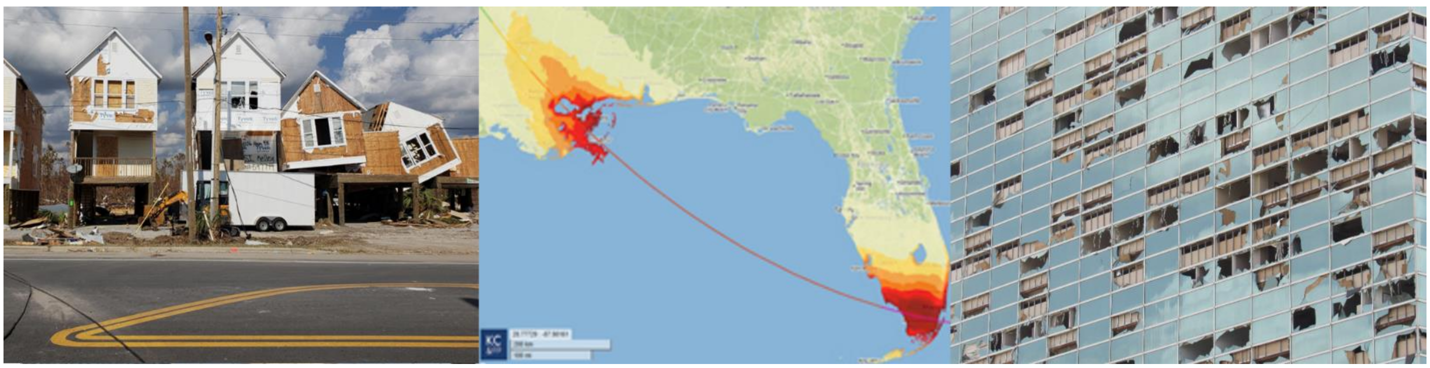
KCC US Hurricane Reference Model Version 4.0

RiskInsight® 4.11.1.7



Submitted in compliance with the 2021 Standards of the Florida Commission on Hurricane Loss Projection Methodology

JUNE 27, 2023

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KC &CO
KAREN CLARK & COMPANY

116 Huntington Avenue
Boston, MA 02116

T 617.423.2800
F 617.423.2808

www.karenclarkandco.com

November 4, 2022

Floyd Yager, Chair
Florida Commission on Hurricane Loss Projection Methodology
c/o Donna Sirmons
Florida State Board of Administration
1801 Hermitage Boulevard, Suite 100
Tallahassee, FL 32308

Re: Certification of KCC US Hurricane Reference Model Version 4.0

Dear Commission Chair Yager,

We are pleased to submit the Karen Clark & Company (KCC) US Hurricane Reference Model Version 4.0 for review and certification by the Commission. In accordance with the 2021 Hurricane Standards, we submit the data and analyses performed for the General, Meteorological, Vulnerability, Actuarial, Statistical, and Computer Information Hurricane Standards. All model components have been reviewed by experts in the areas of meteorology, engineering, statistics, actuarial science, and computer science for compliance with the Commission's Standards, as documented in the Expert Certification Forms G1-G6. The document has undergone editorial review in compliance with Form G-7, and the model is ready to be reviewed by the Professional Team.

Enclosed, please find five bound copies of the KCC submission. Please let me know if you have any questions on the enclosed.

Sincerely,

Glen Daraskevich
Senior Vice President

Hurricane Model Identification

Name of Hurricane Model:	KCC US Hurricane Reference Model
Hurricane Model Version Identification:	4.0
Hurricane Model Platform Names and Identifications With primary Hurricane Model Platform and Identification Designated:	RiskInsight® 4.11.1.7 (Primary Platform)
Interim Hurricane Model Update Version Identification:	
Interim Data Update Designation:	
Name of Modeling Organization:	Karen Clark & Company
Street Address:	116 Huntington Avenue
City, State, ZIP Code:	Boston, MA 02116
Mailing Address, if different from above:	Same as Above
Contact Person:	Glen Daraskevich
Phone Number: 617.423.2800	*Fax Number:* 617.423.2808
E-mail Address:	gdaraskevich@karenclarkandco.com
Date:	June 27, 2023

Description of Trade Secret Information

The following items are trade secret information and will be presented to the Commission during the closed meeting and to the Professional Team during the onsite visit:

- Form V-3
- Form V-5
- Form A-6
- Additional information regarding the handling of client insurer claims data

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General Hurricane Standards

G-1 Scope of the Hurricane Model and Its Implementation

A. The hurricane model shall project loss costs and probable maximum loss levels for damage to insured residential property from hurricane events.

All model components of the KCC US Hurricane Reference Model utilize scientific data and engineering analyses to capture the damaging effects of hurricane events and are consistent with the observed hurricane climatology and the current state of research. The loss costs and probable maximum loss levels output by the model reflect the damage to insured residential properties from hurricane events.

B. A documented process shall be maintained to assure continual agreement and correct correspondence of databases, data files, and computer source code to presentation materials, scientific and technical literature, and modeling organization documents.

KCC employs documented procedures to ensure the continuity and accuracy of databases, data files, computer source code, presentation materials, scientific and technical literature, including all materials shared with the Commission and Professional Team. All data files, data sets, and source code are stored in centralized repositories to ensure KCC staff have access to the latest information and can verify all changes. All changes are first discussed in meetings between Subject Matter Experts (SMEs) and upon approval requirement documents are updated. As changes are implemented, documented checklists are followed to ensure agreement and correctness between databases, data files, and source code to presentation materials, technical papers, and KCC modeling documents.

C. All software, data, and flowcharts (1) located within the hurricane model, (2) used to validate the hurricane model, (3) used to project modeled hurricane loss costs and hurricane probable maximum loss levels, and (4) used to create forms required by the Commission in the Hurricane Standards Report of Activities shall fall within the scope of the Computer/Information Standards and shall be located in centralized, model-level file areas.

All information and software files used to develop and validate the model and generate losses for the KCC US Hurricane Reference Model are centrally located and comply with the Computer/Information Standards. As specified in the Computer/Information Standards, KCC uses Microsoft Team Foundation Server and Github to maintain all source code, data files, flowcharts and documentation pertaining to the KCC US Hurricane Reference Model. This includes all materials used to generate the KCC submission document and associated forms.

D. A subset of the forms shall be produced through an automated procedure or procedures as indicated in the form instructions.

When specified, an automated procedure or procedures were employed as indicated in the form instructions. The forms impacted by this include Form M-1: Annual Occurrence Rates, Form M-3: Radius of Maximum Winds and Radii of Standard Wind Thresholds, Form S-1: Probability and Frequency of Florida Landfalling Hurricanes per Year, Form S-2: Examples of Hurricane Loss Exceedance Estimates, Form A-3: Hurricane Losses, Form A-4: Hurricane Output Ranges, Form A-5: Percentage Change in Hurricane Output Ranges, Form A-6: Logical Relationship to Hurricane Risk (Trade Secret Item), Form A-7: Percentage Change in Logical Relationship to Hurricane Risk, and Form A-8: Hurricane Probable Maximum Loss for Florida. In compliance with the preceding General Standards and the Computer/Information Standards, all programs or scripts used to generate these forms are located on Team Foundation Server and Github.

E. Vintage of data, code, and scientific and technical literature used shall be justifiable.

The vintage of data, code, and scientific and technical literature used to develop and validate the KCC US Hurricane Reference Model has been justified by the appropriate SMEs.

Disclosures

1. Specify the hurricane model version identification. If the hurricane model submitted for review is implemented on more than one platform, specify each hurricane model platform identifying the primary platform and the distinguishing aspects of each platform.

The KCC US Hurricane Reference Model is Version 4.0 on the RiskInsight® platform Version 4.11.1.7.

2. Provide a comprehensive summary of the hurricane model. This summary should include a technical description of the hurricane model, including each major component of the hurricane model used to project loss costs and probable maximum loss levels for damage to insured residential property from hurricane events causing damage in Florida. Describe the theoretical basis of the hurricane model and include a description of the methodology, particularly the wind components, the vulnerability components, and the insured loss components used in the hurricane model. The description should be complete and must not reference unpublished work.

The KCC US Hurricane Reference Model has four primary components:

- Event Catalog Module
- Intensity Footprint Module
- Vulnerability Module
- Financial Module

The KCC US Hurricane Reference Model is run on the RiskInsight® loss modeling platform which reads in the exposure data, applies the intensity footprints and the vulnerability functions, and estimates the insured losses using a comprehensive Financial Module.

Event Catalog Module

The Event Catalog includes over 80,000 potential hurricanes, over 30,000 of which impact the state of Florida. The Event Catalog includes by-passing storms and hurricanes with multiple landfalls. Each event in the catalog is assigned parameters that are used to generate the high-resolution intensity footprints for the event.

Event parameters include:

- Peak wind speed at landfall (V_{max})
- Radius of maximum winds (R_{max})
- Forward speed
- Storm track

The **peak wind speed at landfall** is defined as the peak 1-minute sustained wind speed at 10-meter height and is the primary determinant of storm intensity. KCC scientists employ statistical simulation techniques that ensure the distribution of V_{max} is appropriate for each landfall point and that the pattern is consistent between landfall points. In the event catalog, there are no abrupt changes in V_{max} between nearby landfall points except in areas where geography and/or meteorology warrant such changes.

KCC scientists use the historical data, statistical techniques, and meteorological expertise to develop the distributions. The historical data are derived from the normative sources, including HURDAT2 (Landsea & Franklin, 2013) and Ho et al. (1987) for historical storms for which HURDAT2 does not include the landfall wind speed.

KCC experts partition the historical data into regions of coastline for which the meteorological characteristics of hurricanes should be the same or very similar. The data are then fit to a Pareto distribution following the work of Palutikof et al. (1999), Brabson and Palutikof (2000), Jagger and Elsner

(2006), and Emanuel and Jagger (2010). The parameters for the estimated Pareto distributions are used to generate the V_{max} at landfall for each event in the catalog. To ensure consistency between neighboring landfall points and regions, the distribution parameters are smoothed at the region boundaries. The KCC sampling methodology ensures that the event catalog covers the full range of wind speeds at every landfall point.

The **radius of maximum winds (R_{max})** determines the geographical extent of the wind footprint for each event. In accordance with published literature (Willoughby et al., 2006) and observed data, R_{max} is generated as a function of V_{max} and latitude as shown below:

$$R_{max} = C_1 * e^{(C_2 * V_{max} + C_3 * latitude)}$$

The residual distances between observed R_{max} and the R_{max} calculated using the above formula are used to define the natural variability in this parameter for a given maximum wind speed and latitude. Deviations from the calculated R_{max} are applied to events in the catalog and are selected from a distribution of the observed residuals.

In general, stronger storms will have a smaller R_{max} and weaker storms will have a larger R_{max}. For each event in the catalog, the R_{max} changes as the storm propagates and the wind speeds decay over land.

The **forward speed** of a hurricane is not correlated with V_{max} but is correlated with latitude. In general, as hurricanes move into the northerly latitudes, the forward speed increases. Forward speeds are selected from a distribution that represents the natural variation in this parameter.

The **storm track** is a significant parameter because it influences the geographical distribution of wind speeds over land. The observational dataset includes approximately 70 landfalling hurricanes in Florida—a sample too small to fully represent the pattern of storm tracks expected over a longer time period as represented by the model Event Catalog. Rather than tie the modeled events too closely to what has been observed in the last 100 years, KCC used the historical data and climatology to model storm tracks.

KCC scientists segmented the historical tracks according to lengths of coastline for which the tracks are or are expected to be similar and then analyzed the angles at which the historical tracks crossed the coast at landfall. Each landfall point in the model has three tracks associated with it—the mean track angle and one standard deviation in either direction. The movement of the storm over land is modeled using the general tendency for hurricanes to eventually curve to the north and northeast. The KCC track generation technique ensures that there is a smooth transition in track angle and consistent spacing between landfall points while maintaining the climatology of storm movement after landfall.

KCC scientists selected this track generation methodology for several reasons, including:

- Every track in the model is realistic and conforms to hurricane climatology.
- There is consistent spatial coverage and no geographical bias. No geographical point is over or under sampled as can happen with random sampling techniques.

Once the event characteristics are defined, the track files for the events are created. Each track file contains for each hour—starting several hours before landfall and continuing until V_{max} drops below 25 mph—the latitude and longitude of the track position at that hour, the V_{max}, and the R_{max}. The hourly V_{max} values after landfall are calculated using the storm decay, or the filling rate, which is consistent with the published literature, including the Kaplan and DeMaria (1995) inland wind decay model.

Intensity Footprint Module

The track files are read into the KCC windfield generation program, WindfieldBuilder®, to determine the maximum 10-meter, 1-minute sustained wind speed for every point on a high-resolution 1-kilometer grid.

The hourly track points are interpolated to 5-minute track points and the wind speeds are calculated for every 5-minute time step as described below.

The **radial extent of the wind footprint** is determined using the Willoughby formulations (Willoughby et al., 2006). Winds inside the eyewall are estimated using a power function of the distance from the eye, and winds outside the eyewall are estimated using an exponential decay which depends on V_{max} and R_{max}. In the region near the eyewall (the transition region) winds are calculated as the weighted sum of the inner and outer wind profiles. For Category 1 and 2 storms, the single exponential profile is used, and for major hurricanes, the dual exponential is used, following the analysis of Willoughby et al. (2006).

The **asymmetry of the windfield** is captured as a function of the forward speed and the angle between the track direction and surface wind direction.

Terrain impacts are accounted for using the wind direction at each 5-minute time step and eight direction dependent surface roughness factors. The roughness factors are calculated using the most recent LULC (Land Use/Land Cover) data provided by the United States Geological Survey (USGS) (NLCD, 2019) and the generally accepted peer reviewed literature (ESDU, 2002; Simiu & Scanlan, 1996; Wieringa et al., 2001). KCC scientists and engineers employ a 12-kilometer fetch when accounting for the upwind terrain which is within the acceptable ranges from the published literature (Powell & Houston, 1996a; Vickery et al., 2009b).

The wind speed for each 5-minute time step is calculated for each 1-kilometer grid cell, and the maximum wind speed calculated for each grid cell is saved for the intensity footprint. The wind footprint for each event in the catalog is pre-calculated and then stored in a database for use during model loss analyses.

Vulnerability Module

The KCC US Hurricane Reference Model incorporates thousands of vulnerability functions reflecting differences in construction, occupancy, age of structure, region, and other property-specific characteristics. For each combination, damages are estimated separately for building, appurtenant structure, contents, and time element coverages.

Several sources of information are utilized for the construction of the vulnerability functions. First and foremost is the knowledge and expertise of KCC wind and structural engineers who have extensive experience in wind engineering and catastrophe modeling.

