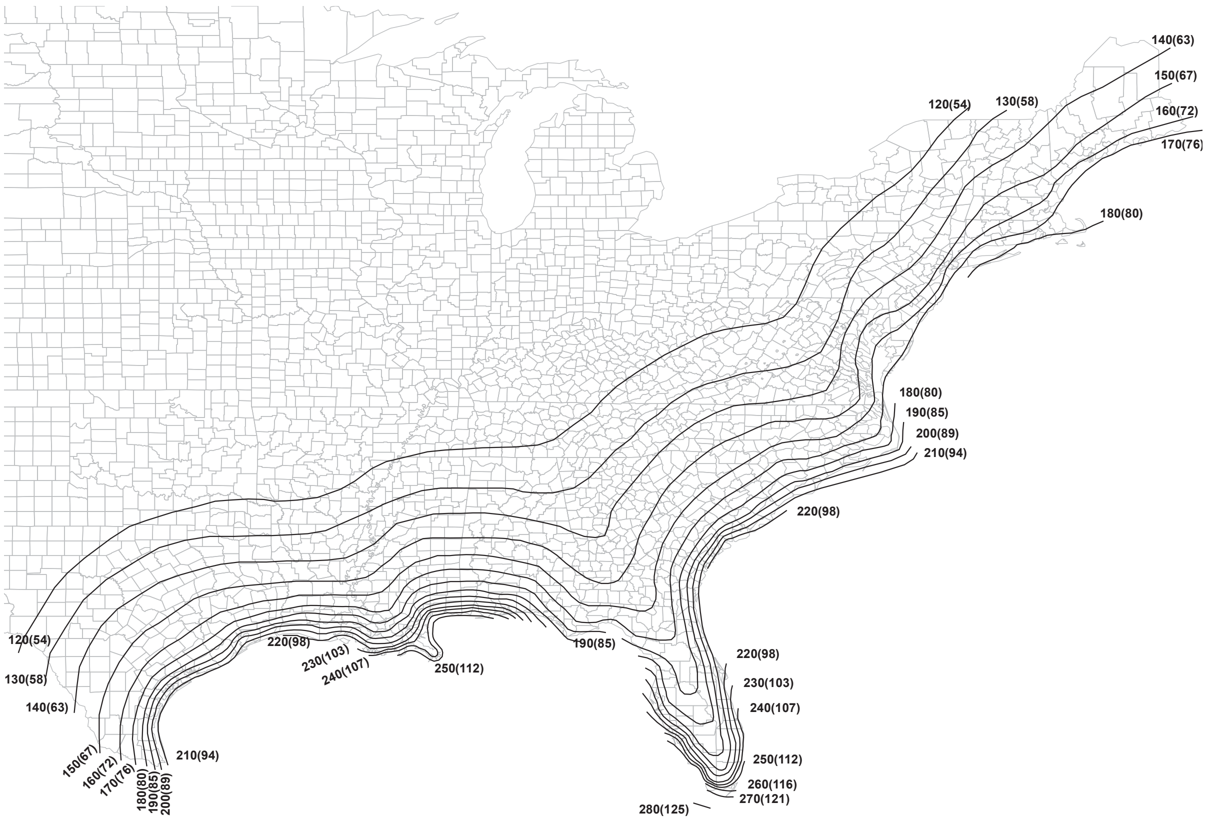

Figure 3-1a. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-6}.

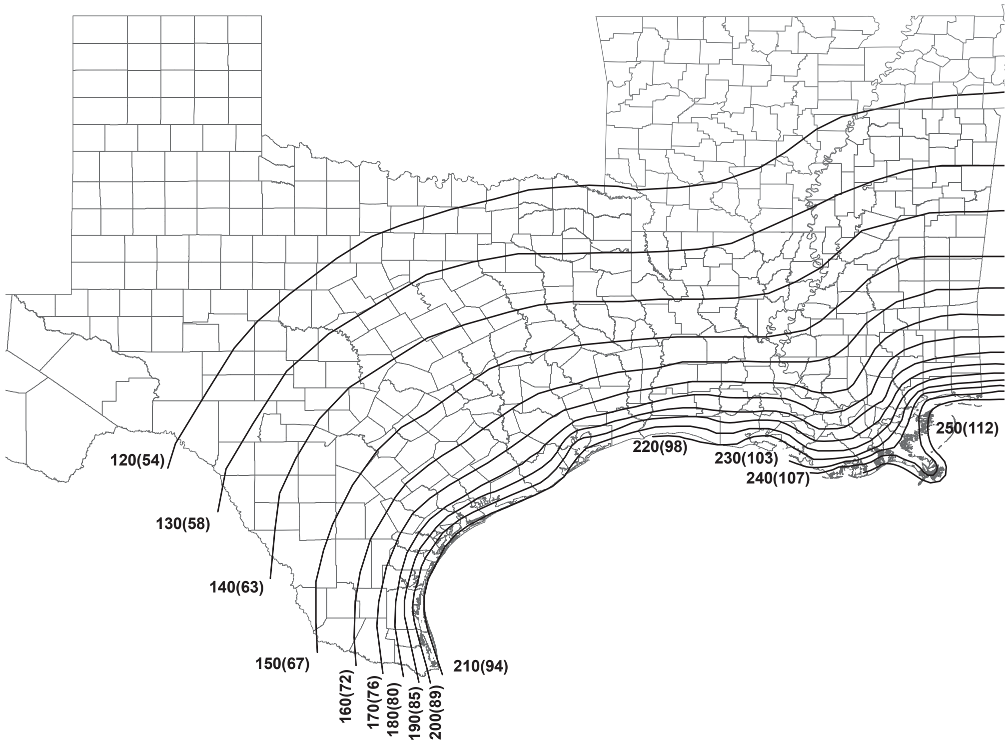

Figure 3-1b. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-6} (Texas to Mississippi)

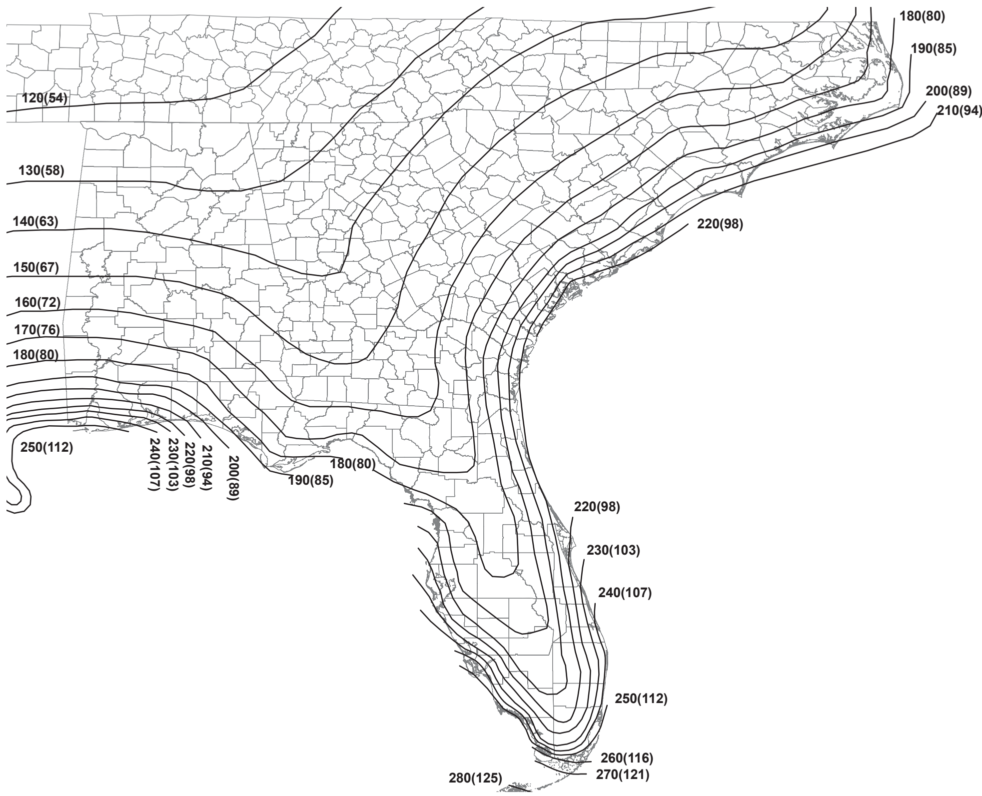

Figure 3-1c. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-6} (Alabama to North Carolina)

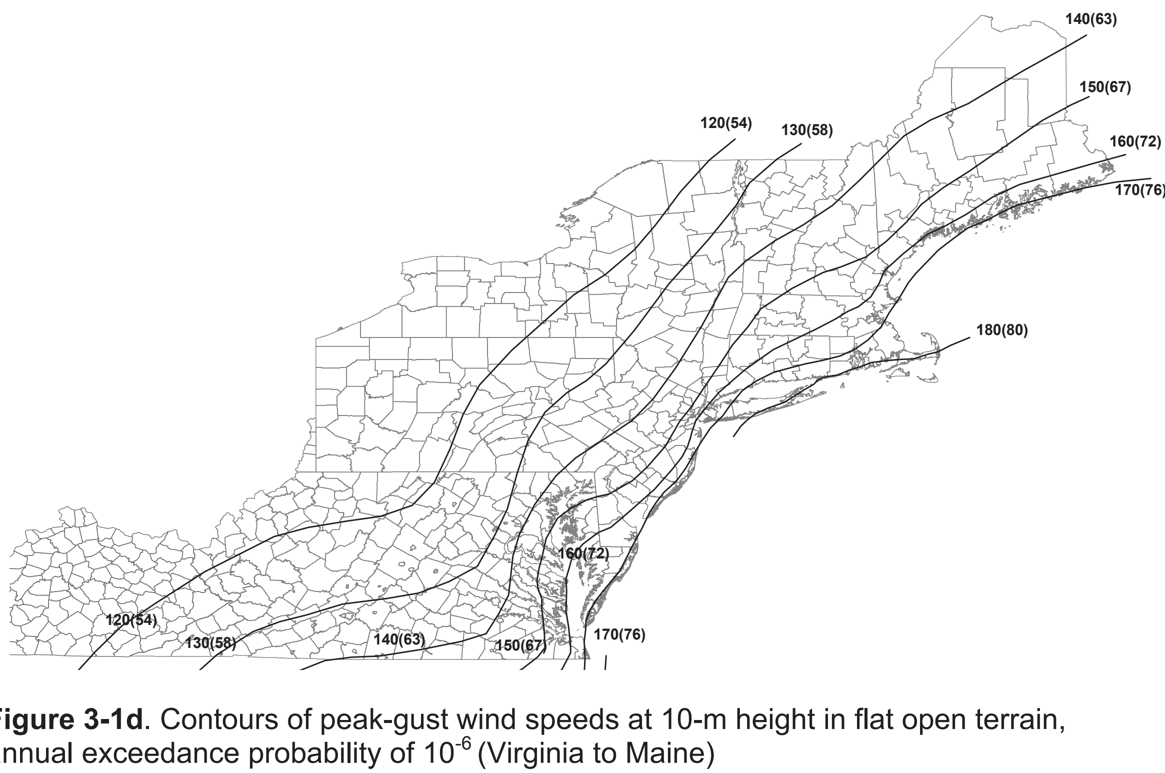

Figure 3-1d. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-6} (Virginia to Maine)

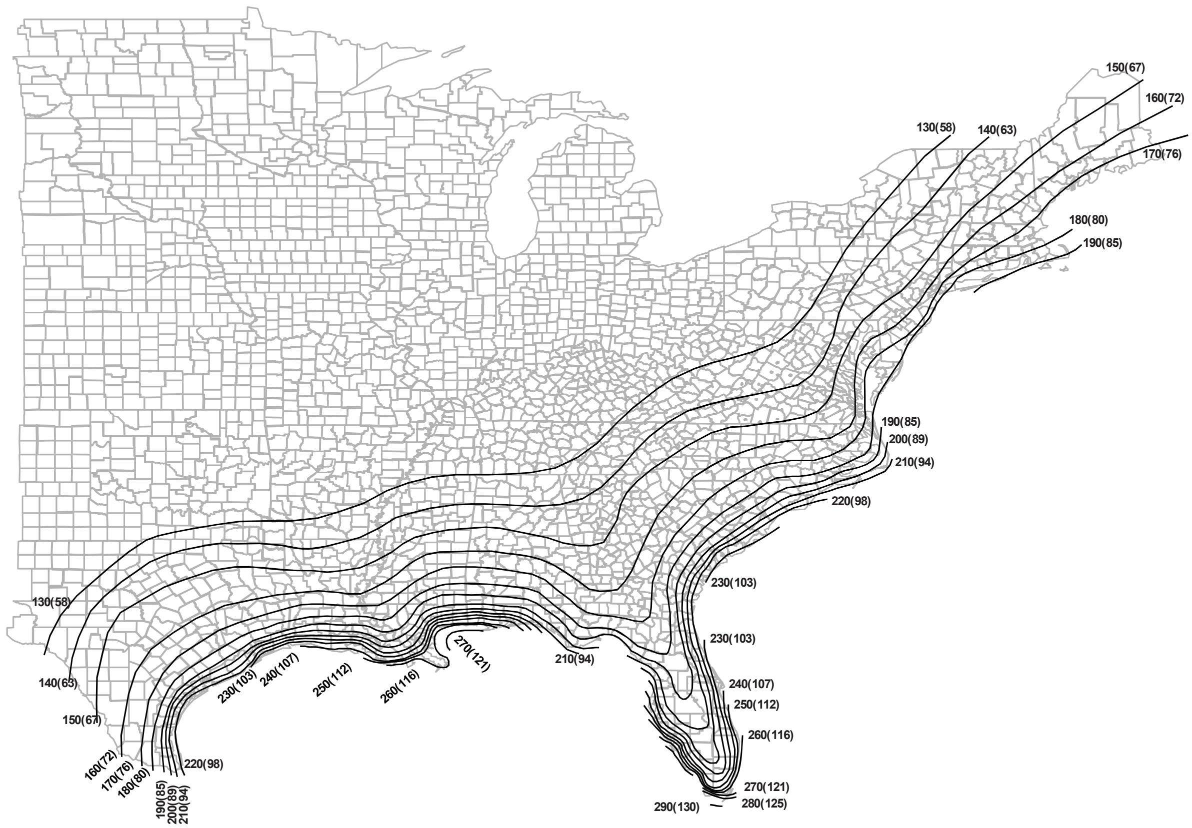

Figure 3-2a. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-7}.

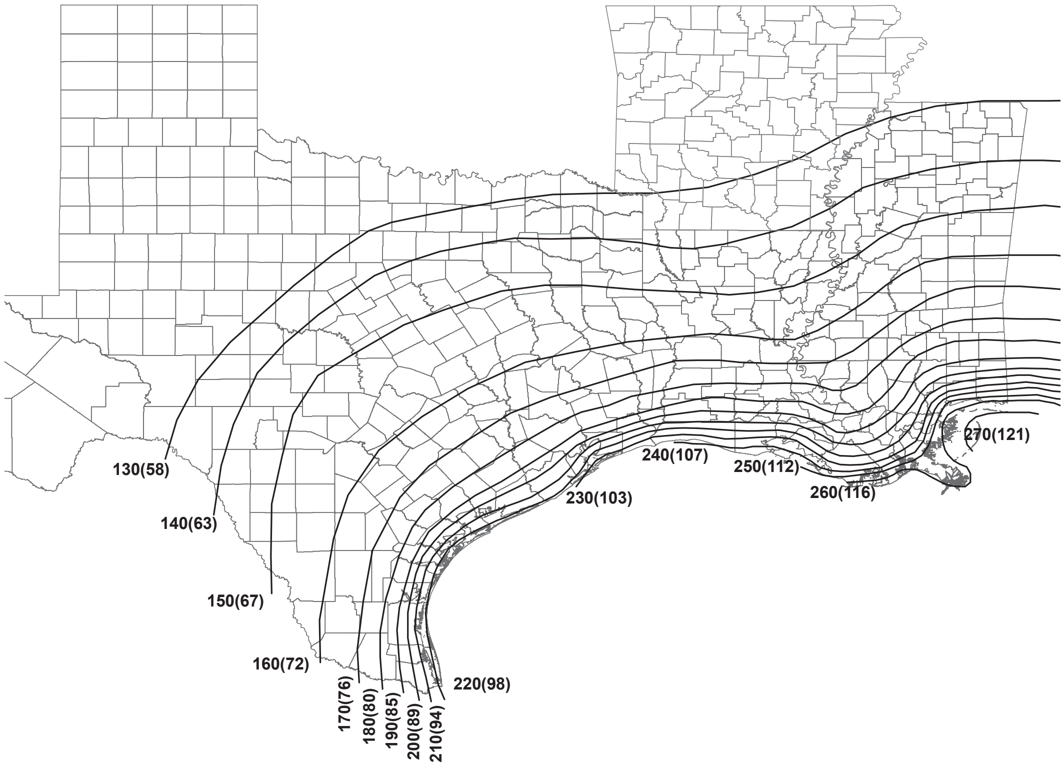

Figure 3-2b. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-7} (Texas to Mississippi)

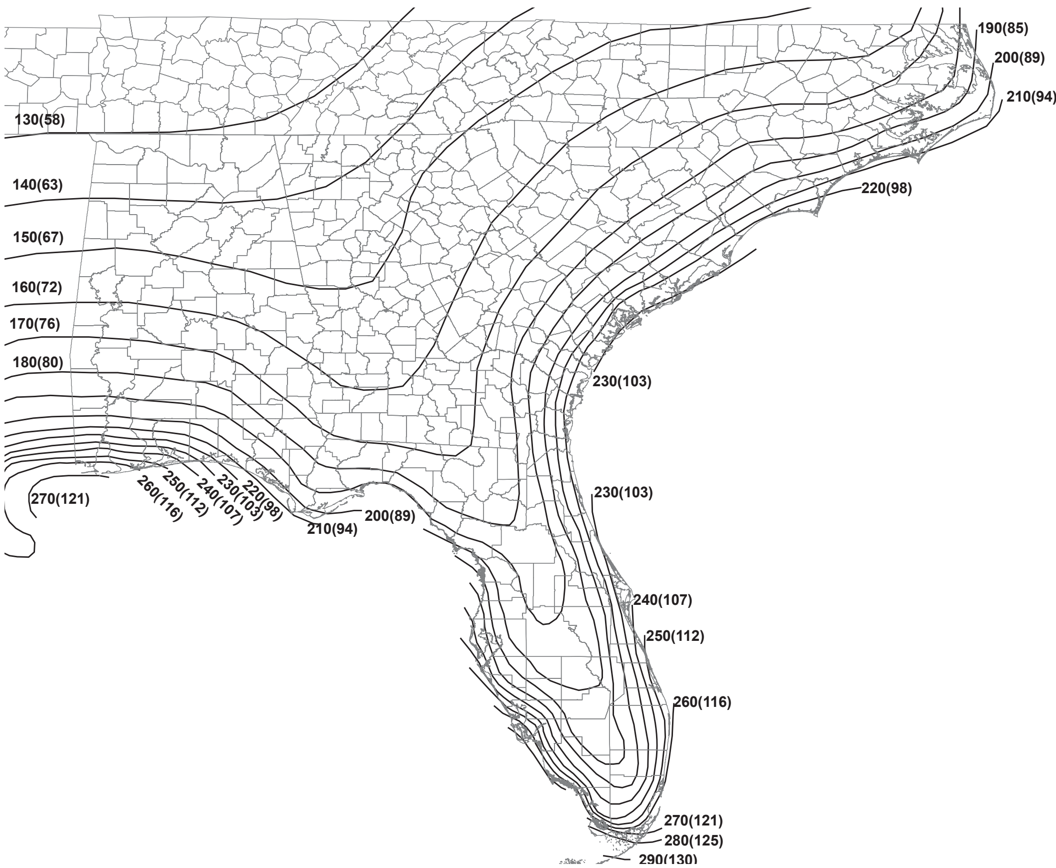

Figure 3-2c. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-7} (Alabama to North Carolina)