KCC scientists and engineers have published and are well versed in the normative literature on wind damageability. They have been engaged in experimental studies, including wind tunnel tests, as well as analytical studies that include finite volume and finite element modeling of progressive wind damage to building components.

KCC experts have conducted post-disaster field surveys for 20 significant landfalling hurricanes since Hurricane Hugo in 1989. KCC engineers have reviewed the building codes in all coastal states and have surveyed the local building inventories. Literature on the Florida building inventory (Michalski, 2016) is also used to inform the regional variation of vulnerability across the state. Billions of dollars of insurer claims data for actual events have been used to inform and validate the model vulnerability functions.

KCC uses a component-based methodology to develop the vulnerability functions. In this method, relevant building components are first identified and related to different states of damage. A vulnerability function is then developed for each component, and the component vulnerabilities are combined to produce the vulnerability of the building structure. This approach is well documented in the literature (e.g., Cope, 2004; Li & Ellingwood, 2006; Unanwa, et al., 2000).

The vulnerability functions provide estimates of the mean damage in response to 1-minute sustained wind speeds experienced at the location. For each structure type (construction, occupancy, year built, etc.) there are four vulnerability functions representing the Mean Damage Ratios (MDRs) for building, appurtenant structure, contents, and time element coverages.

The KCC vulnerability functions have been validated using industry losses and client-specific claims data.

Financial Module

The MDRs from the vulnerability functions are expressed as percentages of the coverage replacement values. For each MDR, the RiskInsight® Financial Module considers the full range of damage levels around the mean (the secondary uncertainty) with empirical distributions. Empirical distributions are chosen because actual hurricane losses do not exhibit a simple central behavior, and these distributions better correlate with reality and actual claims experience.

RiskInsight® represents the secondary uncertainty distributions as discrete bins, where each bin corresponds to the probability of experiencing a specific damage level, and every distribution includes a non-zero probability mass at 0 and at 100 percent loss. Secondary uncertainty is always considered in the loss calculations.

There are 100,000 secondary uncertainty distributions for MDRs ranging from .00001 to 1. KCC scientists developed a complex iterative process to create these distributions so that the following mathematical constraints are met:

- The probabilities add up to 1
- The MDRs are maintained
- The probability mass at 0 falls as the MDR increases
- The probability mass at 1 rises as the MDR increases

The diagram below illustrates the implementation of secondary uncertainty in the KCC US Hurricane Reference Model.

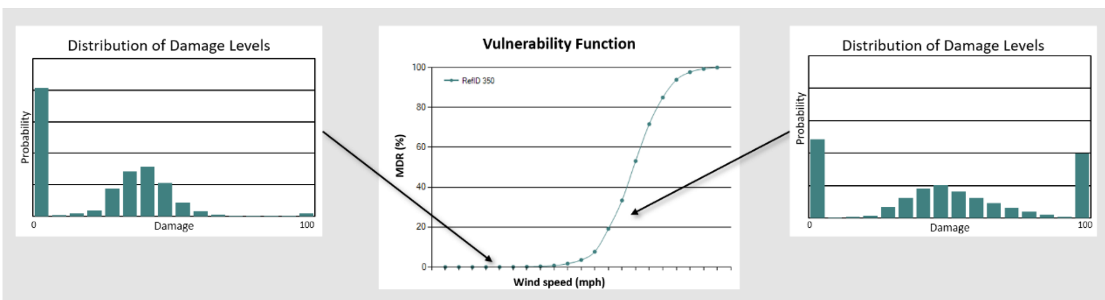

Figure 1 - Illustration of secondary uncertainty for different MDRs

The KCC US Hurricane Reference Model calculates losses at the location level and for individual coverages separately. The location level losses can be aggregated to different levels of resolution, such as five-digit ZIP Codes or counties, and they serve as the basis for the loss cost and probable maximum loss estimates.

3. Provide a flowchart that illustrates interactions among major hurricane model components.

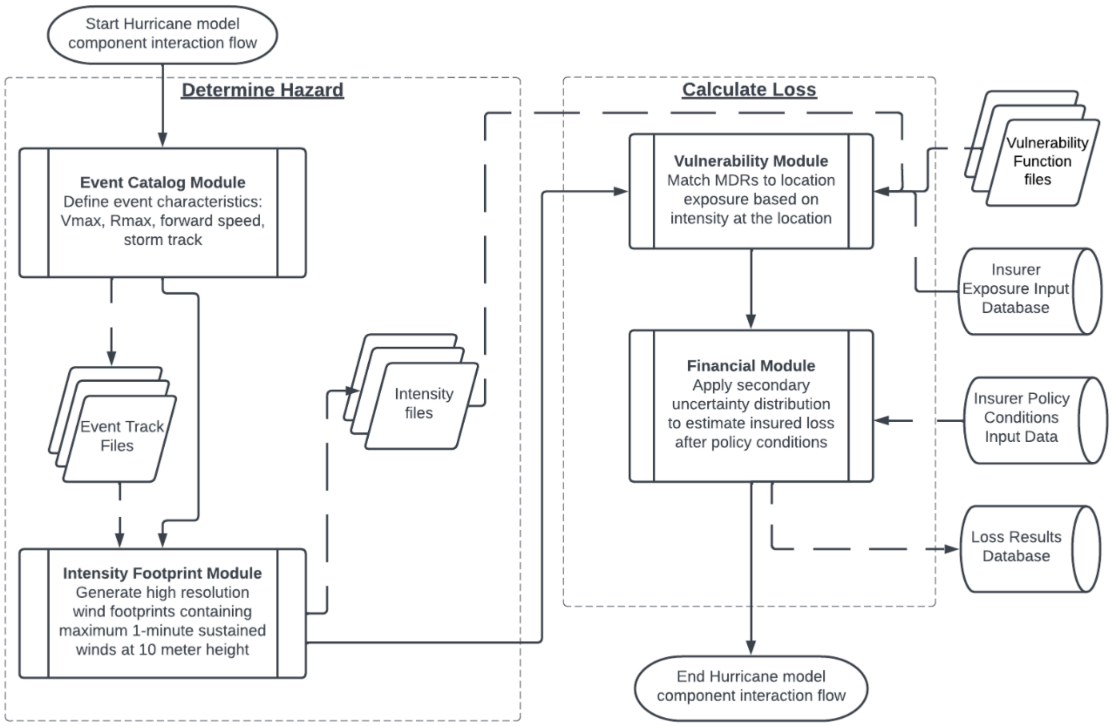

Figure 2 - Interaction between model components of the KCC US Hurricane Reference Model

4. Provide a diagram defining the network organization in which the hurricane model is designed and operates.

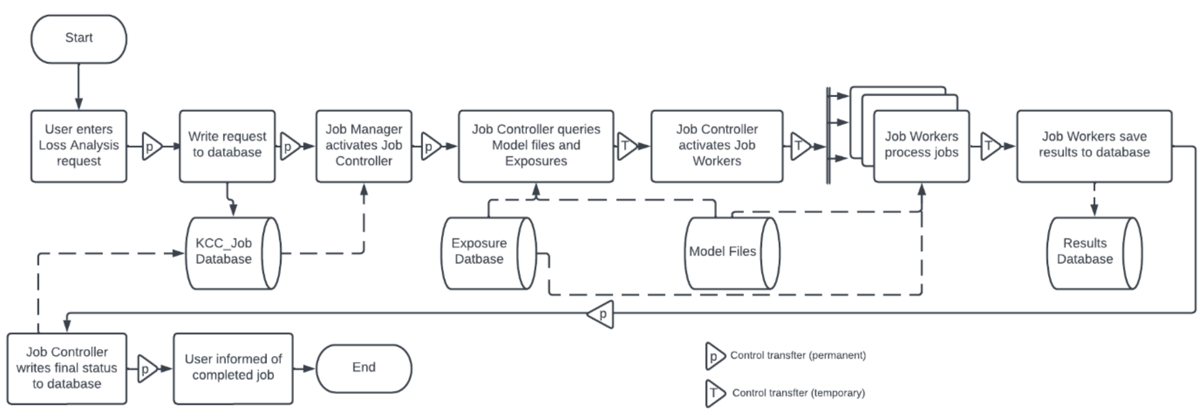

Figure 3 - KCC network organization diagram

5. ***Provide detailed information on the hurricane model implementation on more than one platform, if applicable. In particular, submit forms S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled; V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage; A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code; A-4, Hurricane Output Ranges; and A-8, Hurricane Probably Maximum Loss for Florida, from each platform including additional calculations showing no differences.***

The KCC US Hurricane Reference Model is implemented only on the RiskInsight platform.

6. ***Provide a comprehensive list of complete references pertinent to the hurricane model by standard grouping using professional citation standards.***

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7. Provide the following information related to changes in the hurricane model from the currently accepted hurricane model to the initial submission this year.

A. Hurricane model changes:

1. A summary description of changes that affect the personal or commercial residential hurricane loss costs or hurricane probable maximum loss levels,

Event Catalog Module updates:

- Inclusion of 2019-2021 events
- Consideration of climate change impacts on hurricane intensity distributions
- Updated storm tracks including re-intensification over the Gulf of Mexico

Intensity Footprint Module updates:

- Updated land cover dataset used to calculate wind speed over land

Vulnerability Module updates:

- Updated site-built building vulnerability functions associated with Very-New year-built band
- Updated manufactured home vulnerability functions associated with year-built bands
- Updated vulnerability functions for commercial residential, renters, and condos occupancy types when building height is unknown

Zip Code Centroid update:

- Updated ZIP codes and population-weighted centroids and related databases

Other changes impacting loss costs:

- Inclusion of excess litigation factor for Florida site built single family homes
- Demand surge factors have been updated to reflect increased property values in the 2022 KCC Industry Exposure Database

2. A list of all other changes, and

No other changes were introduced related to the currently accepted model.

3. The rationale for each change.

Event Catalog Module rationale:

The KCC US Hurricane Reference Model was updated to incorporate recent events and the most current data on hurricanes impacting Florida. Event parameter distributions were updated to reflect recent data updates to HURDAT2 for the time periods 1961-1970 and 2019-2021.

With this model update, climate change is explicitly accounted for in accordance with the scientific understanding of the relationship between warming temperatures and hurricanes. Specifically, hurricanes are becoming more intense as sea surface temperatures (SSTs) rise. The increases in intensity that has occurred since the 1900s is reflected in the updated parameter distributions for Vmax. SSTs are also causing more rapid intensification and this has been reflected in the modeling of storms exiting the Florida peninsula and making second landfalls in the Florida panhandle.

Intensity Footprint Module rationale:

The land cover input into the wind speed calculations has been updated to the latest National Land Cover Dataset (NLCD; 2019). The land cover type determines the level of friction applied to the winds during a hurricane event and is a factor in generation of wind footprints.

Vulnerability Module rationale:

The site-built vulnerability functions associated with Very-New year-built band were updated based on detailed analysis of claims data This modification is also motivated by the revisions in Florida Building Code 2020 (effective since 2021) compared to Florida Building Code 2017.

The manufactured home vulnerability functions associated with year-built bands were updated based on detailed analysis of claims data.

The vulnerability functions for unknown height for commercial residential, renters, and condos occupancy types were updated based on an analysis of the weighted average of known building height combinations.

Zip Code Centroid rationale:

The ZIP Codes and centroids are updated as changes are made by the US Postal Service.

Other changes rationale:

Detailed analyses of claims data indicates that the frequency of litigated claims in recent Florida storms is higher compared to recent non-Florida storms and earlier Florida storms. It is also found that the average size of litigated claims is at least four times larger than the average size of non-litigated claims. Depending on the company and storm, excess litigation (as defined as litigated claims frequency greater than four percent) has resulted in increases in insurer losses ranging from 25 to over 50 percent. In anticipation of future legislative actions that could reduce excess litigation, a 15 percent excess litigation factor was selected for site built single family homes.

KCC's US Industry Exposure Database has been updated with property values current as of January 2022. Property values in the industry exposure database have increased and resulted in increases in the resulting demand surge factors.

B. Percentage difference in average annual zero deductible statewide hurricane loss costs based on the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip" for:

1. All changes combined, and

The overall change in average annual zero deductible statewide hurricane loss costs is 17.8%. Note the values in the Table 1 below do not match the overall change due to rounding.

2. Each individual hurricane model component change.

Hurricane Model Component	% Change
Hazard	4.5
Vulnerability	1.0
ZIP Code Centroids	-0.9
Other	13.3

Table 1 - Percent difference in average annual zero deductible hurricane loss costs

C. Color-coded maps by county reflecting the percentage difference in average annual zero deductible statewide hurricane loss costs based on the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip" for each hurricane model component change.

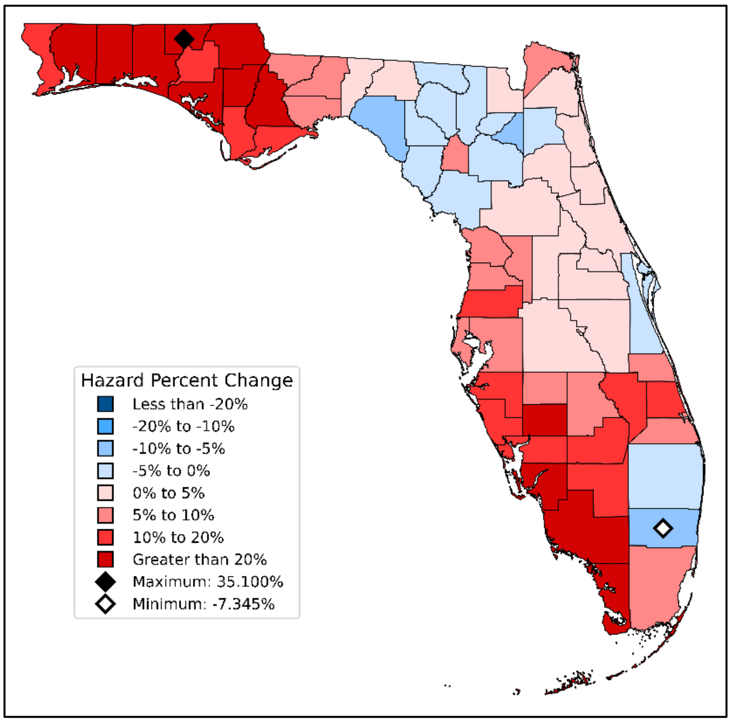


Figure 4 - Percent difference in average annual zero deductible hurricane loss costs due to change in hazard