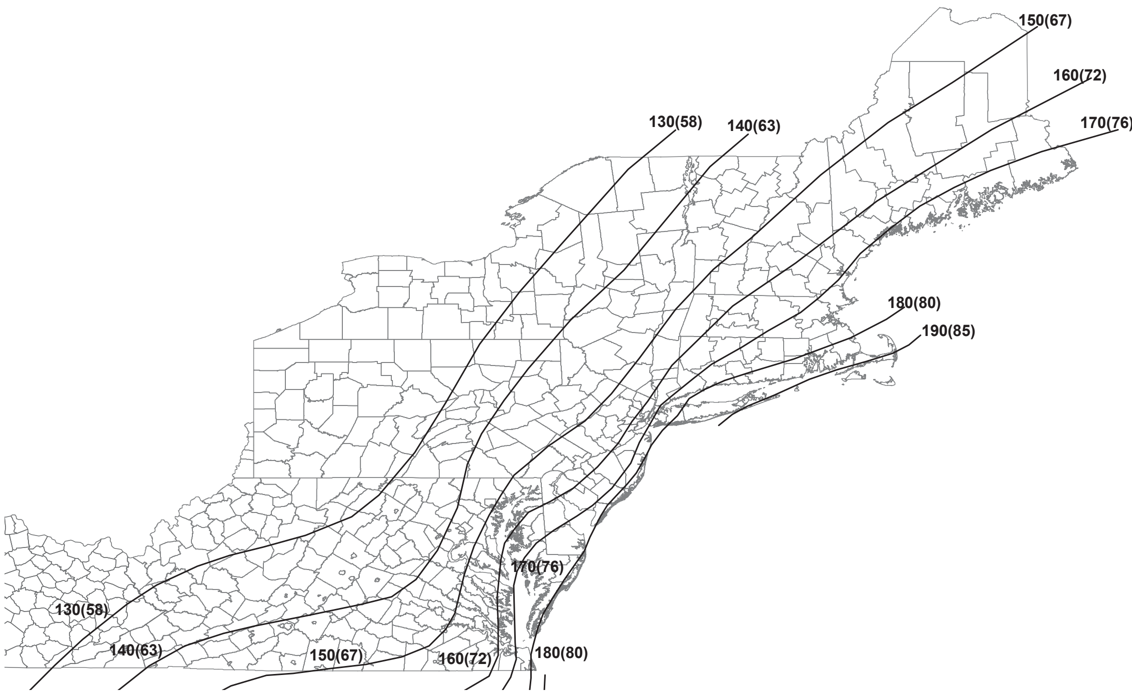

Figure 3-2d. Contours of peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-7} (Virginia to Maine)

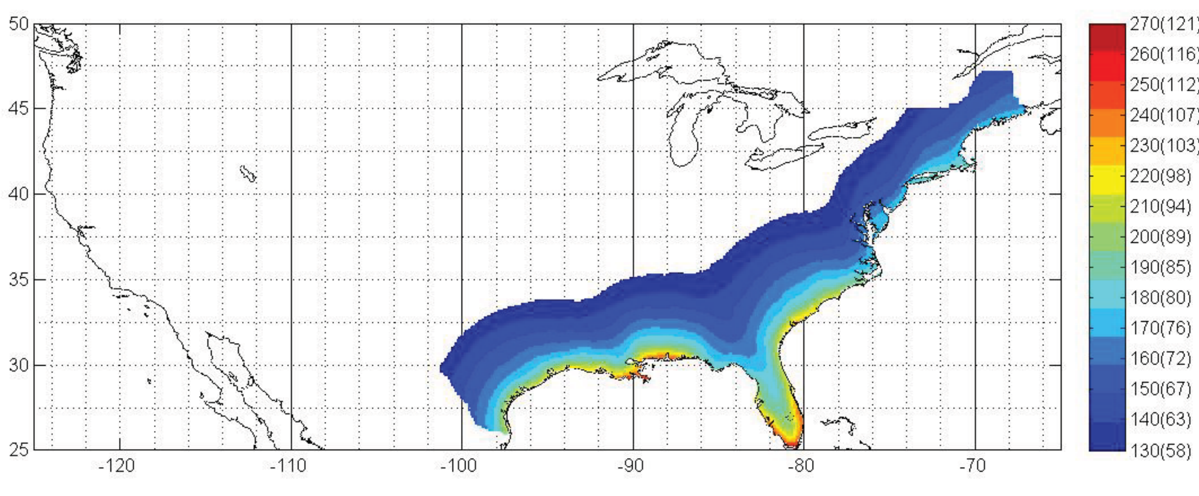

Figure 3-3. Recommended design-basis peak-gust wind speeds at 10-m in flat open terrain, annual exceedance probability of 10^{-6}.

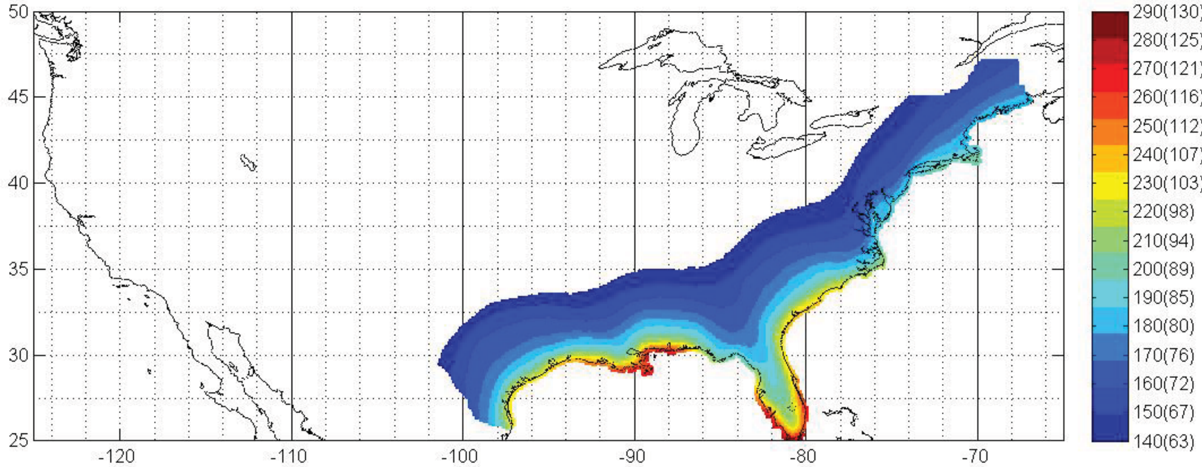

Figure 3-4. Recommended design-basis peak-gust wind speeds at 10-m height in flat open terrain, annual exceedance probability of 10^{-7}.

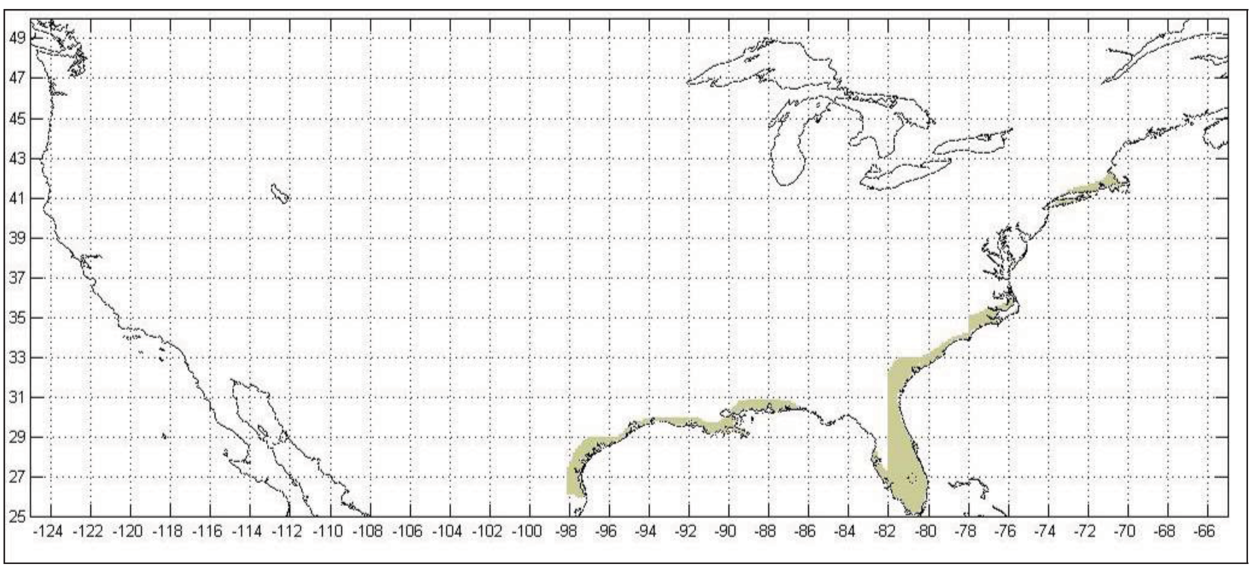

Figure 3-5. Locations where recommended design-basis hurricane wind speeds exceed those for tornadoes, annual exceedance probability of 10^{-6}.

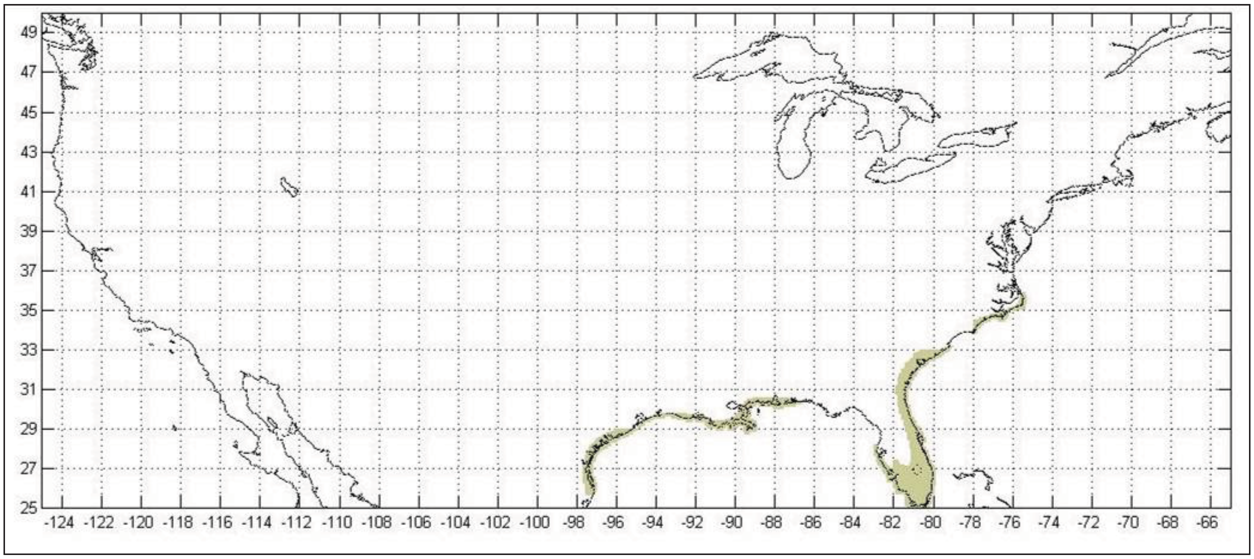

Figure 3-6. Locations where recommended design-basis hurricane wind speeds exceed those for tornadoes, annual exceedance probability of 10^{-7}**).**

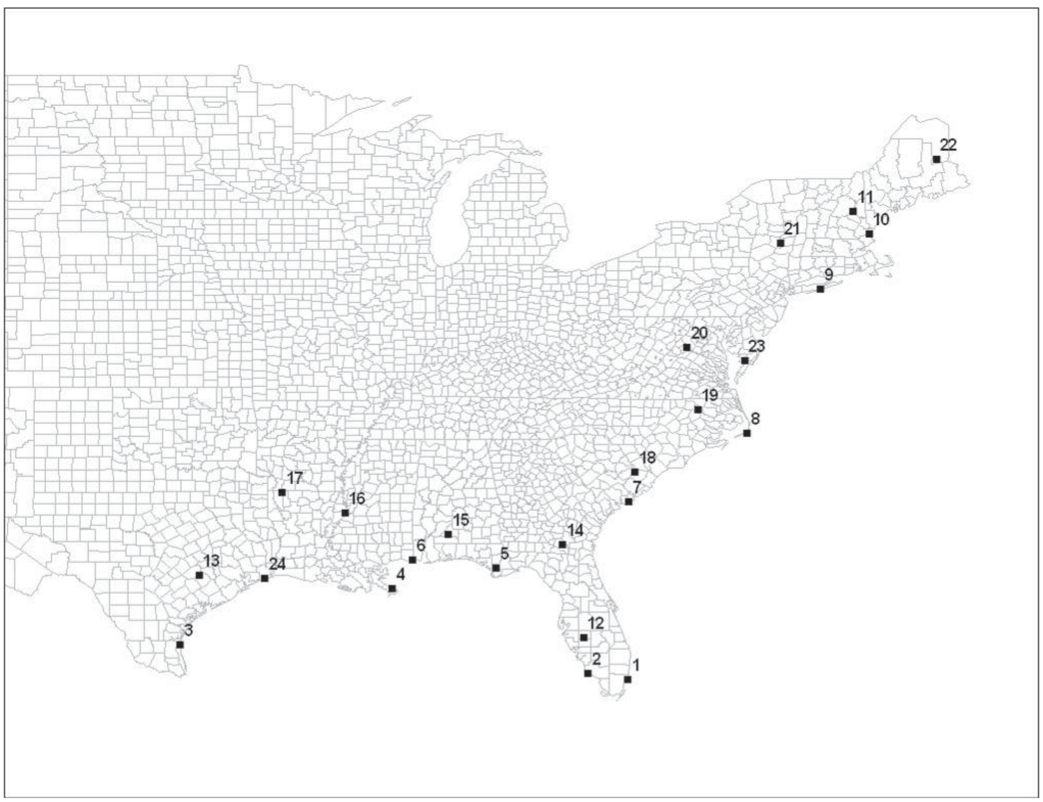

Figure 3-7. Example locations for plotting change in design-basis wind speed versus annual exceedance probability.

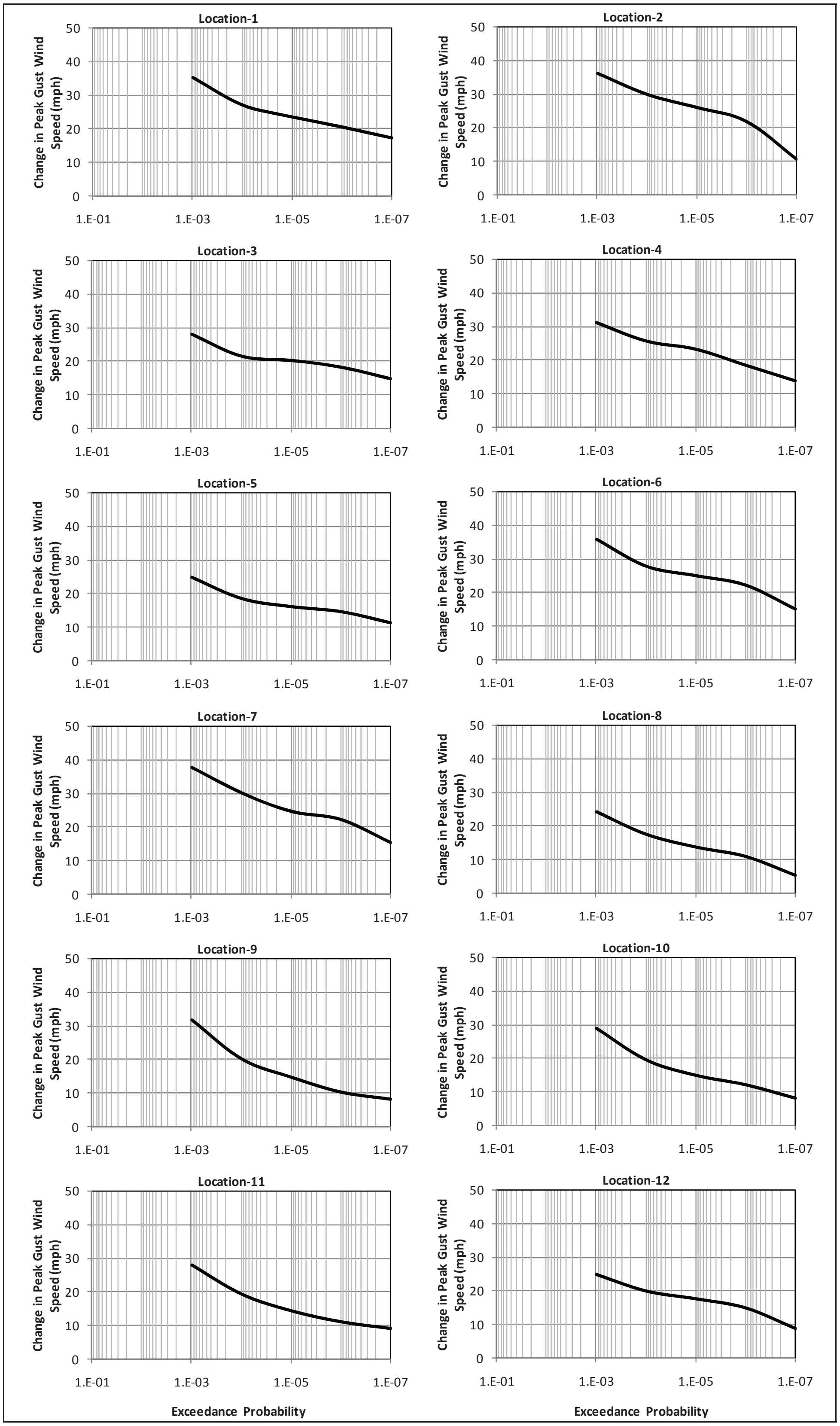

Figure 3-8a. Change in the design-basis wind speed versus annual exceedance probability.

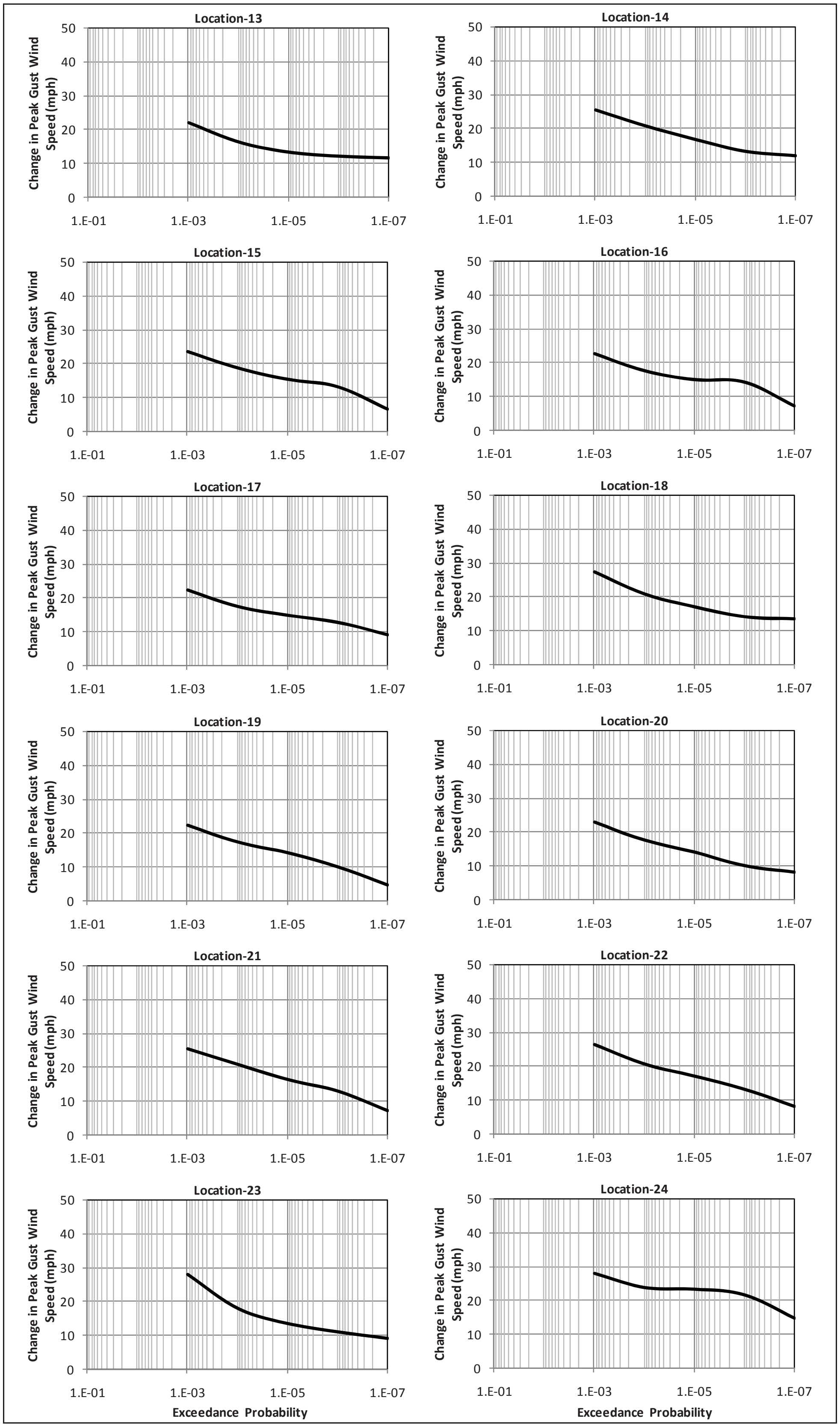

Figure 3-8b. Change in the design-basis wind speed versus annual exceedance probability.

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APPENDIX A: MAXIMUM PEAK GUST WIND SPEEDS ASSOCIATED WITH AN ANNUAL EXCEEDANCE PROBABILITY OF 10^{-6}

Appendix A contains the maximum peak gust wind speeds associated with an annual exceedance probability of 10^{-6} (rounded up to the nearest 10 mph) on a 0.1 by 0.1 degree grid. Latitude and longitude of the grid represents the mid-point of the 0.1 degree by 0.1 degree square.

Wind speed is only provided for locations where the hurricane wind speed exceeds the tornado wind speed with the same exceedance probability (see Figure 3-5).

Latitudes: 25.05 - 25.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.05	80.55	270	121
25.15	80.45	260	116
25.25	81.15	260	116
25.25	80.95	260	116
25.25	80.85	260	116
25.25	80.75	260	116
25.25	80.65	260	116
25.25	80.55	260	116
25.35	80.95	250	112
25.35	80.85	250	112
25.35	80.75	250	112
25.35	80.65	250	112
25.35	80.55	250	112
25.35	80.45	250	112
25.45	81.15	250	112
25.45	81.05	250	112
25.45	80.95	240	107
25.45	80.85	240	107
25.45	80.75	240	107
25.45	80.65	240	107
25.45	80.55	240	107
25.45	80.45	250	112
25.45	80.35	250	112
25.55	81.15	240	107
25.55	81.05	240	107
25.55	80.95	230	103
25.55	80.85	230	103
25.55	80.75	230	103
25.55	80.65	230	103
25.55	80.55	230	103
25.55	80.45	240	107
25.65	81.25	240	107
25.65	81.15	240	107
25.65	81.05	230	103
25.65	80.95	230	103
25.65	80.85	220	98
25.65	80.75	220	98
25.65	80.65	230	103
25.65	80.65	230	103

Latitudes: 25.65 - 25.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.65	80.55	230	103
25.65	80.45	230	103
25.65	80.35	240	107
25.75	81.25	240	107
25.75	81.15	230	103
25.75	81.05	230	103
25.75	80.95	220	98
25.75	80.85	220	98
25.75	80.75	220	98
25.75	80.65	220	98
25.75	80.55	220	98
25.75	80.45	230	103
25.75	80.35	240	107
25.85	81.35	240	107
25.85	81.25	230	103
25.85	81.15	230	103
25.85	81.05	220	98
25.85	80.95	220	98
25.85	80.85	210	94
25.85	80.75	210	94
25.85	80.65	220	98
25.85	80.55	220	98
25.85	80.45	230	103
25.85	80.35	230	103
25.85	80.25	240	107
25.95	97.55	200	89
25.95	97.45	200	89
25.95	81.75	250	112
25.95	81.65	250	112
25.95	81.55	240	107
25.95	81.45	240	107
25.95	81.35	230	103
25.95	81.25	230	103
25.95	81.15	220	98
25.95	81.05	220	98
25.95	80.95	210	94
25.95	80.85	210	94
25.95	80.75	210	94
25.95	80.65	210	94

Latitudes: 25.95 - 26.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.95	80.45	220	98
25.95	80.35	230	103
25.95	80.25	240	107
26.05	97.65	190	85
26.05	97.55	200	89
26.05	97.45	200	89
26.05	97.35	210	94
26.05	81.75	250	112
26.05	81.65	250	112
26.05	81.55	240	107
26.05	81.45	230	103
26.05	81.35	230	103
26.05	81.25	220	98
26.05	81.15	220	98
26.05	81.05	210	94
26.05	80.95	210	94
26.05	80.85	210	94
26.05	80.75	210	94
26.05	80.65	210	94
26.05	80.55	220	98
26.05	80.45	220	98
26.05	80.35	230	103
26.05	80.25	240	107
26.15	98.05	180	80
26.15	97.95	180	80
26.15	97.85	180	80
26.15	97.75	190	85
26.15	97.65	190	85
26.15	97.55	200	89
26.15	97.45	200	89
26.15	97.35	210	94
26.15	81.75	250	112
26.15	81.65	240	107
26.15	81.55	230	103
26.15	81.45	230	103
26.15	81.35	220	98
26.15	81.25	220	98
26.15	81.15	210	94
26.15	81.05	210	94

Latitudes: 26.15 - 26.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.15	80.85	210	94
26.15	80.75	210	94
26.15	80.65	210	94
26.15	80.55	210	94
26.15	80.45	220	98
26.15	80.35	230	103
26.15	80.25	230	103
26.15	80.15	240	107
26.25	98.05	180	80
26.25	97.95	180	80
26.25	97.85	180	80
26.25	97.75	190	85
26.25	97.65	190	85
26.25	97.55	200	89
26.25	97.45	200	89
26.25	81.75	240	107
26.25	81.65	240	107
26.25	81.55	230	103
26.25	81.45	220	98
26.25	81.35	220	98
26.25	81.25	210	94
26.25	81.15	210	94
26.25	81.05	210	94
26.25	80.95	200	89
26.25	80.85	200	89
26.25	80.75	210	94
26.25	80.65	210	94
26.25	80.55	210	94
26.25	80.45	220	98
26.25	80.35	230	103
26.25	80.25	230	103
26.25	80.15	240	107
26.35	98.05	180	80
26.35	97.95	180	80
26.35	97.85	190	85
26.35	97.75	190	85
26.35	97.65	200	89
26.35	97.55	200	89
26.35	97.45	210	94
26.35	97.25	220	98

Latitudes: 26.35 - 26.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps).
26.35	81.85	240	107
26.35	81.75	240	107
26.35	81.65	230	103
26.35	81.55	220	98
26.35	81.45	220	98
26.35	81.35	210	94
26.35	81.25	210	94
26.35	81.15	200	89
26.35	81.05	200	89
26.35	80.95	200	89
26.35	80.85	200	89
26.35	80.75	200	89
26.35	80.65	210	94
26.35	80.55	210	94
26.35	80.45	220	98
26.35	80.35	230	103
26.35	80.25	230	103
26.35	80.15	240	107
26.45	98.05	180	80
26.45	97.95	180	80
26.45	97.85	190	85
26.45	97.75	190	85
26.45	97.65	200	89
26.45	97.55	200	89
26.45	81.85	240	107
26.45	81.75	230	103
26.45	81.65	230	103
26.45	81.55	220	98
26.45	81.45	210	94
26.45	81.35	210	94
26.45	81.25	200	89
26.45	81.15	200	89
26.45	81.05	200	89
26.45	80.95	200	89
26.45	80.85	200	89
26.45	80.75	200	89
26.45	80.65	210	94
26.45	80.55	210	94
26.45	80.45	220	98
26.45	80.35	230	103

Latitudes: 26.45 - 26.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps).
26.45	80.25	230	103
26.45	80.15	240	107
26.55	98.05	180	80
26.55	97.95	180	80
26.55	97.85	190	85
26.55	97.75	190	85
26.55	97.65	200	89
26.55	97.55	200	89
26.55	82.05	240	107
26.55	81.95	240	107
26.55	81.85	230	103
26.55	81.75	230	103
26.55	81.65	220	98
26.55	81.55	210	94
26.55	81.45	210	94
26.55	81.35	210	94
26.55	81.25	200	89
26.55	81.15	200	89
26.55	81.05	200	89
26.55	80.95	200	89
26.55	80.85	200	89
26.55	80.75	200	89
26.55	80.65	210	94
26.55	80.55	210	94
26.55	80.45	220	98
26.55	80.35	230	103
26.55	80.25	230	103
26.55	80.15	240	107
26.65	98.05	180	80
26.65	97.95	180	80
26.65	97.85	190	85
26.65	97.75	190	85
26.65	97.65	200	89
26.65	97.55	200	89
26.65	97.35	210	94
26.65	82.05	240	107
26.65	81.95	230	103
26.65	81.85	230	103
26.65	81.75	220	98
26.65	81.65	220	98

Latitudes: 26.65 - 26.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.65	81.55	210	94
26.65	81.45	210	94
26.65	81.35	200	89
26.65	81.25	200	89
26.65	81.15	200	89
26.65	81.05	200	89
26.65	80.95	200	89
26.65	80.85	200	89
26.65	80.75	210	94
26.65	80.65	210	94
26.65	80.55	210	94
26.65	80.45	220	98
26.65	80.35	230	103
26.65	80.25	230	103
26.65	80.15	240	107
26.75	98.05	180	80
26.75	97.95	180	80
26.75	97.85	190	85
26.75	97.75	190	85
26.75	97.65	200	89
26.75	97.55	210	94
26.75	82.05	230	103
26.75	81.95	230	103
26.75	81.85	220	98
26.75	81.75	220	98
26.75	81.65	210	94
26.75	81.55	210	94
26.75	81.45	200	89
26.75	81.35	200	89
26.75	81.25	200	89
26.75	81.15	200	89
26.75	81.05	200	89
26.75	80.95	200	89
26.75	80.85	200	89
26.75	80.75	210	94
26.75	80.65	210	94
26.75	80.55	220	98
26.75	80.45	220	98
26.75	80.35	230	103
26.75	80.25	240	107

Latitudes: 26.75 - 26.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.75	80.15	240	107
26.85	98.05	180	80
26.85	97.95	180	80
26.85	97.85	190	85
26.85	97.75	190	85
26.85	97.65	200	89
26.85	82.25	240	107
26.85	82.05	230	103
26.85	81.95	220	98
26.85	81.85	220	98
26.85	81.75	210	94
26.85	81.65	210	94
26.85	81.55	200	89
26.85	81.45	200	89
26.85	81.35	200	89
26.85	81.25	200	89
26.85	81.15	200	89
26.85	81.05	200	89
26.85	80.95	200	89
26.85	80.85	200	89
26.85	80.75	210	94
26.85	80.65	210	94
26.85	80.55	220	98
26.85	80.45	220	98
26.85	80.35	230	103
26.85	80.25	240	107
26.85	80.15	240	107
26.95	98.05	180	80
26.95	97.95	180	80
26.95	97.85	190	85
26.95	97.75	190	85
26.95	97.65	200	89
26.95	82.35	230	103
26.95	82.25	230	103
26.95	82.05	220	98
26.95	81.95	220	98
26.95	81.85	210	94
26.95	81.75	210	94
26.95	81.65	200	89
26.95	81.55	200	89

Latitudes: 26.95 - 27.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.95	81.45	200	89
26.95	81.35	200	89
26.95	81.25	200	89
26.95	81.15	200	89
26.95	81.05	200	89
26.95	80.95	200	89
26.95	80.85	200	89
26.95	80.75	210	94
26.95	80.65	210	94
26.95	80.55	220	98
26.95	80.45	230	103
26.95	80.35	230	103
26.95	80.25	240	107
26.95	80.15	240	107
27.05	98.05	180	80
27.05	97.95	180	80
27.05	97.85	190	85
27.05	97.75	190	85
27.05	97.65	200	89
27.05	97.55	210	94
27.05	82.45	230	103
27.05	82.35	230	103
27.05	82.25	220	98
27.05	82.15	220	98
27.05	82.05	210	94
27.05	81.95	210	94
27.05	81.85	210	94
27.05	81.75	200	89
27.05	81.65	200	89
27.05	81.55	200	89
27.05	81.45	200	89
27.05	81.35	200	89
27.05	81.25	200	89
27.05	81.15	200	89
27.05	81.05	200	89
27.05	80.95	200	89
27.05	80.85	200	89
27.05	80.75	210	94
27.05	80.65	210	94
27.05	80.55	220	98

Latitudes: 27.05 - 27.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.05	80.45	230	103
27.05	80.35	230	103
27.05	80.25	240	107
27.15	98.05	180	80
27.15	97.95	180	80
27.15	97.85	190	85
27.15	97.75	190	85
27.15	97.65	200	89
27.15	97.55	210	94
27.15	82.45	230	103
27.15	82.35	220	98
27.15	82.25	220	98
27.15	82.15	210	94
27.15	82.05	210	94
27.15	81.95	210	94
27.15	81.85	200	89
27.15	81.75	200	89
27.15	81.65	200	89
27.15	81.55	200	89
27.15	81.45	190	85
27.15	81.35	190	85
27.15	81.25	190	85
27.15	81.15	200	89
27.15	81.05	200	89
27.15	80.95	200	89
27.15	80.85	200	89
27.15	80.75	210	94
27.15	80.65	220	98
27.15	80.55	220	98
27.15	80.45	230	103
27.15	80.35	240	107
27.15	80.25	240	107
27.25	98.05	180	80
27.25	97.95	180	80
27.25	97.85	190	85
27.25	97.75	190	85
27.25	97.65	200	89
27.25	97.55	200	89
27.25	82.45	220	98
27.25	82.35	220	98

Latitudes: 27.25 - 27.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.25	82.25	210	94
27.25	82.15	210	94
27.25	81.95	200	89
27.25	81.85	200	89
27.25	81.75	200	89
27.25	81.65	190	85
27.25	81.55	190	85
27.25	81.45	190	85
27.25	81.35	190	85
27.25	81.25	190	85
27.25	81.15	190	85
27.25	81.05	200	89
27.25	80.95	200	89
27.25	80.85	200	89
27.25	80.75	210	94
27.25	80.65	220	98
27.25	80.55	220	98
27.25	80.45	230	103
27.25	80.35	240	107
27.35	98.05	180	80
27.35	97.95	180	80
27.35	97.85	190	85
27.35	97.75	190	85
27.35	97.65	200	89
27.35	97.45	210	94
27.35	82.55	220	98
27.35	82.45	220	98
27.35	82.35	210	94
27.35	82.25	210	94
27.35	81.95	200	89
27.35	81.85	200	89
27.35	81.75	190	85
27.35	81.65	190	85
27.35	81.55	190	85
27.35	81.45	190	85
27.35	81.35	190	85
27.35	81.25	190	85
27.35	81.15	190	85
27.35	81.05	200	89
27.35	80.95	200	89

Latitudes: 27.35 - 27.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.35	80.85	200	89
27.35	80.75	210	94
27.35	80.65	220	98
27.35	80.55	220	98
27.35	80.45	230	103
27.35	80.35	240	107
27.45	98.05	180	80
27.45	97.95	180	80
27.45	97.85	180	80
27.45	97.75	190	85
27.45	97.65	200	89
27.45	97.55	200	89
27.45	97.45	210	94
27.45	97.35	210	94
27.45	82.65	220	98
27.45	82.55	220	98
27.45	82.45	210	94
27.45	82.35	210	94
27.45	81.95	190	85
27.45	81.85	190	85
27.45	81.75	190	85
27.45	81.65	190	85
27.45	81.55	190	85
27.45	81.45	190	85
27.45	81.35	190	85
27.45	81.25	190	85
27.45	81.15	190	85
27.45	81.05	200	89
27.45	80.95	200	89
27.45	80.85	210	94
27.45	80.75	210	94
27.45	80.65	220	98
27.45	80.55	230	103
27.45	80.45	230	103
27.45	80.35	240	107
27.55	97.95	180	80
27.55	97.85	180	80
27.55	97.75	190	85
27.55	97.65	190	85
27.55	97.55	200	89