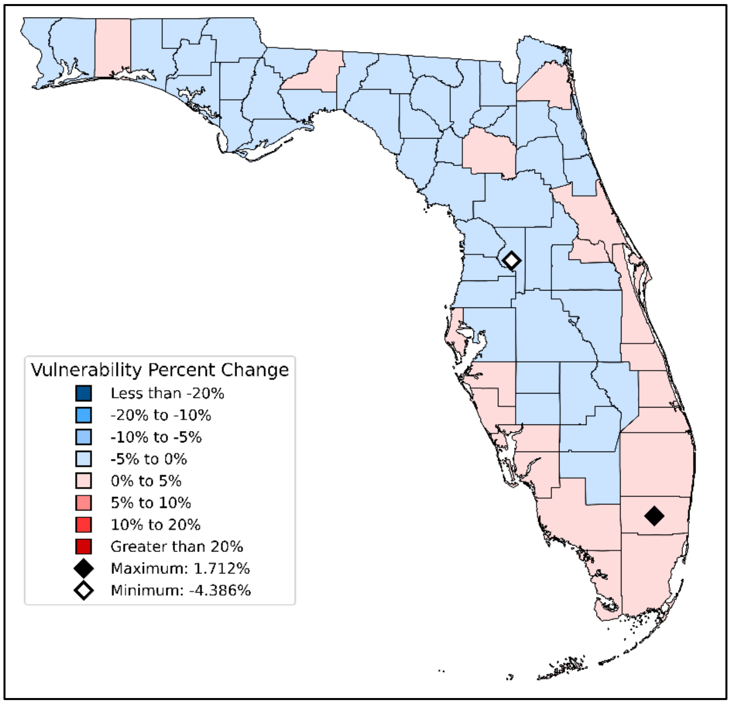


Figure 5 - Percent difference in average annual zero deductible hurricane loss costs due to change in vulnerability

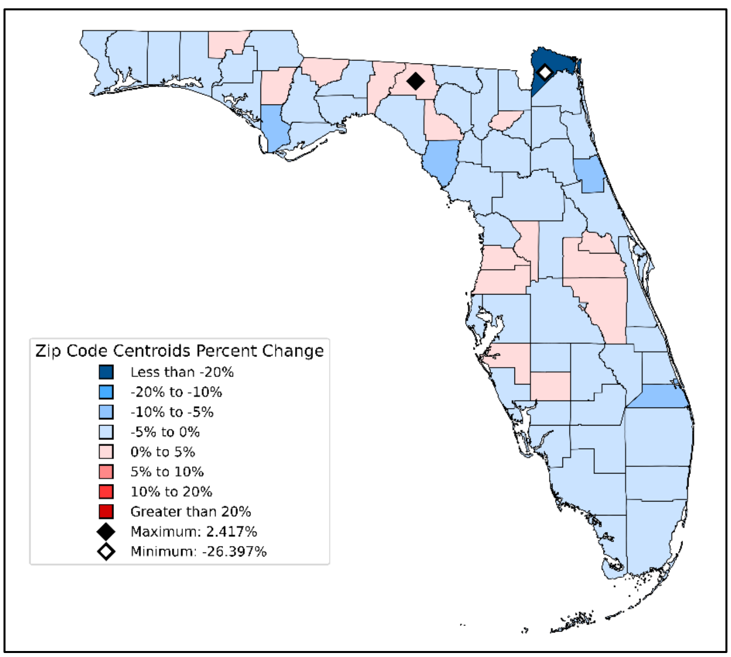


Figure 6 - Percent difference in average annual zero deductible hurricane loss costs due to change in ZIP Code centroids

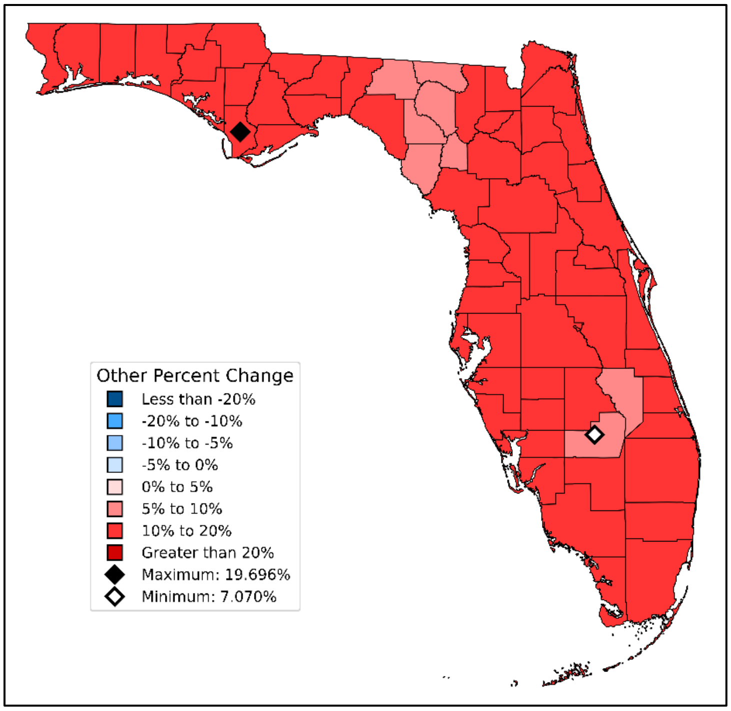


Figure 7 - Percent difference in average annual zero deductible hurricane loss costs due to other changes

D. ***Color-coded map by county reflecting the percentage difference in average annual zero deductible statewide hurricane loss costs based on the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip" for all hurricane model component changes combined.***

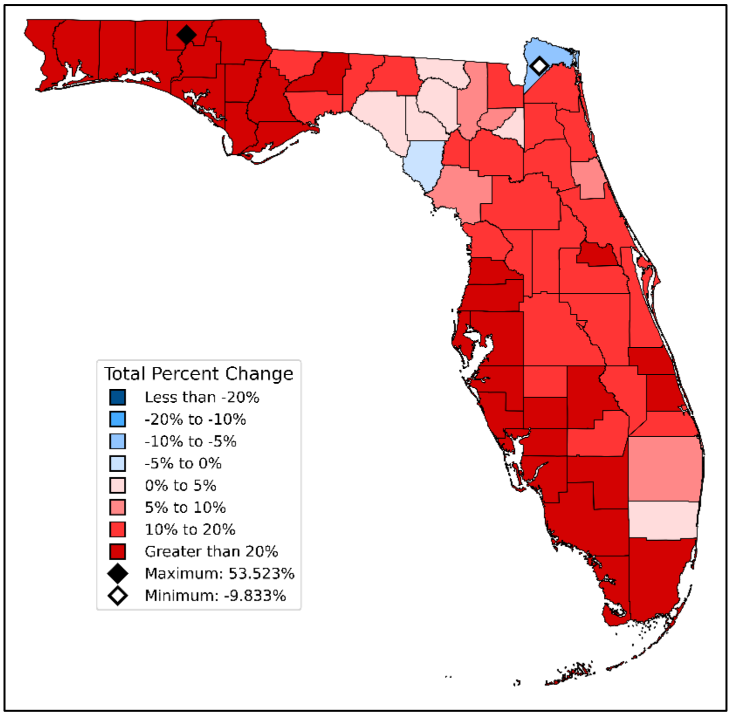


Figure 8 - Percent difference in average annual zero deductible hurricane loss costs due to all changes combined

8. Provide a list and description of any potential interim updates to underlying data relied upon by the hurricane model. State whether the time interval for the update has a possibility of occurring during the period of time the hurricane model could be found acceptable by the Commission under the review cycle in this Hurricane Standards Report of Activities.

The following updates to the underlying data relied upon by the model may be updated after the review cycle of this Report of Activities.

- The vintage of the geocode databases and related ZIP code information may be updated to a new version

G-2 Qualifications of Modeling Organization Personnel and Consultants Engaged in Development of the Hurricane Model

A. Hurricane model construction, testing, and evaluation shall be performed by modeling organization personnel or consultants who possess the necessary skills, formal education, and experience to develop the relevant components for hurricane loss projection methodologies.

The KCC US Hurricane Reference Model was developed and verified by professionals who possess the requisite experience and formal education. Further information about the qualifications of individuals involved in the development, testing, and evaluation of the KCC US Hurricane Reference Model can be found in Standard G-2, Disclosure 2A.

KCC professionals possess a wide range of skills and expertise in fields including meteorology, engineering, computer science, and statistics honed through experience and education. All model developers possess advanced degrees, and the majority hold PhDs in their fields. At each stage of model development, these experts evaluated and tested the model for accuracy and reliability using accepted methodologies and rigorous standards appropriate to their respective disciplines.

B. The hurricane model and hurricane model submission documentation shall be reviewed by modeling organization personnel or consultants in the following professional disciplines with requisite experience: structural/wind engineering (currently licensed Professional Engineer), statistics (advanced degree or equivalent experience), actuarial science (Associate or Fellow of Casualty Actuarial Society or Society of Actuaries), meteorology (advanced degree), and computer/information science (advanced degree or equivalent experience and certifications). These individuals shall certify Expert Certification Forms G-1 through G-6 as applicable.

The KCC US Hurricane Reference Model and associated documentation have been thoroughly reviewed by individuals holding the above-mentioned qualifications and are detailed further in Standard G-2, Disclosure 2A.

Disclosures

1. Modeling Organization Background

A. Describe the ownership structure of the modeling organization engaged in the development of the hurricane model. Describe affiliations with other companies and the nature of the relationship, if any. Indicate if the modeling organization has changed its name and explain the circumstances.

KCC is a privately held firm with no external affiliations.

B. If the hurricane model is developed by an entity other than the modeling organization, describe its organizational structure and indicate how proprietary rights and control over the hurricane model and its components are exercised. If more than one entity is involved in the development of the hurricane model, describe all involved.

KCC developed the KCC US Hurricane Reference Model without an external entity and holds all proprietary rights and control over the model.

C. If the hurricane model is developed by an entity other than the modeling organization, describe the funding source for the development of the hurricane model.

KCC funded the development and implementation of the model.

D. Describe any services other than hurricane modeling provided by the modeling organization.

KCC professionals are globally recognized experts in catastrophe risk assessment and management with extensive experience in all types of natural perils, including earthquakes and other windstorms as well as hurricanes. KCC provides consulting services and licenses software to the insurance industry.

KCC consultants conduct comprehensive reviews of the models and modeling processes for the world's largest (re)insurers and US primary insurers. Other consulting services include M&A due diligence, peer company analyses, and executive briefings.

The KCC suite of models currently includes **US hurricane, storm surge, inland flood, severe convective storm, earthquake, winter storm,** and **wildfire; Canada earthquake; Japan typhoon** and **earthquake; Australia earthquake** and **cyclone; New Zealand earthquake; Mexico earthquake; South America earthquake; Central America earthquake; European wind storm;** and **Caribbean hurricane** and **earthquake.** KCC clients can access these models on a service basis or by licensing the models as part of the RiskInsight® loss modeling platform. KCC models are licensed on an ongoing basis by top 10 US P&C insurers, Florida domestic insurers, and global insurers, reinsurers, and ILS funds.

E. Indicate if the modeling organization has ever been involved directly in litigation or challenged by a governmental authority where the credibility of one of its U.S. hurricane model versions for projection of hurricane loss costs or hurricane probable maximum loss levels was disputed. Describe the nature of each case and its conclusion.

KCC has not been involved in litigation or challenged by a government authority regarding loss cost or probable maximum loss projections for a US hurricane model.

2. Professional Credentials

A. Provide in a tabular format (a) the highest degree obtained (discipline and university), (b) employment or consultant status and tenure in years, and (c) relevant experience and responsibilities of individuals currently involved in the acceptability process or in any of the following aspects of the hurricane model:

1. ***Meteorology***
2. ***Statistics***
3. ***Vulnerability***
4. ***Actuarial Science***
5. ***Computer/Information Science***