Latitudes: 27.55 - 27.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.55	97.45	210	94
27.55	82.65	220	98
27.55	82.55	210	94
27.55	82.45	210	94
27.55	82.35	210	94
27.55	81.95	190	85
27.55	81.85	190	85
27.55	81.75	190	85
27.55	81.65	190	85
27.55	81.55	190	85
27.55	81.45	190	85
27.55	81.35	190	85
27.55	81.25	190	85
27.55	81.15	190	85
27.55	81.05	200	89
27.55	80.95	200	89
27.55	80.85	210	94
27.55	80.75	210	94
27.55	80.65	220	98
27.55	80.55	230	103
27.55	80.45	230	103
27.65	97.95	180	80
27.65	97.85	180	80
27.65	97.75	190	85
27.65	97.65	190	85
27.65	97.55	200	89
27.65	97.45	200	89
27.65	97.35	210	94
27.65	82.55	210	94
27.65	82.45	210	94
27.65	81.95	190	85
27.65	81.85	190	85
27.65	81.75	190	85
27.65	81.65	190	85
27.65	81.55	190	85
27.65	81.45	190	85
27.65	81.35	190	85
27.65	81.25	190	85
27.65	81.15	190	85
27.65	81.05	200	89

Latitudes: 27.65 – 27.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.65	80.95	200	89
27.65	80.85	210	94
27.65	80.75	210	94
27.65	80.65	220	98
27.65	80.55	230	103
27.65	80.45	230	103
27.75	97.95	180	80
27.75	97.85	180	80
27.75	97.75	180	80
27.75	97.65	190	85
27.75	97.55	200	89
27.75	97.45	200	89
27.75	81.95	190	85
27.75	81.85	190	85
27.75	81.75	190	85
27.75	81.65	190	85
27.75	81.55	190	85
27.75	81.45	190	85
27.75	81.35	190	85
27.75	81.25	190	85
27.75	81.15	190	85
27.75	81.05	200	89
27.75	80.95	200	89
27.75	80.85	210	94
27.75	80.75	220	98
27.75	80.65	220	98
27.75	80.55	230	103
27.85	97.85	180	80
27.85	97.75	180	80
27.85	97.65	190	85
27.85	97.55	190	85
27.85	97.25	210	94
27.85	82.85	220	98
27.85	82.75	220	98
27.85	81.95	190	85
27.85	81.85	190	85
27.85	81.75	190	85
27.85	81.65	190	85
27.85	81.55	190	85
27.85	81.45	190	85

Latitudes: 27.85 – 28.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.85	81.35	190	85
27.85	81.25	190	85
27.85	81.15	190	85
27.85	81.05	200	89
27.85	80.95	200	89
27.85	80.85	210	94
27.85	80.75	220	98
27.85	80.65	220	98
27.85	80.55	230	103
27.95	97.85	180	80
27.95	97.75	180	80
27.95	97.65	180	80
27.95	97.55	190	85
27.95	97.45	190	85
27.95	97.35	200	89
27.95	97.25	200	89
27.95	97.15	210	94
27.95	82.85	220	98
27.95	82.75	220	98
27.95	81.95	190	85
27.95	81.85	190	85
27.95	81.75	190	85
27.95	81.65	180	80
27.95	81.55	190	85
27.95	81.45	190	85
27.95	81.35	190	85
27.95	81.25	190	85
27.95	81.15	190	85
27.95	81.05	200	89
27.95	80.95	200	89
27.95	80.85	210	94
27.95	80.75	220	98
27.95	80.65	220	98
28.05	97.75	180	80
28.05	97.65	180	80
28.05	97.55	190	85
28.05	97.45	190	85
28.05	97.35	200	89
28.05	97.25	200	89
28.05	97.15	210	94

Latitudes: 28.05 – 28.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.05	96.95	210	94
28.05	82.75	210	94
28.05	82.65	210	94
28.05	81.95	190	85
28.05	81.85	180	80
28.05	81.75	180	80
28.05	81.65	180	80
28.05	81.55	180	80
28.05	81.45	190	85
28.05	81.35	190	85
28.05	81.25	190	85
28.05	81.15	200	89
28.05	81.05	200	89
28.05	80.95	210	94
28.05	80.85	210	94
28.05	80.75	220	98
28.05	80.65	220	98
28.15	97.75	180	80
28.15	97.65	180	80
28.15	97.55	180	80
28.15	97.45	190	85
28.15	97.35	190	85
28.15	97.25	200	89
28.15	97.05	210	94
28.15	96.85	210	94
28.15	82.75	210	94
28.15	82.65	210	94
28.15	81.95	180	80
28.15	81.85	180	80
28.15	81.75	180	80
28.15	81.65	180	80
28.15	81.55	180	80
28.15	81.45	190	85
28.15	81.35	190	85
28.15	81.25	190	85
28.15	81.15	200	89
28.15	81.05	200	89
28.15	80.95	210	94
28.15	80.85	210	94
28.15	80.75	220	98

Latitudes: 28.25 – 28.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.25	97.65	180	80
28.25	97.55	180	80
28.25	97.45	190	85
28.25	97.35	190	85
28.25	97.25	190	85
28.25	97.15	200	89
28.25	97.05	200	89
28.25	96.95	210	94
28.25	96.85	210	94
28.25	96.65	220	98
28.25	82.75	210	94
28.25	82.65	210	94
28.25	81.95	180	80
28.25	81.85	180	80
28.25	81.75	180	80
28.25	81.65	180	80
28.25	81.55	180	80
28.25	81.45	190	85
28.25	81.35	190	85
28.25	81.25	190	85
28.25	81.15	200	89
28.25	81.05	200	89
28.25	80.95	210	94
28.25	80.85	210	94
28.25	80.75	220	98
28.35	97.65	180	80
28.35	97.55	180	80
28.35	97.45	180	80
28.35	97.35	190	85
28.35	97.25	190	85
28.35	97.15	190	85
28.35	97.05	200	89
28.35	96.95	200	89
28.35	96.85	210	94
28.35	96.65	210	94
28.35	82.75	210	94
28.35	81.95	180	80
28.35	81.85	180	80
28.35	81.75	180	80
28.35	81.65	180	80

Latitudes: 28.35 – 28.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.35	81.55	180	80
28.35	81.45	190	85
28.35	81.35	190	85
28.35	81.25	190	85
28.35	81.15	200	89
28.35	81.05	200	89
28.35	80.95	210	94
28.35	80.85	210	94
28.45	97.55	180	80
28.45	97.45	180	80
28.45	97.35	180	80
28.45	97.25	190	85
28.45	97.15	190	85
28.45	97.05	190	85
28.45	96.95	200	89
28.45	96.85	200	89
28.45	96.75	210	94
28.45	96.65	210	94
28.45	96.55	210	94
28.45	96.45	210	94
28.45	81.95	180	80
28.45	81.85	180	80
28.45	81.75	180	80
28.45	81.65	180	80
28.45	81.55	180	80
28.45	81.45	190	85
28.45	81.35	190	85
28.45	81.25	190	85
28.45	81.15	200	89
28.45	81.05	200	89
28.45	80.95	210	94
28.45	80.85	210	94
28.45	80.75	220	98
28.45	80.65	220	98
28.55	97.45	180	80
28.55	97.35	180	80
28.55	97.25	180	80
28.55	97.15	190	85
28.55	97.05	190	85
28.55	96.95	190	85

Latitudes: 28.55 – 28.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.55	96.85	200	89
28.55	96.75	200	89
28.55	96.65	200	89
28.55	81.95	180	80
28.55	81.85	180	80
28.55	81.75	180	80
28.55	81.65	180	80
28.55	81.55	180	80
28.55	81.45	190	85
28.55	81.35	190	85
28.55	81.25	190	85
28.55	81.15	200	89
28.55	81.05	200	89
28.55	80.95	210	94
28.55	80.85	210	94
28.65	97.35	180	80
28.65	97.25	180	80
28.65	97.15	180	80
28.65	97.05	190	85
28.65	96.95	190	85
28.65	96.85	190	85
28.65	96.75	200	89
28.65	96.45	200	89
28.65	96.25	210	94
28.65	96.15	210	94
28.65	95.95	210	94
28.65	81.95	180	80
28.65	81.85	180	80
28.65	81.75	180	80
28.65	81.65	180	80
28.65	81.55	180	80
28.65	81.45	190	85
28.65	81.35	190	85
28.65	81.25	190	85
28.65	81.15	200	89
28.65	81.05	210	94
28.65	80.95	210	94
28.65	80.85	220	98
28.65	80.75	220	98
28.65	80.65	220	98

Latitudes: 28.75 – 28.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.75	97.25	180	80
28.75	97.15	180	80
28.75	97.05	180	80
28.75	96.95	180	80
28.75	96.85	190	85
28.75	96.75	190	85
28.75	96.65	190	85
28.75	96.55	200	89
28.75	96.45	200	89
28.75	96.35	200	89
28.75	96.25	200	89
28.75	96.15	200	89
28.75	96.05	210	94
28.75	95.95	210	94
28.75	95.85	210	94
28.75	81.95	180	80
28.75	81.85	180	80
28.75	81.75	180	80
28.75	81.65	180	80
28.75	81.55	180	80
28.75	81.45	190	85
28.75	81.35	190	85
28.75	81.25	200	89
28.75	81.15	200	89
28.75	81.05	210	94
28.75	80.95	210	94
28.85	97.15	180	80
28.85	97.05	180	80
28.85	96.95	180	80
28.85	96.85	180	80
28.85	96.75	190	85
28.85	96.65	190	85
28.85	96.55	190	85
28.85	96.45	190	85
28.85	96.35	190	85
28.85	96.25	200	89
28.85	96.15	200	89
28.85	96.05	200	89
28.85	95.95	200	89
28.85	95.85	210	94

Latitudes: 28.85 – 28.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.85	95.75	210	94
28.85	95.65	210	94
28.85	95.55	210	94
28.85	81.95	180	80
28.85	81.85	180	80
28.85	81.75	180	80
28.85	81.65	180	80
28.85	81.55	190	85
28.85	81.45	190	85
28.85	81.35	190	85
28.85	81.25	200	89
28.85	81.15	200	89
28.85	81.05	210	94
28.85	80.95	210	94
28.85	80.85	220	98
28.95	97.05	180	80
28.95	96.95	180	80
28.95	96.85	180	80
28.95	96.75	180	80
28.95	96.65	180	80
28.95	96.55	190	85
28.95	96.45	190	85
28.95	96.35	190	85
28.95	96.25	190	85
28.95	96.15	190	85
28.95	96.05	200	89
28.95	95.95	200	89
28.95	95.85	200	89
28.95	95.75	200	89
28.95	95.65	210	94
28.95	95.55	210	94
28.95	95.45	210	94
28.95	81.95	180	80
28.95	81.85	180	80
28.95	81.75	180	80
28.95	81.65	180	80
28.95	81.55	190	85
28.95	81.45	190	85
28.95	81.35	190	85
28.95	81.25	200	89

Latitudes: 28.95 – 29.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.95	81.15	200	89
28.95	81.05	210	94
28.95	80.95	210	94
29.05	95.45	210	94
29.05	95.35	210	94
29.05	89.35	250	112
29.05	81.95	180	80
29.05	81.85	180	80
29.05	81.75	180	80
29.05	81.65	180	80
29.05	81.55	190	85
29.05	81.45	190	85
29.05	81.35	200	89
29.05	81.25	200	89
29.05	81.15	210	94
29.05	81.05	210	94
29.15	95.35	210	94
29.15	95.25	210	94
29.15	90.25	250	112
29.15	89.25	250	112
29.15	89.15	250	112
29.15	81.95	180	80
29.15	81.85	180	80
29.15	81.75	180	80
29.15	81.65	190	85
29.15	81.55	190	85
29.15	81.45	190	85
29.15	81.35	200	89
29.15	81.25	200	89
29.15	81.15	210	94
29.15	81.05	210	94
29.25	95.25	210	94
29.25	95.15	210	94
29.25	94.95	220	98
29.25	91.15	230	103
29.25	91.05	230	103
29.25	90.85	240	107
29.25	90.75	240	107
29.25	90.25	250	112
29.25	90.15	250	112

Latitudes: 29.25 - 29.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.25	89.45	250	112
29.25	89.35	250	112
29.25	89.25	250	112
29.25	81.95	180	80
29.25	81.85	180	80
29.25	81.75	180	80
29.25	81.65	190	85
29.25	81.55	190	85
29.25	81.45	190	85
29.25	81.35	200	89
29.25	81.25	200	89
29.25	81.15	210	94
29.35	95.15	210	94
29.35	95.05	210	94
29.35	94.95	210	94
29.35	91.25	230	103
29.35	91.15	230	103
29.35	90.95	230	103
29.35	90.85	230	103
29.35	90.75	230	103
29.35	90.65	230	103
29.35	90.55	230	103
29.35	90.45	240	107
29.35	90.35	240	107
29.35	90.25	240	107
29.35	90.15	240	107
29.35	89.75	250	112
29.35	89.55	250	112
29.35	89.45	250	112
29.35	89.35	250	112
29.35	89.25	250	112
29.35	81.95	180	80
29.35	81.85	180	80
29.35	81.75	180	80
29.35	81.65	190	85
29.35	81.55	190	85
29.35	81.45	200	89
29.35	81.35	200	89
29.35	81.25	210	94
29.35	81.15	210	94

Latitudes: 29.45 – 29.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.45	95.05	210	94
29.45	94.95	210	94
29.45	94.75	220	98
29.45	91.25	220	98
29.45	91.15	220	98
29.45	91.05	220	98
29.45	90.95	220	98
29.45	90.85	220	98
29.45	90.75	220	98
29.45	90.65	220	98
29.45	90.55	230	103
29.45	90.45	230	103
29.45	90.35	230	103
29.45	90.25	230	103
29.45	90.15	240	107
29.45	89.85	240	107
29.45	89.75	240	107
29.45	89.65	240	107
29.45	81.95	180	80
29.45	81.85	180	80
29.45	81.75	180	80
29.45	81.65	190	85
29.45	81.55	190	85
29.45	81.45	200	89
29.45	81.35	200	89
29.45	81.25	210	94
29.45	81.15	210	94
29.55	91.95	230	103
29.55	91.85	230	103
29.55	91.35	220	98
29.55	91.25	220	98
29.55	91.15	210	94
29.55	91.05	210	94
29.55	90.95	210	94
29.55	90.85	210	94
29.55	90.75	210	94
29.55	90.65	220	98
29.55	90.55	220	98
29.55	90.45	220	98
29.55	90.35	220	98

Latitudes: 29.55 – 29.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.55	90.25	230	103
29.55	90.05	230	103
29.55	89.95	230	103
29.55	89.85	240	107
29.55	89.75	240	107
29.55	81.95	180	80
29.55	81.85	180	80
29.55	81.75	190	85
29.55	81.65	190	85
29.55	81.55	190	85
29.55	81.45	200	89
29.55	81.35	200	89
29.55	81.25	210	94
29.65	94.75	210	94
29.65	94.65	210	94
29.65	94.55	210	94
29.65	94.45	210	94
29.65	94.35	220	98
29.65	94.25	220	98
29.65	92.75	220	98
29.65	92.65	220	98
29.65	92.55	220	98
29.65	92.45	220	98
29.65	92.35	220	98
29.65	92.25	220	98
29.65	92.15	230	103
29.65	91.95	230	103
29.65	91.55	220	98
29.65	91.45	220	98
29.65	91.35	210	94
29.65	91.25	210	94
29.65	91.15	210	94
29.65	91.05	210	94
29.65	90.95	210	94
29.65	90.85	210	94
29.65	90.75	210	94
29.65	90.65	210	94
29.65	90.55	210	94
29.65	90.45	210	94
29.65	90.35	220	98

Latitudes: 29.65 – 29.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.65	90.25	220	98
29.65	90.15	220	98
29.65	90.05	230	103
29.65	89.95	230	103
29.65	89.85	230	103
29.65	81.95	180	80
29.65	81.85	180	80
29.65	81.75	190	85
29.65	81.65	190	85
29.65	81.55	200	89
29.65	81.45	200	89
29.65	81.35	210	94
29.75	94.65	210	94
29.75	94.55	210	94
29.75	94.45	210	94
29.75	94.35	210	94
29.75	94.25	210	94
29.75	94.15	210	94
29.75	94.05	220	98
29.75	93.95	220	98
29.75	93.05	220	98
29.75	92.95	220	98
29.75	92.85	220	98
29.75	92.75	220	98
29.75	92.65	220	98
29.75	92.55	220	98
29.75	92.45	220	98
29.75	92.35	220	98
29.75	92.25	220	98
29.75	91.65	220	98
29.75	91.55	210	94
29.75	91.45	210	94
29.75	91.35	210	94
29.75	91.25	210	94
29.75	90.45	210	94
29.75	90.35	210	94
29.75	90.25	210	94
29.75	90.15	220	98
29.75	90.05	220	98
29.75	89.95	220	98

Latitudes: 29.75 – 29.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.75	89.85	230	103
29.75	89.75	230	103
29.75	81.95	180	80
29.75	81.85	180	80
29.75	81.75	190	85
29.75	81.65	190	85
29.75	81.55	200	89
29.75	81.45	200	89
29.75	81.35	210	94
29.85	94.25	210	94
29.85	94.15	210	94
29.85	94.05	210	94
29.85	93.85	210	94
29.85	93.75	220	98
29.85	93.65	220	98
29.85	93.55	220	98
29.85	93.45	220	98
29.85	93.35	220	98
29.85	93.25	220	98
29.85	93.15	220	98
29.85	93.05	210	94
29.85	92.95	210	94
29.85	92.85	210	94
29.85	92.75	210	94
29.85	92.65	210	94
29.85	92.55	210	94
29.85	92.45	210	94
29.85	92.35	210	94
29.85	92.25	210	94
29.85	92.15	210	94
29.85	92.05	220	98
29.85	91.85	220	98
29.85	91.75	210	94
29.85	91.65	210	94
29.85	91.55	210	94
29.85	91.45	210	94
29.85	90.35	210	94
29.85	90.25	210	94
29.85	90.15	210	94
29.85	90.05	210	94

Latitudes: 29.85 – 29.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.85	89.95	220	98
29.85	89.85	220	98
29.85	89.75	230	103
29.85	89.65	230	103
29.85	89.55	240	107
29.85	81.95	180	80
29.85	81.85	180	80
29.85	81.75	190	85
29.85	81.65	190	85
29.85	81.55	200	89
29.85	81.45	200	89
29.95	93.95	210	94
29.95	93.75	210	94
29.95	93.65	210	94
29.95	93.55	210	94
29.95	93.45	210	94
29.95	93.35	210	94
29.95	93.25	210	94
29.95	93.15	210	94
29.95	93.05	210	94
29.95	92.95	210	94
29.95	92.85	210	94
29.95	92.75	210	94
29.95	92.65	210	94
29.95	92.55	210	94
29.95	92.45	210	94
29.95	92.35	210	94
29.95	92.25	210	94
29.95	92.15	210	94
29.95	92.05	210	94
29.95	91.95	210	94
29.95	91.85	210	94
29.95	91.75	210	94
29.95	91.65	210	94
29.95	90.15	210	94
29.95	90.05	210	94
29.95	89.95	210	94
29.95	89.85	220	98
29.95	89.55	240	107
29.95	81.95	180	80

Latitudes: 29.95 – 30.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.95	81.85	180	80
29.95	81.75	190	85
29.95	81.65	190	85
29.95	81.55	200	89
29.95	81.45	210	94
29.95	81.35	210	94
30.05	90.05	210	94
30.05	89.95	210	94
30.05	89.85	220	98
30.05	81.95	180	80
30.05	81.85	190	85
30.05	81.75	190	85
30.05	81.65	200	89
30.05	81.55	200	89
30.05	81.45	210	94
30.15	89.95	210	94
30.15	81.95	180	80
30.15	81.85	190	85
30.15	81.75	190	85
30.15	81.65	200	89
30.15	81.55	200	89
30.15	81.45	210	94
30.25	89.75	220	98
30.25	89.65	220	98
30.25	89.55	230	103
30.25	81.95	180	80
30.25	81.85	190	85
30.25	81.75	190	85
30.25	81.65	200	89
30.25	81.55	200	89
30.35	89.85	210	94
30.35	89.75	210	94
30.35	89.65	220	98
30.35	89.55	230	103
30.35	89.45	230	103
30.35	89.25	240	107
30.35	87.75	250	112
30.35	87.65	250	112
30.35	87.45	240	107
30.35	87.25	240	107

Latitudes: 30.35 – 30.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.35	81.95	180	80
30.35	81.85	190	85
30.35	81.75	190	85
30.35	81.65	200	89
30.35	81.55	200	89
30.45	89.75	210	94
30.45	89.65	210	94
30.45	89.55	220	98
30.45	89.45	220	98
30.45	89.35	230	103
30.45	89.25	230	103
30.45	89.15	230	103
30.45	89.05	240	107
30.45	88.95	240	107
30.45	88.85	240	107
30.45	88.75	240	107
30.45	88.65	240	107
30.45	88.55	240	107
30.45	88.45	240	107
30.45	88.35	240	107
30.45	88.25	240	107
30.45	88.15	240	107
30.45	87.85	240	107
30.45	87.75	240	107
30.45	87.65	240	107
30.45	87.55	240	107
30.45	87.35	230	103
30.45	87.25	230	103
30.45	86.95	220	98
30.45	86.85	220	98
30.45	86.75	220	98
30.45	86.65	210	94
30.45	81.95	180	80
30.45	81.85	190	85
30.45	81.75	190	85
30.45	81.65	200	89
30.45	81.55	210	94
30.55	89.65	210	94
30.55	89.55	210	94
30.55	89.45	220	98

Latitudes: 30.55 – 30.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.55	89.35	220	98
30.55	89.25	220	98
30.55	89.15	230	103
30.55	89.05	230	103
30.55	88.95	230	103
30.55	88.85	230	103
30.55	88.75	230	103
30.55	88.65	230	103
30.55	88.55	230	103
30.55	88.45	240	107
30.55	88.35	240	107
30.55	88.25	240	107
30.55	88.15	240	107
30.55	87.85	230	103
30.55	87.75	230	103
30.55	87.65	230	103
30.55	87.55	230	103
30.55	87.45	230	103
30.55	87.35	230	103
30.55	87.25	220	98
30.55	86.95	220	98
30.55	86.85	220	98
30.55	86.75	210	94
30.55	86.65	210	94
30.55	86.55	210	94
30.55	81.95	180	80
30.55	81.85	190	85
30.55	81.75	200	89
30.55	81.65	200	89
30.55	81.55	210	94
30.65	89.55	210	94
30.65	89.45	210	94
30.65	89.35	210	94
30.65	89.25	220	98
30.65	89.15	220	98
30.65	89.05	220	98
30.65	88.95	220	98
30.65	88.85	220	98
30.65	88.75	220	98
30.65	88.65	220	98

Latitudes: 30.65 – 30.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.65	88.55	230	103
30.65	88.45	230	103
30.65	88.35	230	103
30.65	88.25	230	103
30.65	88.15	230	103
30.65	87.95	230	103
30.65	87.85	220	98
30.65	87.75	220	98
30.65	87.65	220	98
30.65	87.55	220	98
30.65	87.45	220	98
30.65	87.35	220	98
30.65	87.25	220	98
30.65	87.15	220	98
30.65	87.05	210	94
30.65	86.95	210	94
30.65	86.85	210	94
30.65	86.75	210	94
30.65	81.95	190	85
30.65	81.85	190	85
30.65	81.75	200	89
30.65	81.65	200	89
30.65	81.55	210	94
30.75	89.45	210	94
30.75	89.35	210	94
30.75	89.25	210	94
30.75	89.15	210	94
30.75	89.05	210	94
30.75	88.95	210	94
30.75	88.85	210	94
30.75	88.75	220	98
30.75	88.65	220	98
30.75	88.55	220	98
30.75	88.45	220	98
30.75	88.35	220	98
30.75	88.25	220	98
30.75	88.15	220	98
30.75	87.95	220	98
30.75	87.85	220	98
30.75	87.75	220	98

Latitudes: 30.75 – 31.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.75	87.65	210	94
30.75	87.55	210	94
30.75	87.45	210	94
30.75	87.35	210	94
30.75	87.25	210	94
30.75	87.15	210	94
30.75	87.05	210	94
30.75	86.95	210	94
30.75	81.95	190	85
30.75	81.85	190	85
30.75	81.75	200	89
30.75	81.65	200	89
30.85	89.05	210	94
30.85	88.95	210	94
30.85	88.85	210	94
30.85	88.75	210	94
30.85	88.65	210	94
30.85	88.55	210	94
30.85	88.45	210	94
30.85	88.35	210	94
30.85	88.25	210	94
30.85	88.15	210	94
30.85	88.05	210	94
30.85	87.95	210	94
30.85	87.85	210	94
30.85	87.75	210	94
30.85	87.65	210	94
30.85	87.55	210	94
30.85	81.95	190	85
30.85	81.85	190	85
30.85	81.75	200	89
30.85	81.65	200	89
30.95	81.95	190	85
30.95	81.85	190	85
30.95	81.75	200	89
30.95	81.65	200	89
30.95	81.55	210	94
30.95	81.45	210	94
31.05	81.95	190	85
31.05	81.85	190	85

Latitudes: 31.05 – 31.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
31.05	81.75	200	89
31.05	81.65	200	89
31.15	81.95	190	85
31.15	81.85	190	85
31.15	81.75	200	89
31.15	81.65	200	89
31.25	81.95	190	85
31.25	81.85	190	85
31.25	81.75	200	89
31.25	81.65	200	89
31.25	81.55	210	94
31.25	81.45	210	94
31.35	81.95	190	85
31.35	81.85	190	85
31.35	81.75	200	89
31.35	81.65	200	89
31.35	81.55	210	94
31.35	81.45	210	94
31.45	81.95	190	85
31.45	81.85	190	85
31.45	81.75	190	85
31.45	81.65	200	89
31.45	81.55	210	94
31.45	81.45	210	94
31.45	81.35	220	98
31.55	81.95	180	80
31.55	81.85	190	85
31.55	81.75	190	85
31.55	81.65	200	89
31.55	81.55	200	89
31.55	81.45	210	94
31.55	81.35	210	94
31.65	81.95	180	80
31.65	81.85	190	85
31.65	81.75	190	85
31.65	81.65	200	89
31.65	81.55	200	89
31.65	81.45	210	94
31.65	81.35	210	94
31.65	81.25	220	98

Latitudes: 31.75 – 32.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
31.75	81.95	180	80
31.75	81.85	190	85
31.75	81.75	190	85
31.75	81.65	190	85
31.75	81.55	200	89
31.75	81.45	210	94
31.75	81.35	210	94
31.85	81.95	180	80
31.85	81.85	180	80
31.85	81.75	190	85
31.85	81.65	190	85
31.85	81.55	200	89
31.85	81.45	200	89
31.85	81.35	210	94
31.85	81.25	210	94
31.85	81.15	220	98
31.95	81.95	180	80
31.95	81.85	180	80
31.95	81.75	190	85
31.95	81.65	190	85
31.95	81.55	190	85
31.95	81.45	200	89
31.95	81.35	210	94
31.95	81.25	210	94
31.95	81.15	220	98
31.95	81.05	220	98
32.05	81.95	180	80
32.05	81.85	180	80
32.05	81.75	180	80
32.05	81.65	190	85
32.05	81.55	190	85
32.05	81.45	200	89
32.05	81.35	200	89
32.05	81.25	210	94
32.05	81.15	210	94
32.05	81.05	220	98
32.15	81.95	180	80
32.15	81.85	180	80
32.15	81.75	180	80
32.15	81.65	190	85

Latitudes: 32.15 – 32.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.15	81.55	190	85
32.15	81.45	190	85
32.15	81.35	200	89
32.15	81.25	200	89
32.15	81.15	210	94
32.15	81.05	210	94
32.15	80.95	220	98
32.25	81.95	180	80
32.25	81.85	180	80
32.25	81.75	180	80
32.25	81.65	180	80
32.25	81.55	190	85
32.25	81.45	190	85
32.25	81.35	200	89
32.25	81.25	200	89
32.25	81.15	210	94
32.25	81.05	210	94
32.25	80.95	220	98
32.25	80.85	220	98
32.25	80.75	220	98
32.35	81.85	180	80
32.35	81.75	180	80
32.35	81.65	180	80
32.35	81.55	180	80
32.35	81.45	190	85
32.35	81.35	190	85
32.35	81.25	200	89
32.35	81.15	200	89
32.35	81.05	210	94
32.35	80.95	210	94
32.35	80.85	220	98
32.35	80.75	220	98
32.35	80.65	230	103
32.35	80.55	230	103
32.45	81.85	180	80
32.45	81.75	180	80
32.45	81.65	180	80
32.45	81.55	180	80
32.45	81.45	190	85
32.45	81.35	190	85

Latitudes: 32.45 – 32.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.45	81.25	190	85
32.45	81.15	200	89
32.45	81.05	200	89
32.45	80.95	210	94
32.45	80.75	220	98
32.45	80.65	220	98
32.45	80.55	230	103
32.55	81.75	180	80
32.55	81.65	180	80
32.55	81.55	180	80
32.55	81.45	180	80
32.55	81.35	190	85
32.55	81.25	190	85
32.55	81.15	190	85
32.55	81.05	200	89
32.55	80.95	200	89
32.55	80.85	210	94
32.55	80.75	220	98
32.55	80.65	220	98
32.55	80.45	230	103
32.55	80.35	230	103
32.65	81.75	180	80
32.65	81.65	180	80
32.65	81.55	180	80
32.65	81.45	180	80
32.65	81.35	180	80
32.65	81.25	190	85
32.65	81.15	190	85
32.65	81.05	200	89
32.65	80.95	200	89
32.65	80.85	210	94
32.65	80.75	210	94
32.65	80.65	220	98
32.65	80.55	220	98
32.65	80.35	220	98
32.65	80.25	230	103
32.65	80.15	230	103
32.65	80.05	230	103
32.75	81.65	180	80
32.75	81.55	180	80

Latitudes: 32.75 – 32.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.75	81.45	180	80
32.75	81.35	180	80
32.75	81.25	180	80
32.75	81.15	190	85
32.75	81.05	190	85
32.75	80.95	200	89
32.75	80.85	200	89
32.75	80.75	210	94
32.75	80.65	210	94
32.75	80.55	210	94
32.75	80.45	220	98
32.75	80.35	220	98
32.75	80.25	220	98
32.75	80.15	220	98
32.75	80.05	220	98
32.75	79.95	230	103
32.85	81.55	180	80
32.85	81.45	180	80
32.85	81.35	180	80
32.85	81.25	180	80
32.85	81.15	190	85
32.85	81.05	190	85
32.85	80.95	190	85
32.85	80.85	200	89
32.85	80.75	200	89
32.85	80.65	210	94
32.85	80.55	210	94
32.85	80.45	210	94
32.85	80.35	210	94
32.85	80.25	220	98
32.85	80.15	220	98
32.85	80.05	220	98
32.85	79.85	220	98
32.85	79.75	230	103
32.95	81.45	180	80
32.95	81.35	180	80
32.95	81.25	180	80
32.95	81.15	180	80
32.95	81.05	190	85
32.95	80.95	190	85

Latitudes: 32.95 – 33.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.95	80.85	190	85
32.95	80.75	200	89
32.95	80.65	200	89
32.95	80.55	200	89
32.95	80.45	210	94
32.95	80.35	210	94
32.95	80.25	210	94
32.95	80.15	210	94
32.95	80.05	220	98
32.95	79.95	220	98
32.95	79.85	220	98
32.95	79.75	220	98
32.95	79.65	220	98
33.05	80.25	210	94
33.05	80.15	210	94
33.05	80.05	210	94
33.05	79.95	210	94
33.05	79.85	220	98
33.05	79.75	220	98
33.05	79.65	220	98
33.05	79.55	220	98
33.05	79.45	220	98
33.15	80.05	210	94
33.15	79.95	210	94
33.15	79.85	210	94
33.15	79.75	210	94
33.15	79.65	220	98
33.15	79.55	220	98
33.15	79.45	220	98
33.15	79.35	220	98
33.25	79.85	210	94
33.25	79.75	210	94
33.25	79.65	210	94
33.25	79.55	210	94
33.25	79.45	220	98
33.25	79.35	220	98
33.35	79.65	210	94
33.35	79.55	210	94
33.35	79.45	210	94
33.35	79.35	220	98

Latitudes: 33.35 – 34.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
33.35	79.25	220	98
33.45	79.55	210	94
33.45	79.45	210	94
33.45	79.35	210	94
33.45	79.25	210	94
33.55	79.35	210	94
33.55	79.25	210	94
33.55	79.15	210	94
33.65	79.25	210	94
33.65	79.15	210	94
33.65	79.05	210	94
33.75	79.05	210	94
33.75	78.95	210	94
33.85	78.95	210	94
33.85	78.85	210	94
33.85	78.75	210	94
33.95	78.75	210	94
33.95	78.65	210	94
33.95	78.55	210	94
33.95	78.45	210	94
33.95	78.35	210	94
33.95	78.25	210	94
33.95	78.15	220	98
34.05	78.55	210	94
34.05	78.45	210	94
34.05	78.35	210	94
34.05	78.25	210	94
34.05	78.15	210	94
34.05	78.05	210	94
34.15	78.25	210	94
34.15	78.15	210	94
34.15	78.05	210	94
34.15	77.95	210	94
34.25	77.95	210	94
34.35	77.95	200	89
34.35	77.85	200	89
34.45	77.95	200	89
34.45	77.85	200	89
34.45	77.75	200	89
34.45	77.65	200	89

Latitudes: 34.55 – 34.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
34.55	77.95	190	85
34.55	77.85	190	85
34.55	77.75	200	89
34.55	77.65	200	89
34.55	77.55	200	89
34.55	77.45	200	89
34.65	77.95	190	85
34.65	77.85	190	85
34.65	77.75	190	85
34.65	77.65	190	85
34.65	77.55	190	85
34.65	77.45	200	89
34.65	77.35	200	89
34.65	77.25	200	89
34.75	77.95	180	80
34.75	77.85	190	85
34.75	77.75	190	85
34.75	77.65	190	85
34.75	77.55	190	85
34.75	77.45	190	85
34.75	77.35	190	85
34.75	77.25	190	85
34.75	77.05	200	89
34.75	76.95	200	89
34.75	76.85	200	89
34.75	76.75	200	89
34.75	76.65	200	89
34.85	77.95	180	80
34.85	77.85	180	80
34.85	77.75	180	80
34.85	77.65	180	80
34.85	77.55	190	85
34.85	77.45	190	85
34.85	77.35	190	85
34.85	77.25	190	85
34.85	77.15	190	85
34.85	77.05	190	85
34.85	76.95	190	85
34.85	76.85	200	89
34.85	76.75	200	89

Latitudes: 34.85 – 35.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
34.85	76.65	200	89
34.85	76.55	200	89
34.95	77.95	180	80
34.95	77.85	180	80
34.95	77.75	180	80
34.95	77.65	180	80
34.95	77.55	180	80
34.95	77.45	180	80
34.95	77.35	180	80
34.95	77.25	190	85
34.95	77.15	190	85
34.95	77.05	190	85
34.95	76.95	190	85
34.95	76.65	190	85
34.95	76.55	200	89
34.95	76.45	200	89
35.05	77.95	180	80
35.05	77.85	180	80
35.05	77.75	180	80
35.05	77.65	180	80
35.05	77.55	180	80
35.05	77.45	180	80
35.05	77.35	180	80
35.05	77.25	180	80
35.05	77.15	180	80
35.05	77.05	190	85
35.05	76.95	190	85
35.05	76.85	190	85
35.05	76.75	190	85
35.15	77.65	180	80
35.15	77.55	180	80
35.15	77.45	180	80
35.15	77.35	180	80
35.15	77.25	180	80
35.15	77.15	180	80
35.15	77.05	180	80
35.15	76.95	180	80
35.15	76.85	180	80
35.15	76.75	190	85
35.15	76.65	190	85

Latitudes: 35.15 – 37.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
35.15	75.95	190	85
35.25	77.35	180	80
35.25	77.25	180	80
35.25	77.15	180	80
35.25	77.05	180	80
35.25	76.95	180	80
35.25	76.85	180	80
35.25	76.75	180	80
35.25	76.65	180	80
35.25	75.65	190	85
35.35	77.15	180	80
35.35	77.05	180	80
35.35	76.95	180	80
35.35	76.85	180	80
35.35	76.75	180	80
35.35	75.55	190	85
35.45	76.75	180	80
35.45	76.55	180	80
35.45	76.45	180	80
35.45	76.35	180	80
35.45	76.25	180	80
35.45	76.15	180	80
35.55	76.45	180	80
35.55	76.35	180	80
35.55	76.25	180	80
35.55	76.15	180	80
35.55	76.05	180	80
35.65	76.25	180	80
35.65	76.15	180	80
35.65	76.05	180	80
35.65	75.95	180	80
35.65	75.85	180	80
35.75	75.95	180	80
35.75	75.85	180	80
35.85	75.95	180	80
35.85	75.85	180	80
36.15	75.85	180	80
36.35	75.85	180	80
37.65	75.75	180	80
37.75	75.65	180	80