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
Computer/ Information	Vivek Basrur	M.S. Management Sciences University of Waterloo B.S. Civil Engineering Indian Institute of Technology	KCC Co-Founder/ 15	Mr. Basrur has over 40 years of experience in software design and development. He architected and designed KCC's RiskInsight® loss modeling platform, which provides advanced exposure management and analytical tools to US and global insurers, reinsurers, and ILS investors. RiskInsight® functionality includes high-resolution global mapping, interactive exposure and loss dashboards, Characteristic Events (CEs), and real-time hurricane tracking along with the traditional Exceedance Probability (EP) curve risk metrics. Prior to co-founding KCC in 2007, Mr. Basrur was the Executive Vice President and Director of Software Development at AIR Worldwide from 1993-2007, where he led the development of AIR's catastrophe modeling software applications. Prior to this, Mr. Basrur was co-founder and Vice President for Software Development of FormWorx Corporation and the principal of an investment consulting practice at Resource Planning Associates. Mr. Basrur received graduate education at the University of Waterloo, Massachusetts Institute of Technology, and Harvard University, and he earned his Civil Engineering undergraduate degree from the Indian Institute of Technology. Mr. Basrur's contributions to the KCC US Hurricane Reference Model include overall management of RiskInsight® development and the implementation of the model components.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
Vulnerability	Girma Tsegaye Bitsuamlak	Ph.D., P. Eng., F CSCE Building Engineering Concordia University	Consultant / N.A.	Dr. Bitsuamlak is the Director for the WindEEE Research Institute and WindEEE Research Facilities (The WindEEE Dome + Boundary Layer Wind Tunnel Laboratory + The Three Little Pigs Laboratory) at Western University and has 18 years of wind engineering experience (including hurricane, tornado, and downburst). In addition to being a licensed Professional Engineer (P.Eng.) and Fellow of Canadian Society of Civil Engineering, he has published more than 200 engineering papers in peer reviewed journals and presented wind engineering research at conferences. He has executed wind-induced load and response studies for socially and historically significant super tall buildings such as Freedom Tower in New York, International Commerce Center in Hong Kong, and Burj Khalifa in Dubai in wind tunnels. He is an expert both in experimental and computational wind engineering. His contributions to the KCC US Hurricane Reference Model include providing an external peer review of the Vulnerability Module.
Meteorology, Computer / Information	Christopher Burke	Ph.D. Physics Tufts University	Senior Research Scientist/ 4	Dr. Burke has extensive experience in computational analytics and working with large datasets. As a postdoctoral researcher, he developed and implemented techniques to computationally reconstruct and analyze the geometry of nanoscopic polymer networks and a physics algorithm to simulate block copolymers with orientational interactions. Dr. Burke has developed and co-taught computational physics and is well-versed in numerical simulation techniques. Dr. Burke has worked on the development of several KCC models, including the Severe Convective Storm and Flood models. His contributions to the KCC US Hurricane Reference Model include developing and optimizing the event footprint generation methodology and computer code.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
General	Karen Clark	M.B.A. M.A. Economics Boston University	CEO and President / 15	Karen Clark is a leading global authority on catastrophe risk assessment and management. Ms. Clark developed the first hurricane model and founded the first catastrophe modeling company, AIR, which she grew to cover all the major natural perils in over 50 countries as well as terrorism in the US. The probabilistic catastrophe modeling techniques and innovative technologies that Ms. Clark pioneered revolutionized the way insurers, reinsurers, and other financial institutions assess and manage their catastrophe risk. Ms. Clark is now leading the KCC team in the development of new scientific models that are transparent to the user and provide additional risk metrics for decision makers. She is also leading the development of RiskInsight, an advanced and open loss modeling platform. Ms. Clark reviewed and visually inspected the major components of the KCC US Hurricane Reference Model.
Computer/ Information	Adrian Corman	Ph.D. Physics University of Missouri	Senior Software Developer / 4	Dr. Corman has ten years of professional programming experience and a strong analytical background. Prior to joining KCC, Dr. Corman was a programmer analyst where he streamlined company processes, maintained SQL databases, created backend and frontend software, and developed stored procedures to increase efficiency. During his graduate research, he used advanced statistical techniques to identify correlations in data and developed software to convert raw data into an appropriate input for computer simulations. His contributions to the KCC US Hurricane Reference Model include the software implementation of model components.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
General, Vulnerability, Computer/ Information	Glen Daraskevich	M.S. Engineering and Information Systems Boston University	Senior Vice President / 14	Mr. Daraskevich has extensive experience in catastrophe modeling, pricing, and risk management. As the head of KCC's consulting practice, Mr. Daraskevich has conducted comprehensive reviews of catastrophe models and catastrophe modeling processes for regional, national, and global insurers. These reviews have entailed detailed model evaluations, peer review studies, and M&A due diligence. Prior to joining KCC, he was the Vice President of the Research and Modeling team at AIR for six years, where he led the development of several of the company's key catastrophe models. He has also directed several post-event damage surveys following hurricanes in 2004, 2005, and 2008. Mr. Daraskevich's contributions to the KCC US Hurricane Reference Model include design of the exposure import and loss results software components, quality assurance, and testing.
General	Emanuel Eagle	B.A. Environmental Studies Connecticut College	Risk Analyst / <1	Mr. Eagle graduated with a degree in Environmental Studies including additional coursework in Computer Science. Mr. Eagle spent three years in a leading limnological research lab conducting time series analysis on temperature trends in the Northeastern United States. This research included geospatial analyses attempting to identify the impacts of geography, geology, and changes in land use on temperature trends. Mr. Eagle also utilized GIS to develop statistical models to estimate the impact of various abiotic factors on hypereutrophication in freshwater ecosystems for a water conservation non-profit. Mr. Eagle's contributions to the KCC US Hurricane Refence Model include conducting geospatial analyses and the validation of geocodes and exposure and loss output.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
Computer/ Information	Grant Elgin	Computer Science	Senior Software Engineer / 11	Mr. Elgin has worked extensively on the RiskInsight® loss modeling platform including developing HazardMapper® for generating the intensity footprints, the interactive map engine for displaying the event footprints, and the Analysis Server Cluster. He has taken academic and professional courses in discrete mathematics, Java, data structures, computer architecture, data structures and algorithms, computer networks, operating systems, dynamic web applications, C#, and software design and defensive programming techniques. Mr. Elgin's contributions to the KCC US Hurricane Reference Model include the software implementation of model components.
Meteorology, Vulnerability	Filmon Habte	Ph.D. Structural/Wind Engineering Florida International University	Senior Wind Engineer / 4	Dr. Habte is an expert in the area of hurricane impacts on structures. During his education, he conducted several experiments using the Wall of Wind to test building components against known wind speeds to identify failure modes. He has published a number of papers and given conference presentations on his research. Dr. Habte has experience conducting statistical and structural analyses to evaluate building vulnerability to different perils, including wind, inland, and coastal flooding. Dr. Habte has led the development of several KCC models, including Caribbean Hurricane and Japan Typhoon. He led the development of the vulnerability functions for the KCC US Hurricane Model, and he has conducted post-disaster surveys for Hurricanes Maria (2017), Irma (2017), Matthew (2016), and Michael (2018). Dr. Habte contributed to the Vulnerability and Intensity Modules.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
General	Tanner Hanwright	M.S. Analytics Georgia Institute of Technology	Senior Data Analyst / 1	Mr. Hanwright works with the model development and client services teams and has contributed to model validation, used RiskInsight® to generate loss and exposure exhibits for client projects, and developed automated procedures for processing model output. Prior to joining KCC, his course work included data analysis for business applications, python, SQL, and data visualization. Mr. Hanwright's contributions to the KCC US Hurricane Reference Model include conducting various test to validate the model output and configuring the model to be used for loss analyses in RiskInsight®.
Statistics	Adam Jaeger	PhD Statistics, University of Georgia	Statistician / <1	Dr Jaeger statistical expertise include computational statistics, nonparametric likelihood inference, and data analytics. Prior to joining KCC, Dr. Jaeger's research projects included Rossby wave detection, prediction of El Niño-Southern Oscillation (ENSO) classification, and spatio-temporal statistics. His contributions to the KCC US Hurricane Reference model include enhancing the methodology for the statistical components of the model and uncertainty analysis.
Vulnerability	Arjun Jayaprakash	Ph.D. Civil Engineering North Carolina State University	Principal Engineer / 2	Since joining KCC, Dr. Jayaprakash has contributed to the development of the KCC industry property database (KPD) as well as the vulnerability modules and model validation for several earthquake and hurricane models, including the KCC Central America Earthquake, Mexico Earthquake, and US Hurricane Reference Models.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
General, Statistics, Vulnerability	Nozar Kishi	Ph.D. M.S. Structural Engineering University of Kyoto	Vice President of Model Development / 6	Dr. Kishi has 25 years of catastrophe modeling experience and has been an engineer on staff at EQECAT (now CoreLogic), RMS, and AIR, and was the Chief Research Scientist at Flagstone Re from 2006 to 2010. In addition to developing vulnerability functions for hurricanes, earthquakes, floods, and wild fires, he has conducted extensive post-event reconnaissance surveys including for Hurricanes Bonnie (1998), Isabel (2003), Ivan (2004), Matthew (2016), Harvey (2017), Irma (2017), and Typhoons Paka (1997) and Chaba (2004). Dr. Kishi's contributions to the KCC US Hurricane Reference Model include peer reviewing the vulnerability functions and probabilistic components of the model.
Vulnerability	Shaoning Li	Ph.D. Structural / Wind Engineering Northeastern University	Wind Engineer / <1	Dr. Li has a background in structure analysis, aerodynamic simulations, probabilistic analysis, statistical analysis, and wind tunnel experiments. His experience also encompasses the research on the uncertainties of wind borne-debris impact. He has published a number of papers and given conference presentations about his research. Dr. Li's contributions to the KCC US Hurricane Reference Model include developing and reviewing the vulnerability module.
Computer/ Information, Statistics	Marshall Pagano	B.A. Mathematics and Quantitative Economics Tufts University	Director, Client Services / 6	Mr. Pagano has extensive experience in working with insurer exposure data and catastrophe loss analytics. Mr. Pagano is an expert on the RiskInsight® loss modeling platform and has used the software to perform loss analyses for major insurers, to conduct detailed claims analyses, and to provide insurers with estimates of claims and losses as catastrophe events are unfolding. Prior to joining KCC, he conducted data analyses and developed predictive models for political polls. Mr. Pagano's contributions to the KCC US Hurricane Reference Model include designing and documenting the KCC database schema, designing and documenting quality assurance tests, managing the testing process, and working with client exposure and claims data.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
Computer/ Information	Arthur Phung	B.S. Mechanical Engineering Boston University	Senior Software Developer / 1	Mr. Phung contributes to RiskInsight® software development and has worked on a modern, web-based user interface for submitting losses and an integrated licensing system to verify valid hardware clients connected to the platform. Mr. Phung is also responsible for implementing interactive applications to modernize and streamline the current workflow of RiskInsight®. Mr. Phung's primary contributions to the RiskInsight 4.11 release include updates to the user interface to support a more intuitive process for submitting losses, and introducing job templates to allow clients to specify pre-defined Florida rate filing settings.
Computer / Information	David Richards	B.S. Electrical Engineering University of Massachusetts	Senior Software Engineer / 11	Mr. Richards has extensive experience in catastrophe modeling software, particularly web-based applications. Prior to joining KCC, he spent seven years as a software engineer at AIR Worldwide developing the geocoding and address standardization services, the CATstation web application, and the AIRProfiler loss analysis product. His contributions to the KCC US Hurricane Reference Model include developing the address standardization and geocoding web service and the process for importing data into the KCC exposure databases.
Actuarial	Melinda Vasecka, ACAS	B.A. Mathematics University of Minnesota, Twin Cities	Director, Actuarial Services / < 1	Ms. Vasecka has over 20 years of experience in the insurance and catastrophe modeling industries, with extensive experience in risk management, reinsurance, catastrophe modeling, and reserving and is an Associate of the Casualty Actuarial Society. Prior to joining KCC, Ms. Vasecka led the risk management and ceded reinsurance teams for catastrophe-exposed primary insurers. In these roles, she conducted model reviews, led the companies' exposure management process, developed profitability models, and helped develop both reinsurance structures and reinsurance placements. Ms. Vasecka's contributions to the model include working with client exposure and claims data and reviewing tests of loss results.

Standard(s)	Individual	A. Degree, Discipline, University	B. KCC Status / Tenure (years)	C. Experience and Responsibilities
Meteorology, Statistics,	Daniel Ward	Ph.D. Atmospheric Science Colorado State University	Director, Model Development / 6	Dr. Ward's doctoral research encompassed developing numerical weather and climate models as well as field-based research. Dr. Ward participated in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report as a Contributing Author and collaborated with scientists at the National Center for Atmospheric Research on global earth systems modeling. His published research includes aerosol dispersal and the effects of land use change on carbon cycle feedbacks and global climate forcing. Dr. Ward has worked on the development of the KCC US Flood and Severe Convective Storm models as well as KCC's Hurricane models. Dr. Ward's contributions to the KCC US Hurricane Reference Model include generating the historical and stochastic catalogs and the event intensity footprints.
Computer/ Information	Nicholas Weed	B.A. Computer Science and Chinese Williams College	Senior Software Developer / 2	Mr. Weed works extensively on the RiskInsight® application as a full stack developer, with a focus on model management tools and software deployment processes. The primary components Mr. Weed has worked on are the model manager, the RiskInsight® API, and the loss dashboards. Prior to joining KCC, he was a student at Williams College, where he studied Computer Science and Chinese. Relevant coursework includes distributed systems, computer organization, parallel programming, algorithm design and analysis, among others. Mr. Weed's contributions to the KCC US Hurricane Reference model include the software implementation of model components.

Table 2 – KCC professional credentials

B. Identify any new employees or consultants (since the previous submission) engaged in the development of the hurricane model or the acceptability process.

New KCC employees since the previous submission include Emanual Eagle, Risk Analyst, Tanner Hanwright, Senior Risk Analyst, Arthur Phung, Software Developer, Adam Jaeger, Statistician, Arjun Jayaprakash, Principal Engineer, Shaoning Li, Wind Engineer, Melinda Vasecka, Director, Actuarial Services, and Nick Weed, Senior Software Developer. Dr. Girma Bitsuamlak acted as a consultant and performed an independent review of the US Hurricane Vulnerability Module.

C. Provide visual business workflow documentation connecting all personnel related to hurricane model design, testing, execution, maintenance, and decision-making.

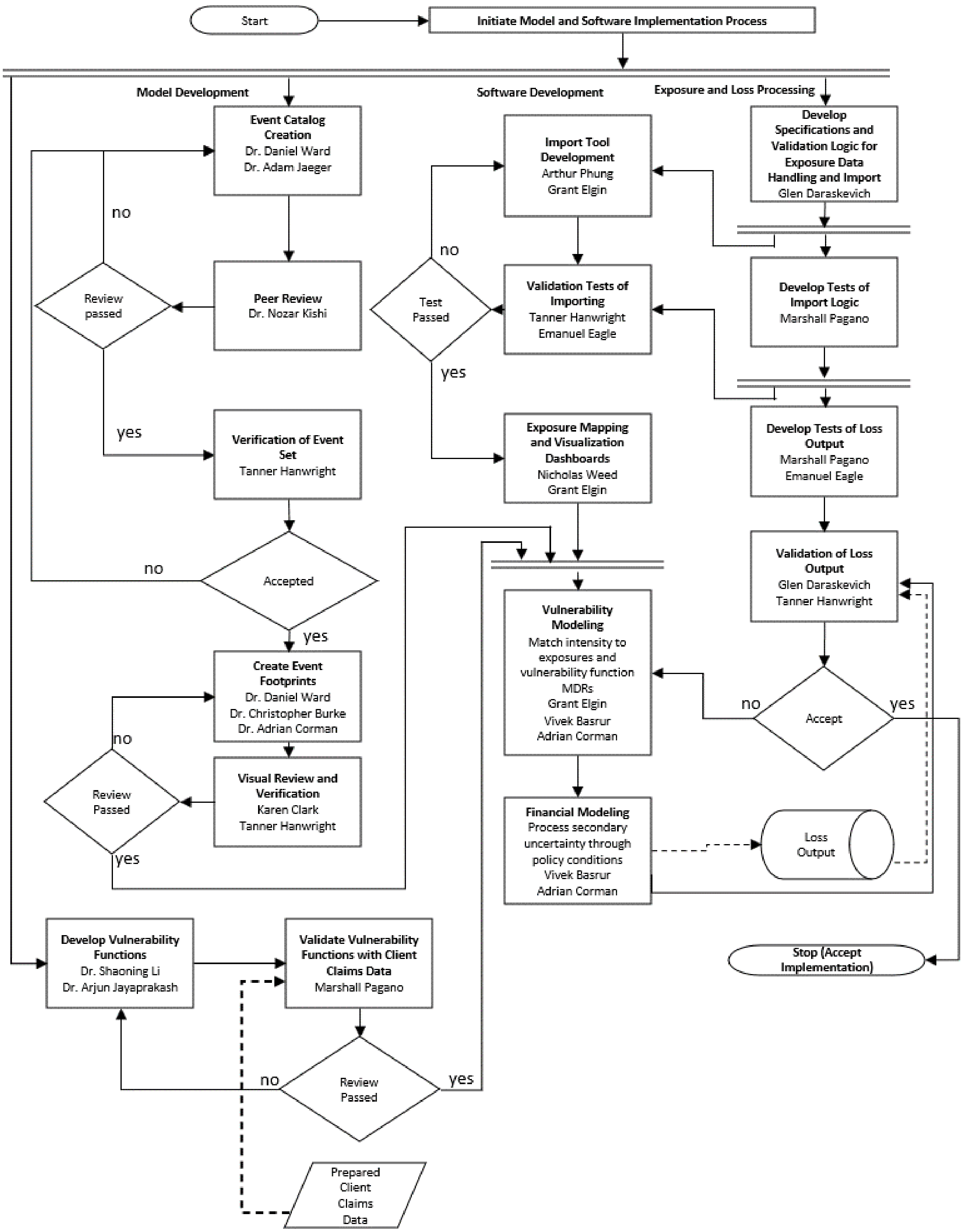


Figure 9 - Workflow of KCC professionals involved in development of the KCC US Hurricane Reference Model

3. Independent Peer Review

A. Provide reviewer names and dates of external independent peer reviews that have been performed on the following components as currently functioning in the hurricane model:

1. Meteorology

2. Statistics

3. Vulnerability

4. Actuarial Science

5. Computer/Information Science.

The Vulnerability Module was reviewed by J. Michael Grayson, Ph.D., P.E., in 2018 and 2020, and by Girma Bitsuamlak, Ph.D., P.E. in 2022.

B. Provide documentation of independent peer reviews directly relevant to the modeling organization responses to the current hurricane standards, disclosures, or forms. Identify any unresolved or outstanding issues as a result of these reviews.

There are no unresolved or outstanding issues. The peer review letter written by Dr. Bitsuamlak can be found in Appendix F: Model Evaluation.

C. Describe the nature of any on-going or functional relationship the modeling organization has with any of the persons performing the independent peer reviews.

KCC has no ongoing or functional relationship to Dr. Grayson or Dr. Bitsuamlak other than as a peer reviewer for the KCC vulnerability module.

4. Provide a completed Form G-1, General Standards Expert Certification. Provide a link to the location of the form.

Form G-1: General Hurricane Standards Expert Certification

5. Provide a completed Form G-2, Meteorological Standards Expert Certification. Provide a link to the location of the form.

Form G-2: Meteorological Hurricane Standards Expert Certification

6. Provide a completed Form G-3, Statistical Standards Expert Certification. Provide a link to the location of the form.

Form G-3: Statistical Hurricane Standards Expert Certification

7. Provide a completed Form G-4, Vulnerability Standards Expert Certification. Provide a link to the location of the form.

Form G-4: Vulnerability Hurricane Standards Expert Certification

8. Provide a completed Form G-5, Actuarial Standards Expert Certification. Provide a link to the location of the form.

Form G-5: Actuarial Hurricane Standards Expert Certification

9. Provide a completed Form G-6, Computer/Information Standards Expert Certification. Provide a link to the location of the form.

Form G-6: Computer/Information Hurricane Standards Expert Certification

G-3 Insured Exposure Location

A. ZIP Code centroids, when used at the date of submission of the hurricane model. ZIP Code information shall originate from the United States Postal Service.

KCC uses United States Postal Service (USPS) ZIP Code data that is post-processed by a third-party vendor Claritas. KCC's current iteration of ZIP Code database is from October 2022.

B. ZIP Code centroids, when used in the hurricane model, shall be based on population data.

KCC's ZIP Code centroids are based on data from Claritas' "ZIPCENT22" dataset, the Florida Department of Revenue's Tax Data Parcel database, and 2020 US Census population data. The centroids are population-weighted.

C. ZIP Code information purchased by the modeling organization shall be verified by the modeling organization for accuracy and appropriateness.

All ZIP Code data purchased from the third-party vendor is subjected to quality control testing. Proprietary ZIP boundaries are compared to previous editions of data from a prior vendor Zip-Codes.com. The Florida Department of Revenue's Tax Data Parcel database is also used to ensure all parcels fall within their Zip Code boundary. ZIP centroids are subject to automated testing to verify that no points fall in a waterbody or outside a ZIP boundary.

D. If any hurricane model components are dependent on ZIP Code databases, a logical process shall be maintained for ensuring these components are consistent with the recent ZIP Code database updates.

During loss analyses, a location's geocode, rather than its ZIP Code, is utilized. However, in certain cases where a geocode is not able to be obtained at the street-address level, a ZIP Code centroid (population-weighted) is used as the geocode. Additionally, Florida vulnerability regions are defined at ZIP Code-level resolution.

The KCC ZIP Code centroid database used in the model is developed from the proprietary Claritas data set, and supplemented with Florida Department of Revenue's Tax Data Parcel database and data obtained from the Census. KCC has a documented procedure for accessing recent updates to USPS ZIP Codes and verifying that all valid Postal Codes from the **USPS Address Information System Products** exist in the KCC ZIP Code database. Each time the KCC ZIP Code databased is updated, SMEs verify that dependent components remain consistent with any changes to the ZIP Code database.

E. Geocoding methodology shall be justified.

KCC geocoding uses justified, industry-proven geocoding methods that are routinely quality-checked to ensure accuracy.

Disclosures

1. List the current ZIP Code databases used by the hurricane model and the hurricane model components to which they relate. Provide the effective (official United States Postal Service) dates corresponding to the ZIP Code databases.

KCC uses three ZIP Code databases: ZIP Code boundaries generated by Claritas, ZIP Code population-weighted centroids acquired from Claritas and data from Florida Department of Revenue's Tax Data Parcel database. Each of these products are compiled using the recent release of the United States Postal Service's ZIP Code data. The effective date of KCC's ZIP Code databases is October 2022.

2. Describe in detail how invalid ZIP Codes are handled.

If, during the process of adding an address to KCC's exposure database, a ZIP Code or geocode is found to be invalid, the address is rejected. Users have the option to correct the data and then re-enter it into the KCC exposure database, such as by directly setting the latitude and longitude or entering a valid ZIP Code (an invalid ZIP Code will not be modeled).

3. Describe the data, methods, and process used in the hurricane model to convert among street addresses, geocode locations (latitude-longitude), and ZIP Codes.

When a new address is imported into the exposure database, it is first checked to see if the address and geocode are already in the database. If not, the address goes through the USPS standardization process where it is sub-divided into its individual components which are then standardized one at a time (e.g., "Florida" standardizes to "FL," as would an error like "Florid," leading zeroes missing from a ZIP Code are added). If the address passes the standardization process, a geocode is requested from KCC's geocoder. The geocoder then converts the input address into a latitude-longitude pairing at the highest possible resolution (ideally street address, but, for example, if an exact match to the street number cannot be found, a centroid interpolated along the street segment containing that address may be returned). If the geocoder is not able to provide a geocode that is based on the full physical address, the address is assigned a population-weighted ZIP Code centroid geocode.

4. List and provide a brief description of each hurricane model ZIP Code-based database (e.g., ZIP Code centroids).

KCC uses three ZIP Code-based databases:

ZIP Code Boundaries

KCC obtains ZIP Code boundary data from Claritas, which uses the United States Postal Service's ZIP Code database to construct polygons for postal ZIP Codes based on carrier route boundaries. These boundaries are used for the creation of thematic maps for aggregation of factors like insured value and loss in the KCC US Hurricane Reference Model. This feature affords users the ability to perform visual inspection at a variety of scales, including the ZIP Code-level.

ZIP Code Centroids

ZIP Code centroids are derived from Claritas database and data acquired from Florida Department of Revenue's Tax Data Parcel. The centroids are population-based (weighted), rather than geometric, and a documented automated verification process is employed to ensure points are within the polygon boundaries, are not over water, and represent the population centroid. A visual inspection is performed by KCC to confirm the centroids are satisfactory prior to inclusion in the model. The geocoded centroids are used to estimate losses when address-level geocoding is not available.

Vulnerability Regions

Vulnerability regions are developed by KCC engineers using the process outlined in Standard V-1, Disclosure 8. ZIP Codes are classified into four vulnerability regions based on the location of their population centroids. When ZIP Code centroids are updated, the ZIP Codes assigned to each region are reviewed for consistency and visually inspected prior to implementation.

5. Describe the process for updating hurricane model ZIP Code-based databases.

KCC reviews annual updates to ZIP Code data from a third-party vendor Claritas. The procedure for reviewing and updating ZIP Code data is as follows:

1. Acquire updated ZIP code data from the provider on an annual basis.
2. Confirm the updated data schema is correct and supported by KCC.
3. Confirm that all valid Postal Codes from the most recent download from the **USPS Address Information System Products** are included.
4. Confirm the data values are valid. Any corrupt geometries or centroids identified are recorded.
5. After the data is validated, comparisons to previous vintage data and to other known datasets, including the Florida Dept of Revenue Tax Data Parcel database and the US Census Block population data, is performed in a GIS application to isolate differences.
6. Any provider centroids that fall over water or are significantly displaced from independently prepared population weighted centroids are identified and recommended changes to provider centroids are proposed.
7. Approved changes are deployed for use in the exposure databases.
8. The updated population-weighted ZIP Code centroids are then assigned to one of the KCC vulnerability regions using a GIS application.
9. ZIP Codes assigned to each region are reviewed for consistency and visually inspected prior to implementation, as described in Standard G-3, Disclosure 4.

G-4 Independence of Hurricane Model Components

The meteorology, vulnerability, and actuarial components of the hurricane model shall each be theoretically sound without compensation for potential bias from other components.

As a part of the model development process, each component is independently validated to ensure that no components are biased. These validations are completed using external data with as many different perspectives as feasible to ensure the consistency and validity of validation results. If a component does not pass a validation test, the component is re-evaluated by KCC scientists, engineers, and/or actuaries to ensure the correctness and accuracy of the component.

Additionally, components are analyzed during the model development process to ensure that a logical relationship to risk is held throughout the entire model. These analyses include visual inspection of event footprints against location-level loss costs to verify that higher wind speed areas exhibit higher losses and examining losses by building type or secondary modifier to ensure the appropriate building types consistently sustain losses appropriate to their expected vulnerability.

Using these and other methods, the KCC US Hurricane Reference Model is theoretically sound and has no compensation for potential bias within any component of the model.

G-5 Editorial Compliance

The submission and any revisions provided to the Commission throughout the review process shall be reviewed and edited by a person or persons with experience in reviewing technical documents who shall certify on Form G-7, Editorial Review Expert Certification, that the submission has been personally reviewed and is editorially correct.

Glen Daraskevich, KCC Senior Vice President and signatory of Form G-7, has personally reviewed the KCC submission document for editorial correctness. Mr. Daraskevich has reviewed the KCC submission for the 2017 and 2019 Hurricane and 2017 Flood FCHLPM Reports of Activity.

Disclosures

1. Describe the process used for document control of the submission. Describe the process used to ensure that the paper and electronic versions of specific files are identical in content.

In order to develop the submission document, each standard was first generated in separate Microsoft Word documents and later aggregated into a master document. The generation of each standard's documentation was initiated by the standards expert, reviewed by the editorial personnel, and finalized by the standards expert. If extensive content edits occurred by either editorial personnel or standards expert, this process was repeated.

During the process of submission development, Track Changes was used extensively to monitor changes to content. Periodically, a new document version was saved, and changes were accepted, declined, or made. This allowed changes at each stage of submission development to be monitored. The documents were saved into a centralized document repository, which allowed multiple individuals to contribute to the documents.

After being finalized, each standard was compiled into the central document. The forms were additionally imported into the central document, and final edits were made, which included formatting and hyperlinking sections. At this time, no content changes were made unless expressly directed by the standards expert.

Once the document was printed and finalized, no further edits were permitted to be made to the electronic version of the submission.

2. Describe the process used by the signatories on Expert Certification Forms G-1 through G-6 to ensure that the information contained under each set of hurricane standards is accurate and complete.

Throughout the process of generating the submission document, SMEs monitored content for completeness and accuracy. Standard experts also reviewed their respective sections prior to the document being compiled and exported as a PDF. Once the document was ready for submission, experts again reviewed their respective standards to ensure the completeness and accuracy of the finalized document.

3. Provide a completed Form G-7, Editorial Review Expert Certification. Provide a link to the location of the form.

Form G-7: Editorial Review Expert Certification

Meteorological Hurricane Standards

M-1 Base Hurricane Storm Set

The Base Hurricane Storm Set is the National Hurricane Center HURDAT2 as of June 10, 2021 (or later), incorporating the period 1900-2020. A model may be constructed in any scientifically sound and defensible fashion. However, annual frequencies used in hurricane model validation shall be based upon the Base Hurricane Storm Set, allowing for modifications if justified. Complete additional season increments and updates to individual historical storms that are approved by the National Hurricane Center are acceptable modifications, as are weighting and partitioning of the Base Hurricane Storm Set, if it is justified in current scientific and technical literature.

Historical data used to develop and validate the KCC US Hurricane Reference Model are from the National Hurricane Center (NHC) Hurricane Database version 2 (HURDAT2) including the years 1900 to 2021 as updated by the Tropical Prediction Center/National Hurricane Center on April 19, 2022.

Disclosures

1. ***Specify the Base Hurricane Storm Set release date and the time period used to develop and implement landfall and by-passing hurricane frequencies into the hurricane model.***

   The Base Hurricane Storm Set is the HURDAT2 (Landsea & Franklin, 2013) released on April 19, 2022. The years 1900 to 2021 (inclusive) from this dataset were used to determine historical landfall and by-passing hurricane frequencies in the hurricane model.

2. ***If the modeling organization has made any modifications to the Base Hurricane Storm Set related to hurricane landfall frequency and characteristics, provide justification for such modifications. Such modifications should be incorporated consistently into Form M-1, Annual Occurrence Rates; Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year; and Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses.***

   The Base Hurricane Storm Set was not modified except for the addition of landfall location and storm intensity for hurricanes that have yet to be reanalyzed as part of the Atlantic Hurricane Database Re-analysis Project. This applies, with a few exceptions, to the years from 1971 to 1982 for which HURDAT2 does not include landfall location or maximum wind speed at the time of landfall. Landfall locations and maximum wind speed at the time of landfall are added for the storms not yet reanalyzed using data from Blake et al. (2011), Ho et al. (1987), and Schwerdt et al. (1979). The six-hourly HURDAT2 track data remain unaltered.

3. ***If the hurricane model incorporates short-term, long-term, or other systematic modification of the historical data leading to differences between modeled climatology and that in the Base Hurricane Storm Set, describe how this is incorporated and provide comparisons to the unmodified Base Hurricane Storm Set, including occurrence and intensity.***

   The KCC US Hurricane Reference Model intensity distributions (represented by Vmax) are developed using landfall event wind speed data that has been adjusted for the effects of climate change. It is now the generally accepted scientific consensus that climate change is impacting hurricane intensity. Studies have shown that increases in tropical sea surface temperatures as a result of the warming global climate lead to the potential for more intense tropical cyclones (e.g., Knutson et al., 2020; Seneveratne et al., 2021). Hurricanes that made landfall in Florida in decades past would have had the potential to reach a higher intensity on average if they had all occurred today. To account for this effect, KCC scientists developed a set of landfall event wind speeds in which historical landfalling wind speeds are consistent with the present, warmer climate. The impact on individual historical events is greatest for the oldest events, which occurred in the relatively coolest climate, and decreases toward zero as the year of occurrence approaches the present day. The magnitude of the impact decreases especially rapidly after the 1970s when the rate of climate change quickened.