Latitudes: 38.45 – 41.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
38.45	75.15	180	80
40.65	73.65	180	80
40.75	73.55	180	80
40.75	73.45	180	80
40.75	73.35	180	80
40.75	73.25	180	80
40.75	73.15	180	80
40.85	73.45	180	80
40.85	73.35	180	80
40.85	73.25	180	80
40.85	73.15	180	80
40.85	73.05	180	80
40.85	72.95	180	80
40.85	72.85	190	85
40.85	72.75	190	85
40.85	72.65	190	85
40.85	72.55	190	85
40.95	73.15	180	80
40.95	73.05	180	80
40.95	72.95	180	80
40.95	72.85	180	80
40.95	72.75	180	80
40.95	72.65	180	80
40.95	72.45	190	85
40.95	72.35	190	85
40.95	72.25	190	85
41.05	72.55	180	80
41.05	72.25	190	85
41.05	72.05	190	85
41.15	73.25	180	80
41.15	72.35	180	80
41.25	73.05	180	80
41.35	72.95	180	80
41.35	72.85	180	80
41.35	72.75	180	80
41.35	72.65	180	80
41.35	72.55	180	80
41.35	72.45	180	80
41.35	72.35	180	80
41.35	72.25	180	80

Latitudes: 41.35 – 41.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
41.35	72.15	180	80
41.35	72.05	180	80
41.35	71.95	180	80
41.35	71.85	180	80
41.35	71.75	180	80
41.35	70.85	190	85
41.35	70.05	190	85
41.45	72.65	180	80
41.45	72.55	180	80
41.45	72.45	180	80
41.45	72.35	180	80
41.45	72.25	180	80
41.45	72.15	180	80
41.45	72.05	180	80
41.45	71.95	180	80
41.45	71.85	180	80
41.45	71.75	180	80
41.45	71.65	180	80
41.45	71.55	180	80
41.45	70.65	190	85
41.55	72.35	180	80
41.55	72.25	180	80
41.55	72.15	180	80
41.55	72.05	180	80
41.55	71.95	180	80
41.55	71.85	180	80
41.55	71.75	180	80
41.55	71.65	180	80
41.55	71.55	180	80
41.55	71.15	190	85
41.55	71.05	190	85
41.65	71.95	180	80
41.65	71.85	180	80
41.65	71.75	180	80
41.65	71.65	180	80
41.65	71.55	180	80
41.65	71.15	180	80
41.65	71.05	180	80
41.65	70.95	180	80
41.65	70.65	190	85

Latitudes: 41.65 – 42.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
41.65	70.55	180	80
41.65	70.45	190	85
41.65	70.35	190	85
41.75	71.55	180	80
41.75	71.45	180	80
41.75	71.35	180	80
41.75	71.25	180	80
41.75	71.15	180	80
41.75	71.05	180	80
41.75	70.95	180	80
41.75	70.85	180	80
41.75	70.75	180	80
41.75	70.65	180	80
41.75	70.55	180	80
41.75	70.45	180	80
41.75	70.15	180	80
41.75	70.05	190	85
41.85	71.35	180	80
41.85	71.25	180	80
41.85	71.15	180	80
41.85	71.05	180	80
41.85	70.95	180	80
41.85	70.85	180	80
41.85	70.75	180	80
41.85	70.65	180	80
41.95	71.15	180	80
41.95	71.05	180	80
41.95	70.95	180	80
41.95	70.85	180	80
41.95	70.75	180	80
41.95	70.65	180	80
41.95	70.05	180	80
42.05	71.05	180	80
42.05	70.95	180	80
42.05	70.85	180	80
42.05	70.75	180	80
42.05	70.15	180	80
42.15	70.95	180	80
42.15	70.85	180	80
42.15	70.75	180	80

Latitudes: 42.25 – 44.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
42.25	70.85	180	80
44.35	68.25	180	80

APPENDIX B: MAXIMUM PEAK GUST WIND SPEEDS ASSOCIATED WITH AN ANNUAL EXCEEDANCE PROBABILITY OF 10^{-7}

Appendix B contains the maximum peak gust wind speeds associated with an annual exceedance probability of 10^{-7} (rounded up to the nearest 10 mph) on a 0.1 by 0.1 degree grid. Latitude and longitude of the grid represents the mid-point of the 0.1 degree by 0.1 degree square.

Wind speed is only provided for locations where the hurricane wind speed exceeds the tornado wind speed with the same exceedance probability (see Figure 3-6).

Latitudes: 25.05 - 25.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.05	81.25	290	130
25.05	81.15	290	130
25.05	81.05	280	125
25.05	80.95	280	125
25.05	80.85	280	125
25.05	80.75	280	125
25.05	80.65	280	125
25.05	80.55	280	125
25.05	80.45	280	125
25.05	80.35	280	125
25.05	80.25	280	125
25.15	81.35	280	125
25.15	81.25	280	125
25.15	81.15	280	125
25.15	81.05	280	125
25.15	80.95	270	121
25.15	80.85	270	121
25.15	80.75	270	121
25.15	80.65	270	121
25.15	80.55	270	121
25.15	80.45	270	121
25.15	80.35	270	121
25.15	80.25	280	125
25.25	81.35	280	125
25.25	81.25	280	125
25.25	81.15	270	121
25.25	81.05	270	121
25.25	80.95	270	121
25.25	80.85	260	116
25.25	80.75	260	116
25.25	80.65	260	116
25.25	80.55	260	116
25.25	80.45	270	121
25.25	80.35	270	121
25.25	80.25	270	121
25.25	80.15	270	121
25.35	81.35	280	125
25.35	81.25	270	121
25.35	81.15	270	121

Latitudes: 25.35 - 25.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.35	81.05	260	116
25.35	80.95	260	116
25.35	80.85	250	112
25.35	80.75	250	112
25.35	80.65	250	112
25.35	80.55	260	116
25.35	80.45	260	116
25.35	80.35	260	116
25.35	80.25	270	121
25.35	80.15	270	121
25.45	81.35	270	121
25.45	81.25	270	121
25.45	81.15	260	116
25.45	81.05	250	112
25.45	80.95	250	112
25.45	80.85	250	112
25.45	80.75	240	107
25.45	80.65	250	112
25.45	80.55	250	112
25.45	80.45	250	112
25.45	80.35	260	116
25.45	80.25	260	116
25.55	81.35	270	121
25.55	81.25	260	116
25.55	81.15	250	112
25.55	81.05	250	112
25.55	80.95	240	107
25.55	80.85	240	107
25.55	80.75	240	107
25.55	80.65	240	107
25.55	80.55	240	107
25.55	80.45	250	112
25.55	80.35	250	112
25.55	80.25	260	116
25.55	80.15	260	116
25.65	97.45	210	94
25.65	97.35	210	94
25.65	81.45	270	121
25.65	81.35	260	116

Latitudes: 25.65 - 25.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.65	81.25	250	112
25.65	81.15	250	112
25.65	81.05	240	107
25.65	80.95	240	107
25.65	80.85	230	103
25.65	80.75	230	103
25.65	80.65	230	103
25.65	80.55	240	107
25.65	80.45	240	107
25.65	80.35	250	112
25.65	80.25	250	112
25.65	80.15	260	116
25.75	97.55	210	94
25.75	97.45	210	94
25.75	97.35	220	98
25.75	97.25	220	98
25.75	97.15	220	98
25.75	81.85	280	125
25.75	81.75	280	125
25.75	81.65	270	121
25.75	81.55	270	121
25.75	81.45	260	116
25.75	81.35	260	116
25.75	81.25	250	112
25.75	81.15	240	107
25.75	81.05	230	103
25.75	80.95	230	103
25.75	80.85	230	103
25.75	80.75	230	103
25.75	80.65	230	103
25.75	80.55	230	103
25.75	80.45	240	107
25.75	80.35	240	107
25.75	80.25	250	112
25.75	80.15	260	116
25.75	80.05	260	116
25.85	97.55	210	94
25.85	97.45	210	94
25.85	97.35	220	98

Latitudes: 25.85 - 25.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
25.85	97.25	220	98
25.85	97.15	220	98
25.85	97.05	230	103
25.85	81.85	280	125
25.85	81.75	270	121
25.85	81.65	270	121
25.85	81.55	260	116
25.85	81.45	260	116
25.85	81.35	250	112
25.85	81.25	240	107
25.85	81.15	240	107
25.85	81.05	230	103
25.85	80.95	220	98
25.85	80.85	220	98
25.85	80.75	220	98
25.85	80.65	220	98
25.85	80.55	230	103
25.85	80.45	230	103
25.85	80.35	240	107
25.85	80.25	250	112
25.85	80.15	260	116
25.85	80.05	260	116
25.95	97.55	210	94
25.95	97.45	210	94
25.95	97.35	220	98
25.95	97.25	220	98
25.95	97.15	230	103
25.95	97.05	230	103
25.95	81.85	270	121
25.95	81.75	270	121
25.95	81.65	260	116
25.95	81.55	260	116
25.95	81.45	250	112
25.95	81.35	240	107
25.95	81.25	240	107
25.95	81.15	230	103
25.95	81.05	220	98
25.95	80.95	220	98
25.95	80.85	220	98
25.95	80.75	220	98

Latitudes: 25.95 - 26.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps).
25.95	80.65	220	98
25.95	80.55	230	103
25.95	80.45	230	103
25.95	80.35	240	107
25.95	80.25	250	112
25.95	80.15	250	112
25.95	80.05	260	116
26.05	97.55	210	94
26.05	97.45	210	94
26.05	97.35	220	98
26.05	97.25	220	98
26.05	97.15	230	103
26.05	97.05	230	103
26.05	81.95	280	125
26.05	81.85	270	121
26.05	81.75	270	121
26.05	81.65	260	116
26.05	81.55	250	112
26.05	81.45	240	107
26.05	81.35	240	107
26.05	81.25	230	103
26.05	81.15	220	98
26.05	81.05	220	98
26.05	80.95	220	98
26.05	80.85	220	98
26.05	80.75	220	98
26.05	80.65	220	98
26.05	80.55	220	98
26.05	80.45	230	103
26.05	80.35	240	107
26.05	80.25	250	112
26.05	80.15	250	112
26.05	80.05	260	116
26.15	97.55	210	94
26.15	97.45	220	98
26.15	97.35	220	98
26.15	97.25	220	98
26.15	97.15	230	103
26.15	97.05	230	103
26.15	81.95	270	121

Latitudes: 26.15 - 26.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps).
26.15	81.85	270	121
26.15	81.75	260	116
26.15	81.65	250	112
26.15	81.55	240	107
26.15	81.45	240	107
26.15	81.35	230	103
26.15	81.25	220	98
26.15	81.15	220	98
26.15	81.05	220	98
26.15	80.95	210	94
26.15	80.85	210	94
26.15	80.75	220	98
26.15	80.65	220	98
26.15	80.55	220	98
26.15	80.45	230	103
26.15	80.35	240	107
26.15	80.25	250	112
26.15	80.15	250	112
26.15	80.05	260	116
26.15	79.95	260	116
26.25	97.65	210	94
26.25	97.55	210	94
26.25	97.45	220	98
26.25	97.35	220	98
26.25	97.25	230	103
26.25	97.15	230	103
26.25	97.05	230	103
26.25	81.95	270	121
26.25	81.85	260	116
26.25	81.75	260	116
26.25	81.65	250	112
26.25	81.55	240	107
26.25	81.45	230	103
26.25	81.35	230	103
26.25	81.25	220	98
26.25	81.15	220	98
26.25	81.05	210	94
26.25	80.95	210	94
26.25	80.85	210	94
26.25	80.75	210	94

Latitudes: 26.25 - 26.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.25	80.65	220	98
26.25	80.55	220	98
26.25	80.45	230	103
26.25	80.35	240	107
26.25	80.25	250	112
26.25	80.15	250	112
26.25	80.05	260	116
26.25	79.95	260	116
26.35	97.65	210	94
26.35	97.55	210	94
26.35	97.45	220	98
26.35	97.35	220	98
26.35	97.25	230	103
26.35	97.15	230	103
26.35	82.25	280	125
26.35	82.15	270	121
26.35	82.05	270	121
26.35	81.95	270	121
26.35	81.85	260	116
26.35	81.75	250	112
26.35	81.65	240	107
26.35	81.55	230	103
26.35	81.45	230	103
26.35	81.35	220	98
26.35	81.25	220	98
26.35	81.15	210	94
26.35	81.05	210	94
26.35	80.95	210	94
26.35	80.85	210	94
26.35	80.75	210	94
26.35	80.65	220	98
26.35	80.55	220	98
26.35	80.45	230	103
26.35	80.35	240	107
26.35	80.25	250	112
26.35	80.15	250	112
26.35	80.05	260	116
26.35	79.95	270	121
26.45	97.65	210	94
26.45	97.55	210	94

Latitudes: 26.45 - 26.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.45	97.45	220	98
26.45	97.35	220	98
26.45	97.25	230	103
26.45	97.15	230	103
26.45	82.25	270	121
26.45	82.15	270	121
26.45	82.05	270	121
26.45	81.95	260	116
26.45	81.85	250	112
26.45	81.75	240	107
26.45	81.65	240	107
26.45	81.55	230	103
26.45	81.45	220	98
26.45	81.35	220	98
26.45	81.25	210	94
26.45	81.15	210	94
26.45	81.05	210	94
26.45	80.95	210	94
26.45	80.85	210	94
26.45	80.75	220	98
26.45	80.65	220	98
26.45	80.55	220	98
26.45	80.45	230	103
26.45	80.35	240	107
26.45	80.25	250	112
26.45	80.15	250	112
26.45	80.05	260	116
26.45	79.95	270	121
26.55	97.65	210	94
26.55	97.55	210	94
26.55	97.45	220	98
26.55	97.35	220	98
26.55	97.25	230	103
26.55	97.15	230	103
26.55	82.35	270	121
26.55	82.25	270	121
26.55	82.15	270	121
26.55	82.05	260	116
26.55	81.95	260	116
26.55	81.85	250	112

Latitudes: 26.55 - 26.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.55	81.75	240	107
26.55	81.65	230	103
26.55	81.55	220	98
26.55	81.45	220	98
26.55	81.35	210	94
26.55	81.25	210	94
26.55	81.15	210	94
26.55	81.05	210	94
26.55	80.95	210	94
26.55	80.85	210	94
26.55	80.75	220	98
26.55	80.65	220	98
26.55	80.55	230	103
26.55	80.45	230	103
26.55	80.35	240	107
26.55	80.25	250	112
26.55	80.15	250	112
26.55	80.05	260	116
26.55	79.95	270	121
26.65	97.65	210	94
26.65	97.55	210	94
26.65	97.45	220	98
26.65	97.35	220	98
26.65	97.25	230	103
26.65	82.35	270	121
26.65	82.25	270	121
26.65	82.15	260	116
26.65	82.05	260	116
26.65	81.95	250	112
26.65	81.85	240	107
26.65	81.75	230	103
26.65	81.65	230	103
26.65	81.55	220	98
26.65	81.45	220	98
26.65	81.35	210	94
26.65	81.25	210	94
26.65	81.15	210	94
26.65	81.05	210	94
26.65	80.95	210	94
26.65	80.85	210	94

Latitudes: 25.65 - 26.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.65	80.75	220	98
26.65	80.65	220	98
26.65	80.55	230	103
26.65	80.45	230	103
26.65	80.35	240	107
26.65	80.25	250	112
26.65	80.15	260	116
26.65	80.05	260	116
26.65	79.95	270	121
26.75	97.65	210	94
26.75	97.55	220	98
26.75	97.45	220	98
26.75	97.35	230	103
26.75	97.25	230	103
26.75	82.45	270	121
26.75	82.35	270	121
26.75	82.25	260	116
26.75	82.15	260	116
26.75	82.05	250	112
26.75	81.95	240	107
26.75	81.85	240	107
26.75	81.75	230	103
26.75	81.65	220	98
26.75	81.55	220	98
26.75	81.45	210	94
26.75	81.35	210	94
26.75	81.25	210	94
26.75	81.15	210	94
26.75	81.05	210	94
26.75	80.95	210	94
26.75	80.85	220	98
26.75	80.75	220	98
26.75	80.65	220	98
26.75	80.55	230	103
26.75	80.45	230	103
26.75	80.35	240	107
26.75	80.25	250	112
26.75	80.15	260	116
26.75	80.05	260	116
26.75	79.95	270	121

Latitudes: 26.85 - 26.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.85	97.65	210	94
26.85	97.55	220	98
26.85	97.45	220	98
26.85	97.35	230	103
26.85	97.25	230	103
26.85	82.55	260	116
26.85	82.45	260	116
26.85	82.35	260	116
26.85	82.25	250	112
26.85	82.15	250	112
26.85	82.05	240	107
26.85	81.95	240	107
26.85	81.85	230	103
26.85	81.75	220	98
26.85	81.65	220	98
26.85	81.55	210	94
26.85	81.45	210	94
26.85	81.35	210	94
26.85	81.25	210	94
26.85	81.15	210	94
26.85	81.05	210	94
26.85	80.95	210	94
26.85	80.85	220	98
26.85	80.75	220	98
26.85	80.65	220	98
26.85	80.55	230	103
26.85	80.45	240	107
26.85	80.35	240	107
26.85	80.25	250	112
26.85	80.15	260	116
26.85	80.05	260	116
26.85	79.95	270	121
26.95	97.65	210	94
26.95	97.55	220	98
26.95	97.45	220	98
26.95	97.35	230	103
26.95	97.25	230	103
26.95	82.55	260	116
26.95	82.45	260	116
26.95	82.35	250	112

Latitudes: 26.95 - 27.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
26.95	82.25	250	112
26.95	82.15	240	107
26.95	82.05	240	107
26.95	81.95	230	103
26.95	81.85	220	98
26.95	81.75	220	98
26.95	81.65	220	98
26.95	81.55	210	94
26.95	81.45	210	94
26.95	81.35	210	94
26.95	81.25	210	94
26.95	81.15	210	94
26.95	81.05	210	94
26.95	80.95	210	94
26.95	80.85	220	98
26.95	80.75	220	98
26.95	80.65	230	103
26.95	80.55	230	103
26.95	80.45	240	107
26.95	80.35	240	107
26.95	80.25	250	112
26.95	80.15	260	116
26.95	80.05	260	116
26.95	79.95	270	121
27.05	97.65	210	94
27.05	97.55	220	98
27.05	97.45	220	98
27.05	97.35	230	103
27.05	97.25	230	103
27.05	82.65	260	116
27.05	82.55	260	116
27.05	82.45	250	112
27.05	82.35	250	112
27.05	82.25	240	107
27.05	81.95	220	98
27.05	81.85	220	98
27.05	81.75	210	94
27.05	81.65	210	94
27.05	81.55	210	94
27.05	81.45	210	94

Latitudes: 27.05 - 27.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.05	81.35	210	94
27.05	81.25	210	94
27.05	81.15	210	94
27.05	81.05	210	94
27.05	80.95	210	94
27.05	80.85	220	98
27.05	80.75	220	98
27.05	80.65	230	103
27.05	80.55	230	103
27.05	80.45	240	107
27.05	80.35	250	112
27.05	80.25	250	112
27.05	80.15	260	116
27.05	80.05	260	116
27.15	97.65	210	94
27.15	97.55	210	94
27.15	97.45	220	98
27.15	97.35	230	103
27.15	97.25	230	103
27.15	82.75	260	116
27.15	82.65	250	112
27.15	82.55	250	112
27.15	82.45	240	107
27.15	82.35	240	107
27.15	81.95	220	98
27.15	81.85	210	94
27.15	81.75	210	94
27.15	81.65	210	94
27.15	81.55	210	94
27.15	81.15	210	94
27.15	81.05	210	94
27.15	80.95	210	94
27.15	80.85	220	98
27.15	80.75	220	98
27.15	80.65	230	103
27.15	80.55	230	103
27.15	80.45	240	107
27.15	80.35	250	112
27.15	80.25	250	112
27.15	80.15	260	116