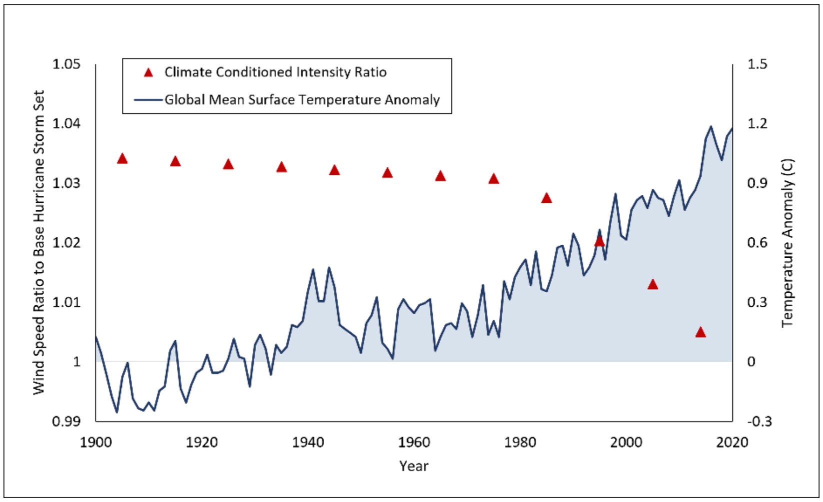


Figure 10 – The ratio of climate conditioned landfall intensities to the Base Hurricane Storm Set intensities by decade (red triangles) and global mean surface temperature anomalies (dark blue line)

4. Provide a completed Form M-1, Annual Occurrence Rates. Provide a link to the location of the form.

Form M-1: Annual Occurrence Rates

5. If the modeling organization has accounted for climate change in either the historical record or hurricane model development, justify its use in modeling Florida hurricane rates from the peer-reviewed scientific literature. Describe the analysis and its impacts on Florida hurricane rates.

The current scientific consensus on the connection between climate change and hurricanes, as communicated by the Intergovernmental Panel on Climate Change (IPCC) (Seneveratne et al., 2021), Knutson et al. (2020), and Knutson et al. (2021), expresses high confidence that warming global temperatures have caused an increase in hurricane intensity. The high scientific confidence is supported by recent observation-based studies that detected an increasing signal in global tropical cyclone intensity over the past four decades (Kossin et al., 2013; Kossin et al., 2020). Attribution of this trend to climate change is supported qualitatively by global climate model studies, all of which agree that climate warming leads to greater tropical cyclone intensity, including in the North Atlantic basin (Knutson et al., 2021).

The magnitude of the trend in intensity with past climate change was calculated based on an analysis by KCC scientists of global tropical cyclone intensities from the Global Hurricane Severity (HURSAT) dataset (Knapp and Kossin, 2007; Knapp et al., 2011). The HURSAT dataset covers the time period 1979 to 2017 and consists of intensity data that has been estimated from geostationary satellite data using the Advanced Dvorak Technique (Olander and Velden, 2007; 2019) for all tropical basins and all years. Using the global data allows for isolation of the climate change signal, which impacts tropical cyclone intensity in all basins, from natural climate variability that can impact individual basins and is usually cyclical.

Trends in the quantiles of hurricane lifetime maximum intensity are calculated from the full HURSAT dataset and applied to historical US landfalling hurricane intensity data to generate a hypothetical set of hurricane events with landfall wind speeds consistent with the present climate. The amount of the trend applied to the historical intensity data depends on the hurricane wind speed and the proportion of climate change that has occurred since the landfall year, using sea surface temperature trends as a proxy for climate change. This analysis results in a shift in hurricane intensities toward higher Saffir-Simpson categories, consistent with previous studies (e.g. Elsner et al., 2008; Kossin et al., 2020).

The shift in hurricane intensities due to climate change is implemented in the KCC US Hurricane Reference Model by fitting the maximum wind speed distributions for the Florida regions using the climate change adjusted landfall intensity data. This results in a higher average wind speed for hurricanes impacting Florida and consequently higher rates compared to a model hurricane set that does not account for climate change.

M-2 Hurricane Parameters and Characteristics

Methods for depicting all modeled hurricane parameters and characteristics, including but not limited to windspeed, radial distributions of wind and pressure, minimum central pressure, radius of maximum winds, landfall frequency, tracks, spatial and time variant windfields, and conversion factors, shall be based on information documented in current scientific and technical literature.

All methods for depicting modeled hurricane parameters in the KCC US Hurricane Reference Model, including the model event set and event footprints, are based on current scientific and technical literature.

Disclosures

1. Identify the hurricane parameters (e.g., central pressure, radius of maximum winds) that are used in the hurricane model.

The hurricane parameters used in the KCC US Hurricane Reference Model are:

- Maximum sustained wind speed
- Radius of maximum winds
- Track location and direction
- Forward speed
- Over-land decay rates
- Wind profile parameters

2. Describe the dependencies among variables in the windfield component and how they are represented in the hurricane model, including the mathematical dependence of modeled windfield as a function of distance and direction from the center position.

The wind speed (V) at any location within the hurricane windfield is a function of distance from the center of the storm (r), R_{max}, and the maximum wind speed. In a stationary hurricane, the structure is roughly symmetric about the center with a maximum wind speed located at a distance equal to the radius of maximum winds.

The KCC US Hurricane Reference Model utilizes the model first defined in Willoughby et al. (2006) for this radial wind profile. The main advantage of the Willoughby profile over other commonly used wind profiles is its flexible treatment of the decrease in wind speeds with distance from R_{max} as well as its handling of the transition from inner to outer winds in the vicinity of the eye wall. Winds inside the eye are estimated using a power function of the distance from the center of the storm and outside the eye as an exponential decay that depends on storm-specific distances. In the region near the eye-wall (identified as the "transition region"), winds are calculated as weighted sums of wind profiles inside and outside the eye.

Willoughby provides formulations for two types of wind profiles, namely the single- and dual-exponential profile. In the KCC US Hurricane Reference Model, the choice of profile formulation depends on the intensity of the storm.

Other windfield parameters, such as X1 (the exponential decay length in the outer vortex), n (the exponent for the power law inside the eye), and A (sets the proportion of the two exponentials in the profile) are calculated from the V_{max} and latitude of the storm. The formulations for X1, n, and A are specified in Willoughby et al. (2006), and X2 is a fixed parameter of 25 km as specified in Willoughby et al. (2006). The R_{max} is a function of the peak wind speed and the latitude of the cyclone center following the equation given by Willoughby et al. (2006) with coefficients estimated using historical data, hereafter referred to as the modified Willoughby equation. Asymmetry of the windfield is calculated by adding or deducting an asymmetry value that depends on the wind direction relative to the motion of the storm as described by Schwerdt et al. (1979).

3. Identify whether hurricane parameters are modeled as random variables, functions, or fixed values for the stochastic storm set. Provide rationale for the choice of parameter representations.

Maximum Wind Speed

The peak 1-minute sustained wind speed at landfall (V_{max}) for the simulated event is used to quantify the storm intensity. V_{max} is modeled as a random variable following the Generalized Pareto Distribution fit to historical data. This distribution is often used for calculating extreme wind occurrence (Brabson & Palutikof, 2000; Palutikof et al., 1999) and has been shown to best represent hurricane wind speed frequency by Jagger and Elsner (2006). A follow-up study also found good agreement between the theoretical distribution and the historical data for a large set of open-ocean hurricanes in the Atlantic basin (Emanuel & Jagger, 2010).

Radius of Maximum Winds

The radius of maximum winds (R_{max}) is calculated as a function of the V_{max} and the latitude of the storm center and follows the modified Willoughby equation (Willoughby et al., 2006). Uncertainty in the R_{max} is computed using the differences between the observed R_{max} and the R_{max} calculated with the modified Willoughby equation for landfalling hurricanes. These residuals are represented by a normal distribution that describes the natural variation around the calculated value. This distribution was selected based on meteorological expertise and the results of goodness-of-fit tests. Deviations from the calculated R_{max} defined by the fitted distributions are used to select R_{max} values for events in the stochastic storm set.

Track Direction

Track direction at landfall is dependent on the climatological direction of storm movement at each coastal location and the shape of the coastline. Model track directions are fixed values computed from the means and standard deviations of observed hurricane track directions at landfall within approximately 100-mile segments of the coastline. Additional smoothing and minor adjustments are applied to ensure nearly parallel tracks for adjacent coastal points. This methodology ties the model track direction closely to climatology and retains changes in track direction due to the coastline shape. Changes in direction after landfall are computed as a function of latitude that describes the eastward turn of Atlantic hurricanes as they move northward into the path of extratropical waves.

Forward Speed

Forward speed at landfall is modeled as a random variable determined by the climatological movement of hurricanes that cross the state of Florida. The observed forward speeds are drawn from the Base Hurricane Storm Set, and the distribution of the observations is modeled as a Weibull distribution. This distribution was selected based on meteorological expertise and the results of goodness-of-fit tests.

4. Describe if and how any hurricane parameters are treated differently in the historical and stochastic storm sets and provide rationale.

All hurricane parameters used in the KCC stochastic set are developed from the historical database and are treated identically to the historical storm set.

5. State whether the hurricane model simulates surface winds directly or requires conversion between some other reference level or layer and the surface. Describe the source(s) of conversion factors and the rationale for their use. Describe the process for converting the modeled vortex winds to surface winds including the treatment of the inherent uncertainties in the conversion factor with respect to location of the site compared to the radius of maximum winds over time. Justify the variation in the surface winds conversion factor as a function of hurricane intensity and distance from the hurricane center.

The KCC US Hurricane Reference Model simulates surface wind speeds directly, so no conversion is performed in the model. The V_{max} input along with the wind speeds along the track represent the 1-minute sustained wind speed at 10-meter height, and the windfield output is also in 1-minute sustained wind speeds at 10-meter height.

6. Describe how the windspeeds generated in the windfield model are converted from sustained to gust and identify the averaging time.

No conversion is required because all model components utilize the 1-minute sustained wind speed as the intensity measure.

7. Describe the historical data used as the basis for the hurricane model hurricane tracks. Discuss the appropriateness of the hurricane model stochastic hurricane tracks with reference to the historical hurricane data.

KCC scientists used HURDAT2 data from 1900 to 2021 to determine tracks and storm parameters for each landfall point. Observed track direction at landfall is dependent on the climatological direction of storm movement at each coastal location and the shape of the coastline. Modeled storm track direction at landfall is fixed to the climatology and is computed using the mean and standard deviation of observed hurricane track directions at landfall within approximately 100-mile segments of the coastline. Track movement after landfall is based on the results of a linear regression of HURDAT2 storm directions and storm center locations. Thus, modeled tracks are consistent with historical data.

8. If the historical data are partitioned or modified, describe how the hurricane parameters are affected.

The historical data have not been modified but have been grouped into coastal regions for the purpose of parameter estimation.

9. Provide plots of distance along the coast of Florida and adjacent states (x-axis) versus modeled annual landfall occurrence rates (y-axis) in 2 intensity bands (Saffir-Simpson categories 1-2 and 3-5). Any set of coastal segments may be used for this purpose, as long as they are not greater than 100 miles in length. If the modeling organization has a currently accepted hurricane model, then provide the currently accepted hurricane model's rates on the same aces. Also provide on the same axes the modeled annual landfall occurrence rates computed directly from the modeling organization's Base Hurricane Storm Set.

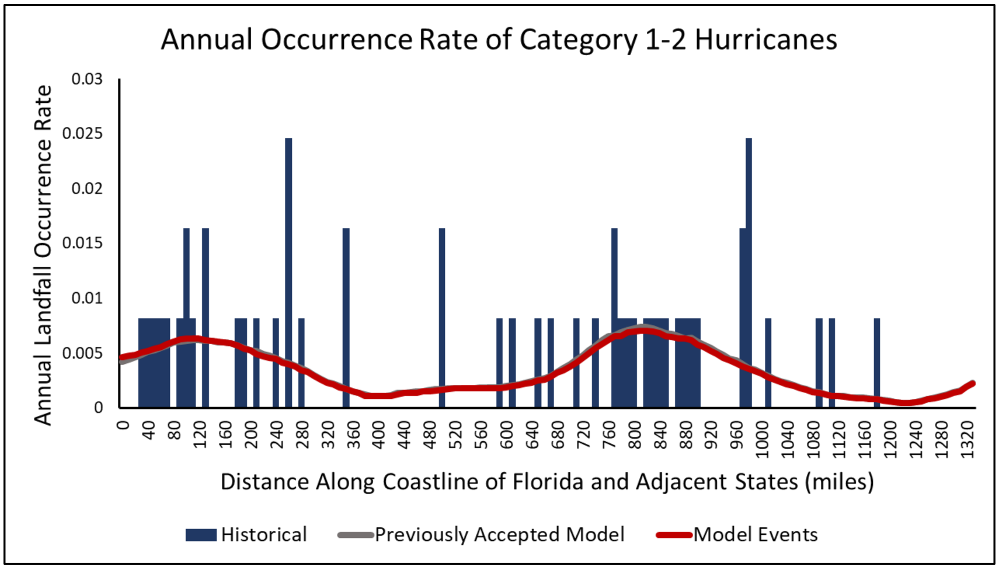


Figure 11 - Historical annual landfall occurrence rate (bars) and model annual landfall occurrence rate by landfall point (lines) for Category 1-2 hurricanes

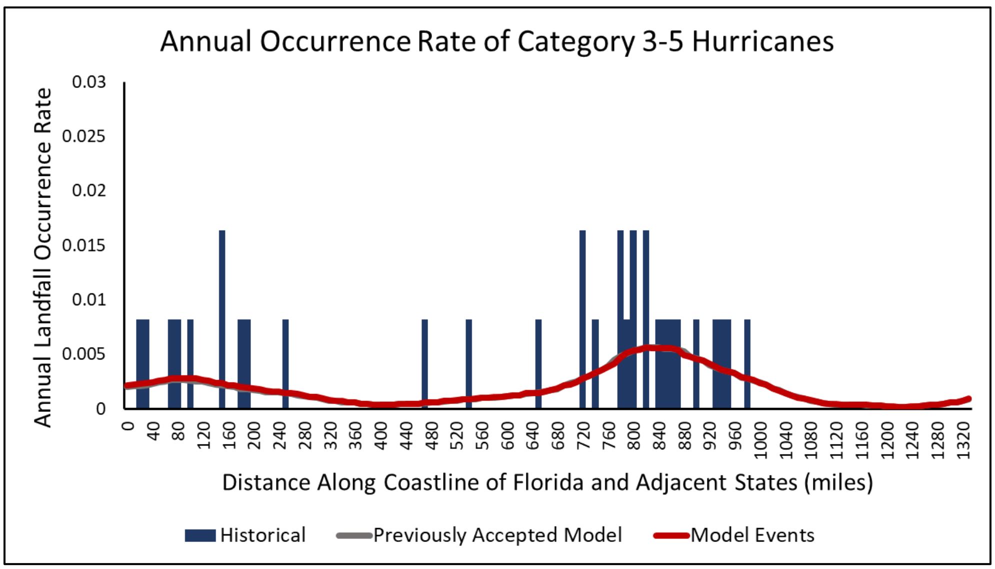


Figure 12 - Historical annual landfall occurrence rate (bars) and model annual landfall occurrence rate by landfall point (lines) for Category 3-5 hurricanes

10. Describe any evolution of the functional representation of hurricane parameters during an individual storm life cycle.

Throughout the evolution of a storm, V_{max} decays as a function of the time since landfall following an exponential equation (Kaplan & DeMaria, 1995). The coefficients in the exponential equation are specific to the region where the storm moves over land. Hurricanes that make a second landfall decay at a rate consistent with the region of the second landfall, which may be different from that of the first landfall. The functional form of the equation remains the same for all storms. Along each storm track, R_{max} changes based on V_{max} and latitude.

M-3 Hurricane Probability Distributions

A. Modeled probability distributions of hurricane parameters and characteristics shall be consistent with historical hurricanes in the Atlantic basin.

All probability distributions and other representations of hurricane parameters in the model were developed from the Base Hurricane Storm Set and are therefore consistent with historical hurricanes in the Atlantic basin.

B. Modeled hurricane landfall frequency distributions shall reflect the Base Hurricane Storm Set used for category 1 to 5 hurricanes and shall be consistent with those observed for each coastal segment of Florida and neighboring states (Alabama, Georgia, and Mississippi).

The distribution of landfall frequency is derived from the historical landfalling hurricanes. The frequency of hurricanes by landfall intensity is consistent with the historical data, as shown in Form M-1.

C. Hurricane models shall use maximum one-minute sustained 10-meter windspeed when defining hurricane landfall intensity. This applies both to the Base Hurricane Storm Set used to develop landfall frequency distributions as a function of coastal location and to the modeled winds in each hurricane which causes damage. The associated maximum one- minute sustained 10-meter windspeed shall be within the range of windspeeds (in statute miles per hour) categorized by the Saffir-Simpson Hurricane Wind Scale.

Saffir-Simpson Hurricane Wind Scale:

Category	***Winds (mph)***	***Damage***
1	*74 – 95*	*Minimal*
2	*96 – 110*	*Moderate*
3	*111 – 129*	*Extensive*
4	*130 – 156*	*Extreme*
5	*157 or higher*	*Catastrophic*

The KCC US Hurricane Reference Model uses 1-minute sustained 10-meter wind speeds to define hurricane intensity and to estimate damages for each hurricane in the stochastic event set. The Saffir-Simpson scale as shown above is used to construct the table in Form M-1.

Disclosures

1. Provide a complete list of the assumptions used in creating the hurricane characteristics databases.

No assumptions were used in creating the hurricane databases.

2. Provide a brief rationale for the probability distributions used for all hurricane parametersand characteristics.

The effectiveness of the Generalized Pareto Distribution for representing the distribution of hurricane intensities has been demonstrated in the literature for Florida and other regions (Emanuel and Jagger, 2010; Jagger and Elsner, 2006). This distribution along with the probability distributions for annual landfall frequency, event day of year, the radius of maximum winds, and the forward speed of hurricanes at landfall have been evaluated using goodness-of-fit tests and the historical data. The following table summarizes the functional forms and justification for hurricane parameters.

Stochastic Hurricane Parameter (Function or Variable)	Functional Form of Distribution	Data Source	Year Range Used		Justification for Functional Form
			For Fitting	For Validation	
Maximum sustained wind speed	Generalized Pareto Distribution (μ, σ, ξ) where, μ, σ, and ξ are the location, scale, and shape parameters, respectively $f(x) = \frac{1}{\sigma}\left(1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right)^{-\left(\frac{1}{\xi}+1\right)}$ $\mu \leq x \leq \mu - \sigma/\xi \ if \ \xi < 0$ $x \geq u \ otherwise$ $\mu, \xi, \in (-\infty, \infty)$ $\sigma \in (0, \infty)$	HURDAT2	1900-2021	1900-2021	The Generalized Pareto Distribution has been shown to accurately represent the distribution of extreme winds (e.g. Palutikof et al., 1999) and specifically for US hurricanes (Jagger and Elsner, 2006; Emanuel and Jagger, 2010). Goodness-of-fit tests support the use of this functional form.
Radius of maximum winds	Normal distribution (μ, σ^2) where μ is the mean, and σ is the standard deviation $R_{max} = f(V_{max}, latitude) + \varepsilon$ $g(x) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$ $\mu \in (-\infty, \infty)$ $\sigma^2 > 0$ $x \in (-\infty, \infty)$	Demuth et al. (2006); Ho et al. (1987)	1900-2021	1900-2021	The model uses the relationship between R_{max}, maximum sustained wind speed, and latitude developed by Willoughby et al. (2006) with coefficients estimated using the historical data. The expected R_{max} decreases with V_{max} and increases with latitude. The residual values, ε, normalized to the expected R_{max}, are modeled using a normal distribution supported by the results of goodness-of-fit tests.
Forward speed	Weibull distribution (α, β) where α and β are the scale and shape parameters, respectively $f(x) = \frac{\beta x^{\beta-1}}{\alpha^\beta}e^{-\left(\frac{x}{\alpha}\right)^\beta}$ $\alpha > 0$ $\beta > 0$ $x > 0$	HURDAT2	1900-2021	1900-2021	The Weibull distribution is suitable for representing the hurricane forward speed data that are both non-negative and positively skewed. The results of goodness-of-fit tests support the choice of the Weibull distribution for representing forward speed.

Stochastic Hurricane Parameter (Function or Variable)	Functional Form of Distribution	Data Source	Year Range Used		Justification for Functional Form
			For Fitting	For Validation	
Annual Landfall Frequency	Empirical Cumulative Distribution Function $p(x) = Pr\{X \leq x\}$ where X is the number of events per year, $x \in \{0, 1, \ldots, 9\}$	HURDAT2	1900-2021	1900-2021	The number of landfall events per year is best represented by an empirical distribution that can accurately reflect both the portion of historical years with no landfalls and the portion with multiple landfalls. Goodness-of-fit tests support the use of the empirical distribution for this model parameter.
Event day of year	Empirical Cumulative Distribution Function $p(x) = Pr\{X \leq x\}$ where X is the number of events that occur on a Julian day, $x \in \{1, \ldots, 365\}$	HURDAT2	1900-2021	1900-2021	The day of the year for an event occurrence is represented by an empirical distribution function, developed based on smoothing of historical event occurrence dates. Goodness-of-fit tests support the use of the empirical distribution for this model parameter.

Table 3 - Data sources and justification of the functional forms for parameters employed in the KCC US Hurricane Reference Model

3. ***Describe and justify any changes made to the modeled Base Hurricane Storm Set in the currently accepted hurricane model that are not reflected in changes to the distributions in Form S-3, Distributions of Stochastic Hurricane Parameters. Describe the methodology used to make such changes.***

There are no changes in the Base Hurricane Storm Set used in the currently accepted model that are not reflected in Form S-3, Distributions of Stochastic Hurricane Parameters.

M-4 Hurricane Windfield Structure

A. Windfields generated by the hurricane model shall be consistent with observed historical storms affecting Florida.

Windfields generated by the KCC US Hurricane Reference Model are consistent with observed historical storms affecting Florida. Comparisons of modeled footprints with wind speed observations confirm good agreement between modeled and observed wind speeds.

B. The land use and land cover (LULC) database shall be consistent with National Land Cover Database (NLCD) 2016 or later. Use of alternate datasets shall be justified.

The KCC US Hurricane Reference Model is based on the NLCD 2019 dataset.

C. The translation of land use and land cover or other source information into a surface roughness distribution shall be consistent with current state-of-the-science and shall be implemented with appropriate geographic-information-system data.

KCC scientists utilized methodologies consistent with current scientific standards. The translation from LULC to roughness lengths and resampling of roughness lengths is performed in accordance with published literature (Simiu, 2011; Simiu & Scanlan, 1996; Wieringa et al., 2001; Taylor, 1987) and has been implemented with GIS data.

D. With respect to multi-story buildings, the hurricane model shall account for the effects of the vertical variation of winds.

The effect of building height is accounted for in the vulnerability functions.

Disclosures

1. Provide a tangential windspeed (y-axis) versus radius (x-axis) plot of the average or default symmetric wind profile used in the hurricane model and justify the choice of this wind profile. If the windfield represents a modification from the currently accepted hurricane model, plot the previous and modified profiles on the same figure using consistent axes. Describe variations between the previous and modified profiles with references to historical storms.

The wind speed radial profile is developed based on the radial variation of winds as described in Willoughby et al. (2006). This wind profile was developed using hundreds of flight-level observations. Reasonable validation against observational data justifies the use of this wind profile.

Figure 13 shows the default wind speed profile versus distance from the eye (expressed as a ratio of the radius of maximum wind speeds), for a maximum wind speed of 110 mph and latitude of 28°. For those input parameters, the model produces the R_{max} and the exponential decay length in the outer vortex (X1) of 126 miles, and exponent for the power law inside the eye (n) of 0.94.

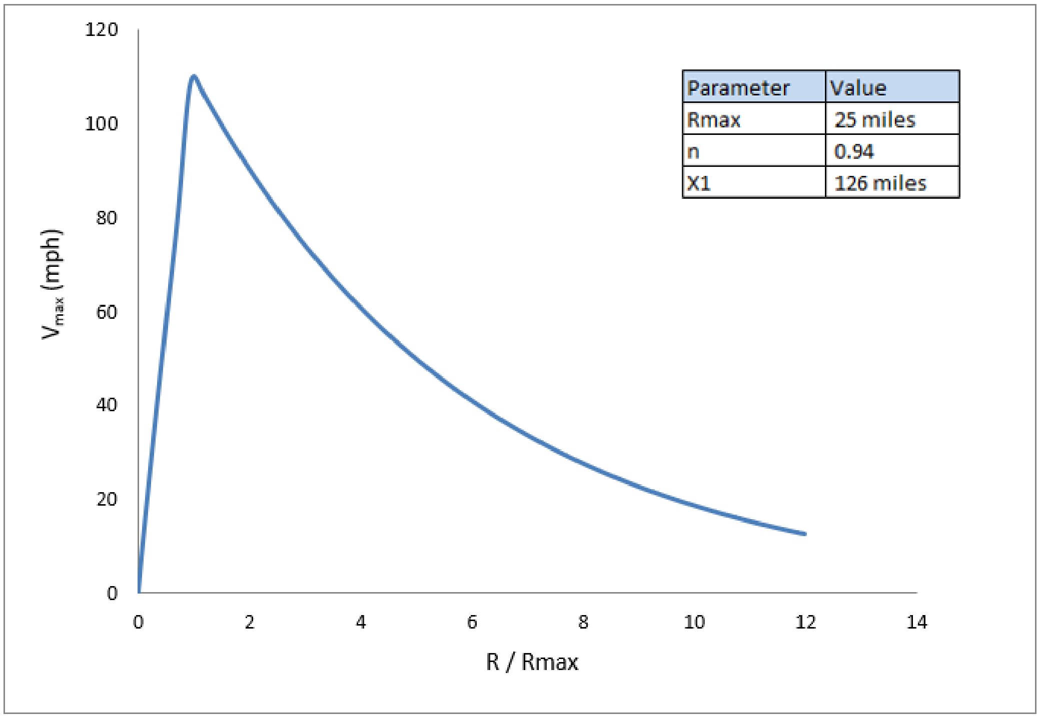


Figure 13 - Rotational wind speed plot of a symmetric wind profile for a Florida hurricane

2. Describe how the vertical variation of winds is accounted for in the hurricane model where applicable. Document and justify any difference in the methodology for treating historical and stochastic storm sets.

The vertical variation of winds is accounted for when estimating the effect of surface terrain and roughness on the windfield. The mean wind speed logarithmic-law profile, which depends on surface terrain, is employed in estimating the mean wind for a given roughness length. The windfield for each hurricane represents winds at 10-meter height only, and the vertical variation of wind on hurricane induced losses is captured by the vulnerability functions. No difference exists in treating the historical versus stochastic storms.

3. Describe the relevance of the formulation of gust factor(s) used in the hurricane model.

In the process of computing surface roughness factors, which requires the estimation of mean wind speeds (assumed as a 1-hour averaged wind speed), published engineering relationships were employed (Simiu, 2011; Simiu & Scanlan, 1996; Powell & Houston, 1996a) to convert 1-minute sustained wind speed to mean wind speed and back. Conversion factors vary depending on surface roughness. For example, higher gust factors are used in rougher terrains.

4. Identify all non-meteorological variables (e.g., surface roughness, topography) that affect windspeed estimation.

Surface roughness and fetch distance affect wind speed estimation. Topography effects are not considered in Florida.

5. Provide the collection and publication dates of the land use and land cover data used in the hurricane model and justify their timeliness for Florida.

The KCC US Hurricane Reference Model uses the National Land Cover Database (NLCD, 2019) as the primary source of land use/land cover (LULC) data. This NLCD database contains a 16-class land cover classification scheme at a 30-meter resolution and is developed by the USGS using Landsat satellite imagery. The NLCD provides LULC data for the entire US and, as such, does not need to be supplemented with additional data sources.

6. Describe the methodology used to convert land use and land cover information into a spatial distribution of roughness coefficients in Florida and neighboring states.

The 2019 Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database (NLCD) 2019 Land Use/Land Cover (LULC) data is used to estimate the roughness of the terrain at a given site, which in turn is used to estimate the surface roughness factors (SRFs).

The NLCD LULC data is provided for 30-meter square pixels, to which appropriate roughness lengths are assigned. When assigning roughness length values to the NLCD 2019 LULC codes, mapping schemes from the scientific literature (e.g., Simiu & Scanlan, 1996; Wieringa et al. 2001) were used. The 30-meter roughness lengths were then resampled to a 1-kilometer grid. In the resampling process, surface roughness averaging was performed using the method suggested in Taylor (1987).

The resampled roughness lengths are then used to calculate direction-dependent SRFs on a 1-kilometer grid using an effective fetch of 12 km. A surface friction model based on engineering and scientific methodologies was used (Cook, 1997; Simiu, 2011; Simiu & Scanlan, 1996; Powell & Houston, 1996a) to calculate the SRFs. Eight sets of SRFs, corresponding to eight wind directions, are developed for each 1-kilometer grid. For each hurricane event at each 5-minute time step, the selection of SRF for a grid depends on the direction of wind, which is estimated from the hurricane wind inflow angle.