Latitudes: 27.15 – 27.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.15	80.05	260	116
27.25	97.65	210	94
27.25	97.55	210	94
27.25	97.45	220	98
27.25	97.35	220	98
27.25	97.25	230	103
27.25	82.75	250	112
27.25	82.65	250	112
27.25	82.55	240	107
27.25	82.45	240	107
27.25	81.95	210	94
27.25	81.85	210	94
27.25	81.75	210	94
27.25	81.15	210	94
27.25	81.05	210	94
27.25	80.95	210	94
27.25	80.85	220	98
27.25	80.75	220	98
27.25	80.65	230	103
27.25	80.55	240	107
27.25	80.45	240	107
27.25	80.35	250	112
27.25	80.25	250	112
27.25	80.15	260	116
27.35	97.55	210	94
27.35	97.45	220	98
27.35	97.35	220	98
27.35	97.25	230	103
27.35	97.15	230	103
27.35	82.85	250	112
27.35	82.75	250	112
27.35	82.65	250	112
27.35	82.55	240	107
27.35	81.95	210	94
27.35	81.85	210	94
27.35	81.05	210	94
27.35	80.95	210	94
27.35	80.85	220	98
27.35	80.75	220	98
27.35	80.65	230	103

Latitudes: 27.35 – 27.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.35	80.55	240	107
27.35	80.45	240	107
27.35	80.35	250	112
27.35	80.25	260	116
27.35	80.15	260	116
27.45	97.55	210	94
27.45	97.45	220	98
27.45	97.35	220	98
27.45	97.25	230	103
27.45	97.15	230	103
27.45	82.85	250	112
27.45	82.75	250	112
27.45	82.65	240	107
27.45	82.55	240	107
27.45	81.05	210	94
27.45	80.95	210	94
27.45	80.85	220	98
27.45	80.75	220	98
27.45	80.65	230	103
27.45	80.55	240	107
27.45	80.45	250	112
27.45	80.35	250	112
27.45	80.25	260	116
27.55	97.55	210	94
27.55	97.45	210	94
27.55	97.35	220	98
27.55	97.25	230	103
27.55	97.15	230	103
27.55	97.05	230	103
27.55	82.85	250	112
27.55	82.75	240	107
27.55	82.65	240	107
27.55	81.05	210	94
27.55	80.95	210	94
27.55	80.85	220	98
27.55	80.75	230	103
27.55	80.65	230	103
27.55	80.55	240	107
27.55	80.45	250	112
27.55	80.35	250	112

Latitudes: 27.55 – 27.86			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.55	80.25	260	116
27.65	97.55	210	94
27.65	97.45	210	94
27.65	97.35	220	98
27.65	97.25	220	98
27.65	97.15	230	103
27.65	97.05	230	103
27.65	82.95	250	112
27.65	82.85	240	107
27.65	82.75	240	107
27.65	81.05	210	94
27.65	80.95	210	94
27.65	80.85	220	98
27.65	80.75	230	103
27.65	80.65	230	103
27.65	80.55	240	107
27.65	80.45	250	112
27.65	80.35	250	112
27.65	80.25	260	116
27.75	97.45	210	94
27.75	97.35	220	98
27.75	97.25	220	98
27.75	97.15	230	103
27.75	97.05	230	103
27.75	96.95	230	103
27.75	82.95	240	107
27.75	82.85	240	107
27.75	82.75	240	107
27.75	81.05	210	94
27.75	80.95	210	94
27.75	80.85	220	98
27.75	80.75	230	103
27.75	80.65	240	107
27.75	80.55	240	107
27.75	80.45	250	112
27.75	80.35	250	112
27.85	97.45	210	94
27.85	97.35	210	94
27.85	97.25	220	98
27.85	97.15	220	98

Latitudes: 27.85 – 28.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
27.85	97.05	230	103
27.85	96.95	230	103
27.85	96.85	230	103
27.85	82.95	240	107
27.85	82.85	240	107
27.85	81.05	210	94
27.85	80.95	210	94
27.85	80.85	220	98
27.85	80.75	230	103
27.85	80.65	240	107
27.85	80.55	240	107
27.85	80.45	250	112
27.85	80.35	250	112
27.95	97.35	210	94
27.95	97.25	220	98
27.95	97.15	220	98
27.95	97.05	220	98
27.95	96.95	230	103
27.95	96.85	230	103
27.95	96.75	230	103
27.95	96.65	230	103
27.95	82.95	240	107
27.95	82.85	240	107
27.95	81.05	210	94
27.95	80.95	220	98
27.95	80.85	220	98
27.95	80.75	230	103
27.95	80.65	240	107
27.95	80.55	240	107
27.95	80.45	250	112
28.05	97.35	210	94
28.05	97.25	210	94
28.05	97.15	220	98
28.05	97.05	220	98
28.05	96.95	220	98
28.05	96.85	230	103
28.05	96.75	230	103
28.05	96.65	230	103
28.05	96.55	230	103
28.05	82.95	240	107

Latitudes: 28.05 – 28.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.05	81.15	210	94
28.05	81.05	210	94
28.05	80.95	220	98
28.05	80.85	220	98
28.05	80.75	230	103
28.05	80.65	240	107
28.05	80.55	240	107
28.05	80.45	250	112
28.15	97.25	210	94
28.15	97.15	210	94
28.15	97.05	220	98
28.15	96.95	220	98
28.15	96.85	220	98
28.15	96.75	230	103
28.15	96.65	230	103
28.15	96.55	230	103
28.15	96.45	230	103
28.15	96.35	230	103
28.15	82.95	240	107
28.15	81.15	210	94
28.15	81.05	210	94
28.15	80.95	220	98
28.15	80.85	230	103
28.15	80.75	230	103
28.15	80.65	240	107
28.15	80.55	240	107
28.25	97.15	210	94
28.25	97.05	210	94
28.25	96.95	220	98
28.25	96.85	220	98
28.25	96.75	220	98
28.25	96.65	230	103
28.25	96.55	230	103
28.25	96.45	230	103
28.25	96.35	230	103
28.25	81.15	210	94
28.25	81.05	210	94
28.25	80.95	220	98
28.25	80.85	230	103
28.25	80.75	230	103

Latitudes: 28.25 – 28.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.25	80.65	240	107
28.25	80.55	240	107
28.35	97.05	210	94
28.35	96.95	210	94
28.35	96.85	220	98
28.35	96.75	220	98
28.35	96.65	220	98
28.35	96.55	220	98
28.35	96.45	230	103
28.35	96.35	230	103
28.35	96.25	230	103
28.35	96.15	230	103
28.35	96.05	230	103
28.35	81.15	210	94
28.35	81.05	210	94
28.35	80.95	220	98
28.35	80.85	230	103
28.35	80.75	230	103
28.35	80.65	240	107
28.35	80.55	240	107
28.35	80.45	250	112
28.45	96.95	210	94
28.45	96.85	210	94
28.45	96.75	210	94
28.45	96.65	220	98
28.45	96.55	220	98
28.45	96.45	220	98
28.45	96.35	220	98
28.45	96.25	230	103
28.45	96.15	230	103
28.45	96.05	230	103
28.45	95.95	230	103
28.45	95.85	230	103
28.45	81.25	210	94
28.45	81.15	210	94
28.45	81.05	220	98
28.45	80.95	220	98
28.45	80.85	230	103
28.45	80.75	240	107
28.45	80.65	240	107

Latitudes: 28.45 – 28.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.45	80.55	240	107
28.45	80.45	250	112
28.55	96.85	210	94
28.55	96.75	210	94
28.55	96.65	210	94
28.55	96.55	220	98
28.55	96.45	220	98
28.55	96.35	220	98
28.55	96.25	220	98
28.55	96.15	220	98
28.55	96.05	230	103
28.55	95.95	230	103
28.55	95.85	230	103
28.55	95.75	230	103
28.55	95.65	230	103
28.55	81.25	210	94
28.55	81.15	210	94
28.55	81.05	220	98
28.55	80.95	230	103
28.55	80.85	230	103
28.55	80.75	240	107
28.55	80.65	240	107
28.55	80.55	240	107
28.55	80.45	250	112
28.65	96.65	210	94
28.65	96.55	210	94
28.65	96.45	210	94
28.65	96.35	220	98
28.65	96.25	220	98
28.65	96.15	220	98
28.65	96.05	220	98
28.65	95.95	220	98
28.65	95.85	220	98
28.65	95.75	230	103
28.65	95.65	230	103
28.65	95.55	230	103
28.65	95.45	230	103
28.65	81.25	210	94
28.65	81.15	210	94
28.65	81.05	220	98

Latitudes: 28.65 – 28.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.65	80.95	230	103
28.65	80.85	230	103
28.65	80.75	240	107
28.65	80.65	240	107
28.65	80.55	240	107
28.75	96.45	210	94
28.75	96.35	210	94
28.75	96.25	210	94
28.75	96.15	210	94
28.75	96.05	220	98
28.75	95.95	220	98
28.75	95.85	220	98
28.75	95.75	220	98
28.75	95.65	220	98
28.75	95.55	230	103
28.75	95.45	230	103
28.75	95.35	230	103
28.75	95.25	230	103
28.75	89.45	270	121
28.75	89.35	270	121
28.75	81.25	210	94
28.75	81.15	220	98
28.75	81.05	220	98
28.75	80.95	230	103
28.75	80.85	230	103
28.75	80.75	240	107
28.75	80.65	240	107
28.75	80.55	240	107
28.85	96.25	210	94
28.85	96.15	210	94
28.85	96.05	210	94
28.85	95.95	210	94
28.85	95.85	220	98
28.85	95.75	220	98
28.85	95.65	220	98
28.85	95.55	220	98
28.85	95.45	230	103
28.85	95.35	230	103
28.85	95.25	230	103
28.85	95.15	230	103

Latitudes: 28.85 – 28.95			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.85	89.55	270	121
28.85	89.45	270	121
28.85	89.35	270	121
28.85	89.25	270	121
28.85	89.15	270	121
28.85	89.05	270	121
28.85	81.35	210	94
28.85	81.25	210	94
28.85	81.15	220	98
28.85	81.05	230	103
28.85	80.95	230	103
28.85	80.85	240	107
28.85	80.75	240	107
28.85	80.65	240	107
28.95	96.05	210	94
28.95	95.95	210	94
28.95	95.85	210	94
28.95	95.75	210	94
28.95	95.65	220	98
28.95	95.55	220	98
28.95	95.45	220	98
28.95	95.35	220	98
28.95	95.25	230	103
28.95	95.15	230	103
28.95	95.05	230	103
28.95	90.95	260	116
28.95	90.85	260	116
28.95	90.75	260	116
28.95	90.65	270	121
28.95	90.35	270	121
28.95	90.25	270	121
28.95	90.15	270	121
28.95	89.55	270	121
28.95	89.45	270	121
28.95	89.35	270	121
28.95	89.25	270	121
28.95	89.15	270	121
28.95	89.05	270	121
28.95	88.95	270	121
28.95	81.35	210	94

Latitudes: 28.95 - 29.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
28.95	81.25	210	94
28.95	81.15	220	98
28.95	81.05	230	103
28.95	80.95	230	103
28.95	80.85	240	107
28.95	80.75	240	107
29.05	94.85	240	107
29.05	91.35	260	116
29.05	91.25	260	116
29.05	91.15	260	116
29.05	91.05	260	116
29.05	90.95	260	116
29.05	90.85	260	116
29.05	90.75	260	116
29.05	90.65	260	116
29.05	90.55	260	116
29.05	90.35	260	116
29.05	90.25	270	121
29.05	90.15	270	121
29.05	90.05	270	121
29.05	89.95	270	121
29.05	89.55	270	121
29.05	89.45	260	116
29.05	89.35	260	116
29.05	89.25	260	116
29.05	89.15	260	116
29.05	89.05	260	116
29.05	88.95	270	121
29.05	81.35	210	94
29.05	81.25	220	98
29.05	81.15	220	98
29.05	81.05	230	103
29.05	80.95	230	103
29.05	80.85	240	107
29.05	80.75	240	107
29.15	94.85	240	107
29.15	94.75	240	107
29.15	94.65	240	107
29.15	91.45	260	116
29.15	91.35	250	112

Latitudes: 29.15 – 29.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.15	91.25	250	112
29.15	91.15	250	112
29.15	91.05	250	112
29.15	90.95	250	112
29.15	90.85	250	112
29.15	90.75	260	116
29.15	90.65	260	116
29.15	90.55	260	116
29.15	90.45	260	116
29.15	90.35	260	116
29.15	90.25	260	116
29.15	90.15	260	116
29.15	90.05	260	116
29.15	89.95	270	121
29.15	89.85	270	121
29.15	89.75	270	121
29.15	89.65	260	116
29.15	89.55	260	116
29.15	89.45	260	116
29.15	89.35	260	116
29.15	89.25	260	116
29.15	89.15	260	116
29.15	89.05	260	116
29.15	88.95	270	121
29.15	81.45	210	94
29.15	81.35	210	94
29.15	81.25	220	98
29.15	81.15	230	103
29.15	81.05	230	103
29.15	80.95	240	107
29.15	80.85	240	107
29.25	94.75	240	107
29.25	94.65	240	107
29.25	91.45	250	112
29.25	91.35	250	112
29.25	91.25	250	112
29.25	91.15	250	112
29.25	91.05	250	112
29.25	90.95	250	112
29.25	90.85	250	112

Latitudes: 29.25 – 29.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.25	90.75	250	112
29.25	90.65	250	112
29.25	90.55	250	112
29.25	90.45	250	112
29.25	90.35	250	112
29.25	90.25	260	116
29.25	90.15	260	116
29.25	90.05	260	116
29.25	89.95	260	116
29.25	89.85	260	116
29.25	89.75	260	116
29.25	89.65	260	116
29.25	89.55	260	116
29.25	89.45	260	116
29.25	89.35	260	116
29.25	89.25	260	116
29.25	89.15	260	116
29.25	89.05	260	116
29.25	88.95	270	121
29.25	81.45	210	94
29.25	81.35	210	94
29.25	81.25	220	98
29.25	81.15	230	103
29.25	81.05	230	103
29.25	80.95	240	107
29.35	94.65	240	107
29.35	94.55	240	107
29.35	94.45	240	107
29.35	94.35	240	107
29.35	92.45	250	112
29.35	92.35	250	112
29.35	92.25	250	112
29.35	91.95	250	112
29.35	91.85	250	112
29.35	91.75	250	112
29.35	91.65	250	112
29.35	91.55	250	112
29.35	91.45	250	112
29.35	91.35	240	107
29.35	91.25	240	107

Latitudes: 29.35 – 29.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.35	91.15	240	107
29.35	91.05	240	107
29.35	90.95	240	107
29.35	90.85	240	107
29.35	90.75	240	107
29.35	90.65	240	107
29.35	90.55	240	107
29.35	90.45	240	107
29.35	90.35	250	112
29.35	90.25	250	112
29.35	90.15	250	112
29.35	90.05	250	112
29.35	89.95	260	116
29.35	89.85	260	116
29.35	89.75	260	116
29.35	89.65	260	116
29.35	89.55	260	116
29.35	89.45	260	116
29.35	89.35	260	116
29.35	89.25	260	116
29.35	89.15	260	116
29.35	89.05	270	121
29.35	81.45	210	94
29.35	81.35	220	98
29.35	81.25	220	98
29.35	81.15	230	103
29.35	81.05	230	103
29.35	80.95	240	107
29.45	94.55	240	107
29.45	94.45	240	107
29.45	94.35	240	107
29.45	94.25	240	107
29.45	94.15	240	107
29.45	92.85	250	112
29.45	92.75	250	112
29.45	92.65	250	112
29.45	92.55	250	112
29.45	92.45	250	112
29.45	92.35	250	112
29.45	92.25	250	112

Latitudes: 29.45 – 29.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.45	92.15	250	112
29.45	92.05	250	112
29.45	91.95	250	112
29.45	91.85	250	112
29.45	91.75	250	112
29.45	91.65	250	112
29.45	91.55	240	107
29.45	91.45	240	107
29.45	91.35	240	107
29.45	91.25	240	107
29.45	90.45	240	107
29.45	90.35	240	107
29.45	90.25	240	107
29.45	90.15	240	107
29.45	90.05	250	112
29.45	89.95	250	112
29.45	89.85	250	112
29.45	89.75	250	112
29.45	89.65	250	112
29.45	89.55	250	112
29.45	89.45	260	116
29.45	89.35	260	116
29.45	89.25	260	116
29.45	89.15	270	121
29.45	81.55	210	94
29.45	81.45	210	94
29.45	81.35	220	98
29.45	81.25	230	103
29.45	81.15	230	103
29.45	81.05	240	107
29.55	94.25	240	107
29.55	94.15	240	107
29.55	94.05	240	107
29.55	93.95	240	107
29.55	93.85	240	107
29.55	93.75	240	107
29.55	93.65	240	107
29.55	93.15	250	112
29.55	93.05	250	112
29.55	92.95	250	112

Latitudes: 29.55 – 29.65			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.55	92.85	250	112
29.55	92.75	250	112
29.55	92.65	250	112
29.55	92.55	250	112
29.55	92.45	250	112
29.55	92.35	250	112
29.55	92.25	250	112
29.55	92.15	250	112
29.55	92.05	250	112
29.55	91.95	250	112
29.55	91.85	240	107
29.55	91.75	240	107
29.55	91.65	240	107
29.55	91.55	240	107
29.55	91.45	240	107
29.55	90.15	240	107
29.55	90.05	240	107
29.55	89.95	240	107
29.55	89.85	250	112
29.55	89.75	250	112
29.55	89.65	250	112
29.55	89.55	250	112
29.55	89.45	260	116
29.55	89.35	260	116
29.55	81.55	210	94
29.55	81.45	210	94
29.55	81.35	220	98
29.55	81.25	230	103
29.55	81.15	230	103
29.55	81.05	240	107
29.65	94.05	240	107
29.65	93.95	240	107
29.65	93.85	240	107
29.65	93.75	240	107
29.65	93.65	240	107
29.65	93.55	240	107
29.65	93.45	240	107
29.65	93.35	240	107
29.65	93.25	240	107
29.65	93.15	240	107

Latitudes: 29.65 – 29.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.65	93.05	240	107
29.65	92.95	240	107
29.65	92.85	240	107
29.65	92.75	240	107
29.65	92.65	240	107
29.65	92.55	240	107
29.65	92.45	240	107
29.65	92.35	240	107
29.65	92.25	240	107
29.65	92.15	240	107
29.65	92.05	240	107
29.65	91.95	240	107
29.65	91.85	240	107
29.65	91.75	240	107
29.65	91.65	240	107
29.65	89.95	240	107
29.65	89.85	240	107
29.65	89.75	250	112
29.65	89.65	250	112
29.65	89.55	250	112
29.65	89.45	260	116
29.65	89.35	260	116
29.65	89.25	270	121
29.65	81.55	210	94
29.65	81.45	220	98
29.65	81.35	220	98
29.65	81.25	230	103
29.65	81.15	230	103
29.75	93.65	240	107
29.75	93.55	240	107
29.75	93.45	240	107
29.75	93.35	240	107
29.75	93.25	240	107
29.75	93.15	240	107
29.75	93.05	240	107
29.75	92.95	240	107
29.75	92.85	240	107
29.75	92.75	240	107
29.75	92.65	240	107
29.75	92.55	240	107

Latitudes: 29.75 – 30.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
29.75	89.85	240	107
29.75	89.75	240	107
29.75	89.65	250	112
29.75	89.55	250	112
29.75	89.45	260	116
29.75	89.35	260	116
29.75	89.25	270	121
29.75	81.65	210	94
29.75	81.55	210	94
29.75	81.45	220	98
29.75	81.35	220	98
29.75	81.25	230	103
29.75	81.15	230	103
29.85	89.75	240	107
29.85	89.65	250	112
29.85	89.55	250	112
29.85	89.45	260	116
29.85	89.35	260	116
29.85	89.25	270	121
29.85	81.65	210	94
29.85	81.55	210	94
29.85	81.45	220	98
29.85	81.35	230	103
29.85	81.25	230	103
29.85	81.15	230	103
29.95	89.75	240	107
29.95	89.65	240	107
29.95	89.55	250	112
29.95	89.45	260	116
29.95	89.35	260	116
29.95	89.25	270	121
29.95	81.65	210	94
29.95	81.55	220	98
29.95	81.45	220	98
29.95	81.35	230	103
29.95	81.25	230	103
30.05	89.65	240	107
30.05	89.55	250	112
30.05	89.45	250	112
30.05	89.35	260	116

Latitudes: 30.05 – 30.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.05	88.05	280	125
30.05	87.95	280	125
30.05	87.85	270	121
30.05	87.75	270	121
30.05	87.65	270	121
30.05	81.65	210	94
30.05	81.55	220	98
30.05	81.45	220	98
30.05	81.35	230	103
30.05	81.25	230	103
30.15	89.65	240	107
30.15	89.55	240	107
30.15	89.45	250	112
30.15	89.35	260	116
30.15	89.25	260	116
30.15	89.15	270	121
30.15	89.05	270	121
30.15	88.75	270	121
30.15	88.65	270	121
30.15	88.55	270	121
30.15	88.45	270	121
30.15	88.25	270	121
30.15	88.15	270	121
30.15	88.05	270	121
30.15	87.95	270	121
30.15	87.85	270	121
30.15	87.75	270	121
30.15	87.65	270	121
30.15	87.55	260	116
30.15	87.45	260	116
30.15	87.35	260	116
30.15	87.25	260	116
30.15	87.15	260	116
30.15	87.05	250	112
30.15	81.75	210	94
30.15	81.65	210	94
30.15	81.55	220	98
30.15	81.45	220	98
30.15	81.35	230	103
30.15	81.25	230	103

Latitudes: 30.25 – 30.35			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.25	89.55	240	107
30.25	89.45	250	112
30.25	89.35	250	112
30.25	89.25	260	116
30.25	89.15	260	116
30.25	89.05	260	116
30.25	88.95	260	116
30.25	88.85	260	116
30.25	88.75	260	116
30.25	88.65	270	121
30.25	88.55	270	121
30.25	88.45	270	121
30.25	88.35	270	121
30.25	88.25	270	121
30.25	88.15	270	121
30.25	88.05	270	121
30.25	87.95	270	121
30.25	87.85	270	121
30.25	87.75	260	116
30.25	87.65	260	116
30.25	87.55	260	116
30.25	87.45	260	116
30.25	87.35	260	116
30.25	87.25	250	112
30.25	87.15	250	112
30.25	87.05	250	112
30.25	86.95	250	112
30.25	86.85	240	107
30.25	86.75	240	107
30.25	86.65	240	107
30.25	81.75	210	94
30.25	81.65	210	94
30.25	81.55	220	98
30.25	81.45	220	98
30.25	81.35	230	103
30.35	89.45	240	107
30.35	89.35	240	107
30.35	89.25	250	112
30.35	89.15	250	112
30.35	89.05	250	112

Latitudes: 30.35 – 30.45			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.35	88.95	260	116
30.35	88.85	260	116
30.35	88.75	260	116
30.35	88.65	260	116
30.35	88.55	260	116
30.35	88.45	260	116
30.35	88.35	260	116
30.35	88.25	260	116
30.35	88.15	260	116
30.35	88.05	260	116
30.35	87.95	260	116
30.35	87.85	260	116
30.35	87.75	260	116
30.35	87.65	260	116
30.35	87.55	250	112
30.35	87.45	250	112
30.35	87.35	250	112
30.35	87.25	250	112
30.35	87.15	250	112
30.35	87.05	240	107
30.35	86.95	240	107
30.35	86.85	240	107
30.35	86.75	240	107
30.35	81.75	210	94
30.35	81.65	210	94
30.35	81.55	220	98
30.35	81.45	220	98
30.35	81.35	230	103
30.45	89.35	240	107
30.45	89.25	240	107
30.45	89.15	240	107
30.45	89.05	250	112
30.45	88.95	250	112
30.45	88.85	250	112
30.45	88.75	250	112
30.45	88.65	250	112
30.45	88.55	250	112
30.45	88.45	250	112
30.45	88.35	250	112
30.45	88.25	250	112

Latitudes: 30.45 – 30.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.45	88.15	250	112
30.45	88.05	250	112
30.45	87.95	250	112
30.45	87.85	250	112
30.45	87.75	250	112
30.45	87.65	250	112
30.45	87.55	250	112
30.45	87.45	240	107
30.45	87.35	240	107
30.45	87.25	240	107
30.45	87.15	240	107
30.45	87.05	240	107
30.45	86.95	240	107
30.45	81.75	210	94
30.45	81.65	220	98
30.45	81.55	220	98
30.45	81.45	230	103
30.45	81.35	230	103
30.55	89.05	240	107
30.55	88.95	240	107
30.55	88.85	240	107
30.55	88.75	240	107
30.55	88.65	240	107
30.55	88.55	240	107
30.55	88.45	240	107
30.55	88.35	240	107
30.55	88.25	240	107
30.55	88.15	240	107
30.55	88.05	240	107
30.55	87.95	240	107
30.55	87.85	240	107
30.55	87.75	240	107
30.55	87.65	240	107
30.55	87.55	240	107
30.55	87.45	240	107
30.55	87.35	240	107
30.55	81.75	210	94
30.55	81.65	220	98
30.55	81.55	220	98
30.55	81.45	230	103

Latitudes: 30.55 – 31.25			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
30.55	81.35	230	103
30.65	81.75	210	94
30.65	81.65	220	98
30.65	81.55	220	98
30.65	81.45	230	103
30.65	81.35	230	103
30.75	81.85	210	94
30.75	81.75	210	94
30.75	81.65	220	98
30.75	81.55	220	98
30.75	81.45	230	103
30.75	81.35	230	103
30.85	81.85	210	94
30.85	81.75	210	94
30.85	81.65	220	98
30.85	81.55	220	98
30.85	81.45	230	103
30.85	81.35	230	103
30.95	81.85	210	94
30.95	81.75	210	94
30.95	81.65	220	98
30.95	81.55	220	98
30.95	81.45	230	103
30.95	81.35	230	103
31.05	81.85	210	94
31.05	81.75	210	94
31.05	81.65	220	98
31.05	81.55	220	98
31.05	81.45	230	103
31.05	81.35	230	103
31.05	81.25	230	103
31.15	81.85	210	94
31.15	81.75	210	94
31.15	81.65	220	98
31.15	81.55	220	98
31.15	81.45	230	103
31.15	81.35	230	103
31.15	81.25	230	103
31.25	81.75	210	94
31.25	81.65	220	98

Latitudes: 31.25 – 31.75			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
31.25	81.55	220	98
31.25	81.45	230	103
31.25	81.35	230	103
31.25	81.25	230	103
31.25	81.15	240	107
31.35	81.75	210	94
31.35	81.65	210	94
31.35	81.55	220	98
31.35	81.45	220	98
31.35	81.35	230	103
31.35	81.25	230	103
31.35	81.15	240	107
31.45	81.75	210	94
31.45	81.65	210	94
31.45	81.55	220	98
31.45	81.45	220	98
31.45	81.35	230	103
31.45	81.25	230	103
31.45	81.15	230	103
31.45	81.05	240	107
31.55	81.75	210	94
31.55	81.65	210	94
31.55	81.55	220	98
31.55	81.45	220	98
31.55	81.35	230	103
31.55	81.25	230	103
31.55	81.15	230	103
31.55	81.05	240	107
31.65	81.65	210	94
31.65	81.55	210	94
31.65	81.45	220	98
31.65	81.35	220	98
31.65	81.25	230	103
31.65	81.15	230	103
31.65	81.05	240	107
31.65	80.95	240	107
31.75	81.65	210	94
31.75	81.55	210	94
31.75	81.45	220	98
31.75	81.35	220	98

Latitudes: 31.75 – 32.15			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
31.75	81.25	230	103
31.75	81.15	230	103
31.75	81.05	230	103
31.75	80.95	240	107
31.75	80.85	240	107
31.85	81.55	210	94
31.85	81.45	210	94
31.85	81.35	220	98
31.85	81.25	220	98
31.85	81.15	230	103
31.85	81.05	230	103
31.85	80.95	240	107
31.85	80.85	240	107
31.95	81.55	210	94
31.95	81.45	210	94
31.95	81.35	220	98
31.95	81.25	220	98
31.95	81.15	230	103
31.95	81.05	230	103
31.95	80.95	230	103
31.95	80.85	240	107
31.95	80.75	240	107
32.05	81.45	210	94
32.05	81.35	210	94
32.05	81.25	220	98
32.05	81.15	220	98
32.05	81.05	230	103
32.05	80.95	230	103
32.05	80.85	230	103
32.05	80.75	240	107
32.05	80.65	240	107
32.15	81.35	210	94
32.15	81.25	210	94
32.15	81.15	220	98
32.15	81.05	220	98
32.15	80.95	230	103
32.15	80.85	230	103
32.15	80.75	230	103
32.15	80.65	240	107
32.15	80.55	240	107

Latitudes: 32.15 – 32.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.15	80.45	240	107
32.25	81.35	210	94
32.25	81.25	210	94
32.25	81.15	220	98
32.25	81.05	220	98
32.25	80.95	220	98
32.25	80.85	230	103
32.25	80.75	230	103
32.25	80.65	240	107
32.25	80.55	240	107
32.25	80.45	240	107
32.25	80.35	240	107
32.35	81.25	210	94
32.35	81.15	210	94
32.35	81.05	220	98
32.35	80.95	220	98
32.35	80.85	230	103
32.35	80.75	230	103
32.35	80.65	230	103
32.35	80.55	240	107
32.35	80.45	240	107
32.35	80.35	240	107
32.35	80.25	240	107
32.45	81.15	210	94
32.45	81.05	210	94
32.45	80.95	220	98
32.45	80.85	220	98
32.45	80.75	230	103
32.45	80.65	230	103
32.45	80.55	230	103
32.45	80.45	230	103
32.45	80.35	240	107
32.45	80.25	240	107
32.45	80.15	240	107
32.45	80.05	240	107
32.45	79.95	240	107
32.55	81.05	210	94
32.55	80.95	210	94
32.55	80.85	220	98
32.55	80.75	220	98

Latitudes: 32.55 – 32.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.55	80.65	230	103
32.55	80.55	230	103
32.55	80.45	230	103
32.55	80.35	230	103
32.55	80.25	240	107
32.55	80.15	240	107
32.55	80.05	240	107
32.55	79.95	240	107
32.55	79.85	240	107
32.65	80.95	210	94
32.65	80.85	210	94
32.65	80.75	220	98
32.65	80.65	220	98
32.65	80.55	230	103
32.65	80.45	230	103
32.65	80.35	230	103
32.65	80.25	230	103
32.65	80.15	230	103
32.65	80.05	240	107
32.65	79.95	240	107
32.65	79.85	240	107
32.65	79.75	240	107
32.65	79.65	240	107
32.75	80.95	210	94
32.75	80.85	210	94
32.75	80.75	210	94
32.75	80.65	220	98
32.75	80.55	220	98
32.75	80.45	220	98
32.75	80.35	230	103
32.75	80.25	230	103
32.75	80.15	230	103
32.75	80.05	230	103
32.75	79.95	230	103
32.75	79.85	240	107
32.75	79.75	240	107
32.75	79.65	240	107
32.75	79.55	240	107
32.85	80.85	210	94
32.85	80.75	210	94

Latitudes: 32.85 – 34.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
32.85	80.65	210	94
32.85	80.55	220	98
32.85	80.45	220	98
32.85	80.35	220	98
32.85	80.25	220	98
32.85	80.15	230	103
32.85	80.05	230	103
32.85	79.95	230	103
32.85	79.85	230	103
32.85	79.75	230	103
32.85	79.65	240	107
32.85	79.55	240	107
32.85	79.45	240	107
32.85	79.35	240	107
32.95	80.65	210	94
32.95	80.55	210	94
32.95	80.45	210	94
32.95	80.35	220	98
32.95	80.25	220	98
32.95	80.15	220	98
32.95	80.05	220	98
32.95	79.95	230	103
32.95	79.85	230	103
32.95	79.75	230	103
32.95	79.65	230	103
32.95	79.55	230	103
32.95	79.45	240	107
32.95	79.35	240	107
32.95	79.25	240	107
33.05	79.35	240	107
33.05	79.25	240	107
33.05	79.15	240	107
33.15	79.15	240	107
33.15	79.05	240	107
33.75	77.95	230	103
33.85	77.95	230	103
33.85	77.85	230	103
33.95	77.95	230	103
33.95	77.85	230	103
34.05	77.95	230	103

Latitudes: 34.05 – 34.55			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
34.05	77.85	230	103
34.05	77.75	230	103
34.15	77.95	220	98
34.15	77.85	220	98
34.15	77.75	220	98
34.15	77.65	220	98
34.25	77.95	220	98
34.25	77.85	220	98
34.25	77.75	220	98
34.25	77.65	220	98
34.25	77.55	220	98
34.35	77.95	210	94
34.35	77.85	210	94
34.35	77.75	210	94
34.35	77.65	220	98
34.35	77.55	220	98
34.35	77.45	220	98
34.35	77.35	220	98
34.45	77.95	210	94
34.45	77.85	210	94
34.45	77.75	210	94
34.45	77.65	210	94
34.45	77.55	210	94
34.45	77.45	210	94
34.45	77.35	220	98
34.45	77.25	220	98
34.45	77.15	220	98
34.45	76.65	220	98
34.45	76.55	220	98
34.45	76.45	220	98
34.55	77.65	210	94
34.55	77.55	210	94
34.55	77.45	210	94
34.55	77.35	210	94
34.55	77.25	210	94
34.55	77.15	210	94
34.55	77.05	210	94
34.55	76.95	220	98
34.55	76.85	220	98
34.55	76.75	220	98

Latitudes: 34.55 – 35.05			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
34.55	76.65	220	98
34.55	76.55	220	98
34.55	76.45	220	98
34.55	76.35	220	98
34.65	77.35	210	94
34.65	77.25	210	94
34.65	77.15	210	94
34.65	77.05	210	94
34.65	76.95	210	94
34.65	76.85	210	94
34.65	76.75	210	94
34.65	76.65	220	98
34.65	76.55	220	98
34.65	76.45	220	98
34.65	76.35	220	98
34.65	76.25	220	98
34.75	77.05	210	94
34.75	76.95	210	94
34.75	76.85	210	94
34.75	76.75	210	94
34.75	76.65	210	94
34.75	76.55	210	94
34.75	76.45	210	94
34.75	76.35	210	94
34.75	76.25	220	98
34.85	76.75	210	94
34.85	76.65	210	94
34.85	76.55	210	94
34.85	76.45	210	94
34.85	76.35	210	94
34.85	76.25	210	94
34.85	76.15	210	94
34.95	76.45	210	94
34.95	76.35	210	94
34.95	76.25	210	94
34.95	76.15	210	94
34.95	76.05	210	94
34.95	75.95	210	94
34.95	75.85	210	94
35.05	76.15	210	94

Latitudes: 35.05 – 35.85			
Lat.	Long.	Wind Speed (mph)	Wind Speed (mps)
35.05	76.05	210	94
35.05	75.95	210	94
35.05	75.85	210	94
35.05	75.75	210	94
35.05	75.65	220	98
35.05	75.55	220	98
35.05	75.45	220	98
35.15	75.95	210	94
35.15	75.85	210	94
35.15	75.75	210	94
35.15	75.65	210	94
35.15	75.55	210	94
35.15	75.45	220	98
35.25	75.75	210	94
35.25	75.65	210	94
35.25	75.55	210	94
35.25	75.45	210	94
35.35	75.65	210	94
35.35	75.55	210	94
35.35	75.45	210	94
35.35	75.35	220	98
35.45	75.65	210	94
35.45	75.55	210	94
35.45	75.45	210	94
35.45	75.35	210	94
35.55	75.55	210	94
35.55	75.45	210	94
35.55	75.35	210	94
35.65	75.55	210	94
35.65	75.45	210	94
35.65	75.35	210	94
35.75	75.45	210	94
35.85	75.45	210	94

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11. ABSTRACT *(200 words or less)*

This report is intended to provide the technical basis for a potential new regulatory guide that will provide licensees and applicants with guidance that the staff of the U.S. Nuclear Regulatory Commission considers acceptable for use in selecting the design-basis hurricane wind speeds to which a nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public in accordance with General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," and General Design Criterion 4, "Environmental and Dynamic Effects Design Bases," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, Part 50, of the Code of Federal Regulations, "Domestic Licensing of Production and Utilization Facilities."

This report documents the approach and results of an analysis of peak-gust hurricane wind speeds with annual exceedance probabilities of 1E-06 and 1E-07. The analysis used a weighted sampling method to enable the simulation of 10 million years of hurricane wind speeds in the contiguous United States. The staff initiated this study because development of new wind speeds for its guidance on design-basis tornadoes (Revision 1 to Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants"), which was based on the new Enhanced Fujita scale, resulted in a decrease in the tornado design-basis wind speeds. The design-basis tornado wind speeds presented in Regulatory Guide 1.76 correspond to the exceedance frequency of 1E-07 per year. The decrease in the design basis tornado wind speeds was large enough to prompt an investigation into whether hurricane wind gusts with an annual exceedance frequency of 1E-07 would exceed tornado winds at the same annual exceedance frequency. This report considers peak-gust wind speeds for hurricanes that affect the Atlantic and Gulf coasts of the United States.

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