7. Demonstrate the consistency of the spatial distribution of model-generated winds with observed windfields for hurricanes affecting Florida. Describe and justify the appropriateness of the databases used in the windfield validations.

The KCC US Hurricane Reference Model wind footprints have been validated against observed wind speeds tabulated by the NHC. Following an event, the NHC gathers wind observations from multiple sources including the National Weather Service Forecast Offices, the Weather Prediction Center, National Data Buoy Center, the USGS, and the Storm Prediction Center. These observations have varying levels of reliability and accuracy. For the validation process, KCC scientists used only the official observations with information on anemometer height and averaging time. The observations were standardized to 1-minute winds at 10-meter height when necessary. Open terrain exposure (i.e., z_0 = 0.03 m) was assumed in standardizing the wind speed observations. The following figures show wind speed observations versus the KCC US Hurricane Reference Model footprint for four recent hurricanes.

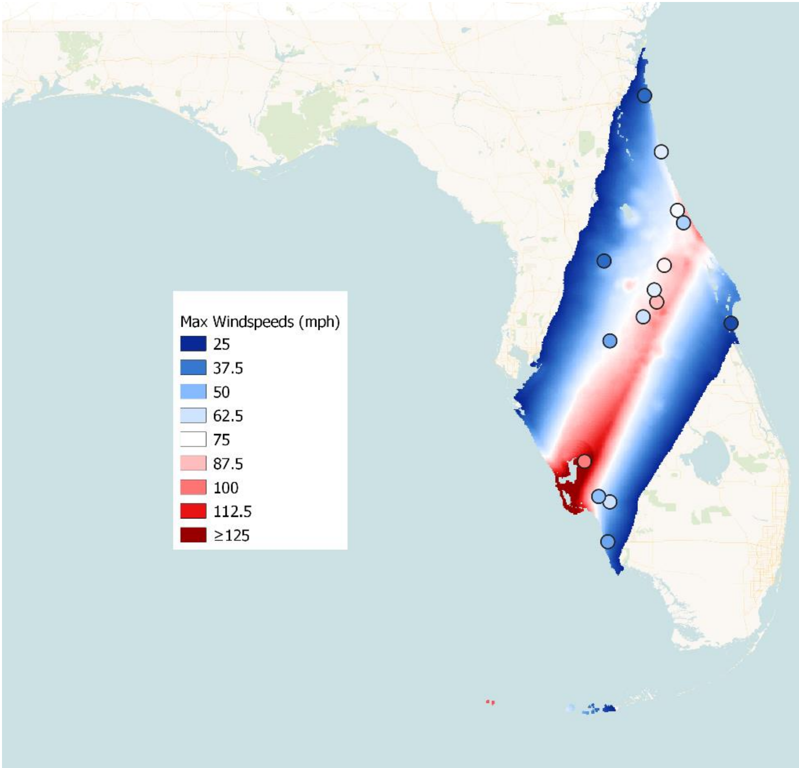


Figure 14 - Observed (circles) versus modeled wind speeds for Hurricane Charley

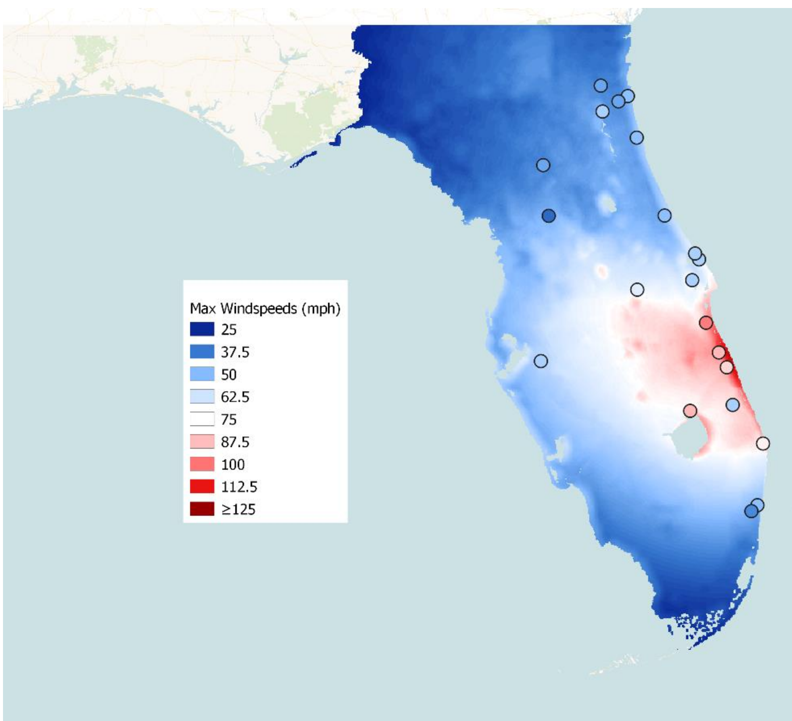


Figure 15 - Observed (circles) versus modeled wind speeds for Hurricane Jeanne

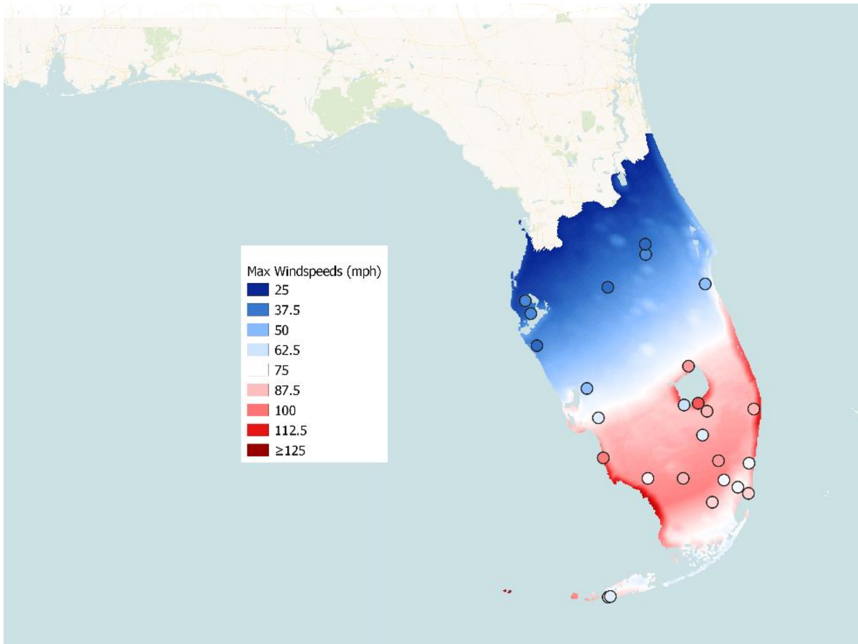


Figure 16 - Observed (circles) versus modeled wind speeds for Hurricane Wilma

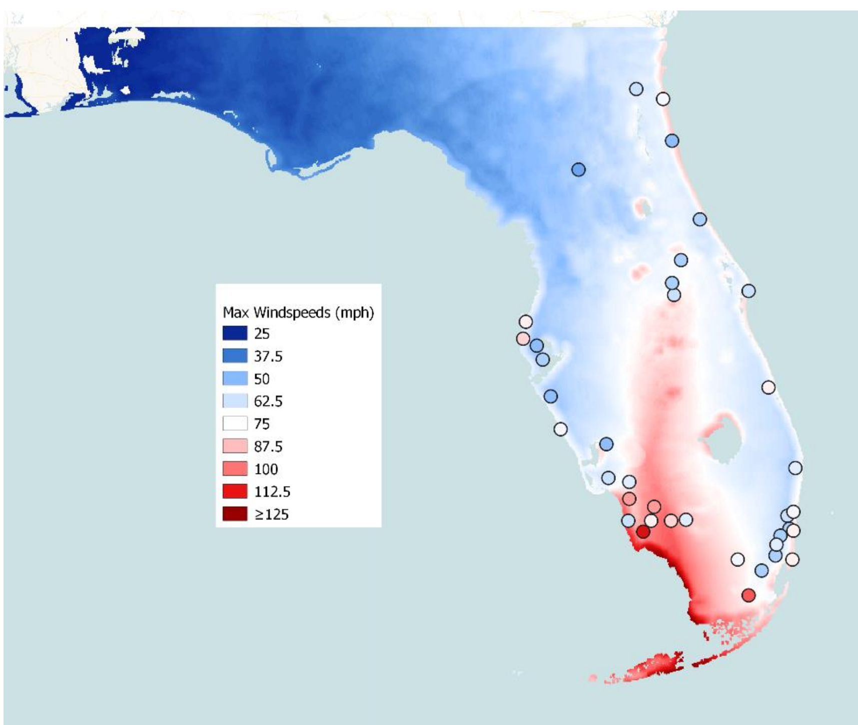


Figure 17 - Observed (circles) versus modeled wind speeds for Hurricane Irma

8. Describe how the hurricane model windfield is consistent with the inherent differences in windfields for such diverse hurricanes as Hurricane Charley (2004), Hurricane Wilma(2005), Hurricane Irma (2017), and Hurricane Michael (2018).

Historically, Florida has experienced hurricanes that have diverse characteristics, including filling rate, forward speed, asymmetry, and radial profiles. The KCC US Hurricane Reference Model captures these differences by using parameters appropriate for each storm. For example, Hurricane Charley was a very tightly wound intense storm for which peak winds decreased rapidly after landfall, but hurricane force winds extended across the state. Wilma also caused more damage on the east coast of Florida even though landfall was on the west coast. Hurricane Irma was characterized by an expansive windfield that caused tropical storm force winds across the entire Florida Peninsula. In contrast, Hurricane Michael was, like Charley, another tightly wound storm with a small radius of maximum wind speed. For the historical storm set, events are modeled using the parameters that represent the characteristics of each storm. Validation tests show good agreement between the modeled and observed wind speeds.

9. Describe any variations in the treatment of the hurricane model windfield for stochastic versus historical storms and justify this variation.

There is no variation between the treatment of stochastic versus historical storms.

10. Provide a completed Form M-2, Maps of Maximum Winds. Provide a link to the location of the form.

Form M-2: Maps of Maximum Winds

M-5 Hurricane Landfall and Over-Land Weakening Methodologies

A. The hurricane over-land weakening rate methodology used by the hurricane model shall be consistent with historical records and with current state-of-the-science.

Historical data from the HURDAT2 database is used along with published scientific studies to develop the over-land weakening rate methodology.

B. The transition of winds from over-water to over-land within the hurricane model shall be consistent with current state-of-the-science.

The treatment of hurricane winds as the storm moves over land is based on a combination of current scientific research, studies, and data that describe the roughness of the surface underlying the winds.

Disclosures

1. Describe and justify the functional form of hurricane decay rates used by the hurricane model.

KCC scientists employ a functional form based on the work of Kaplan and DeMaria (1995) to model the post-landfall decay of the maximum wind speeds that results from a hurricane losing its oceanic source of heat and moisture. Kaplan and DeMaria (1995) show that the decay of storms over land can be modeled with an exponential function with a decay factor fit to data from historical storms with a range of intensities.

This exponential function also captures the observed differences in the decay rates for different regions in Florida. These differences are accounted for in the KCC US Hurricane Reference Model by fitting the exponential function parameters separately for storms in each region.

2. Provide a graphical representation of the modeled decay rates for Florida hurricanes over time compared to wind or central pressure observations.

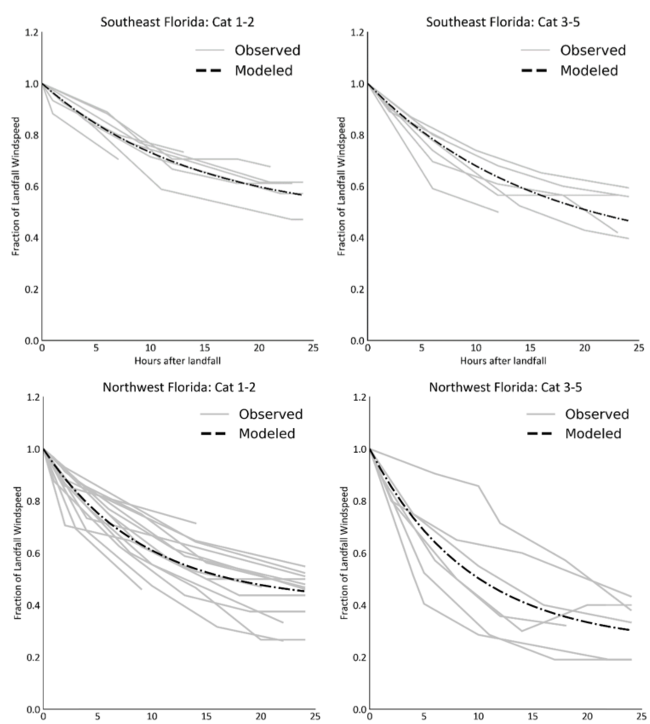


Figure 18 - Time series of the model decay of hurricane maximum wind speed over land compared to the observed decay from historical storms in Southeast and Northwest Florida.

Historical hurricanes that re-emerge over the ocean within 6 hours of their initial landfall are not included in the graphs.

3. Describe the transition from over-water to over-land boundary layer simulated in the hurricane model.

In the KCC US Hurricane Reference Model, the transition from over-water (a smooth surface) to over-land (a comparatively rougher terrain) is captured using surface roughness factors. The surface roughness factors account for fetch, and generally the reduction in wind speed increases as the storm travels further inland.

4. Describe any changes in hurricane parameters, other than intensity, resulting from the transition from over-water to over-land.

Only the storm's maximum wind speed (V_{max}) changes as a result of the transition from over-water to over-land. The R_{max} is a function of the maximum wind speed, so this generally increases as a storm decays over land.

5. Describe the representation in the hurricane model of passage over non-continental U.S. land masses on hurricanes affecting Florida.

Storm intensity in the hurricane model is defined at the point of landfall on the mainland US, which is determined from the historical data. Hurricanes impacting Florida can weaken (Dennis) or strengthen (Charley) just before landfall, so in the KCC US Hurricane Reference Model, the pre-landfall intensities are assumed to be the same as at landfall. Therefore, any pre-landfall impacts from land masses are not relevant to the hurricane model.

6. Describe any differences in the treatment of decay rates in the hurricane model for stochastic hurricanes compared to historical hurricanes affecting Florida.

There is no difference between the treatment of decay rates for the stochastic and historical hurricanes in Florida.

M-6 Logical Relationships of Hurricane Characteristics

A. The magnitude of asymmetry shall increase as the translation speed increases, all other factors held constant.

As the translation speed increases for tropical cyclones in the KCC US Hurricane Reference Model the magnitude of the asymmetry in the windfield also increases, all other factors held constant. The asymmetry in the windfield is calculated from the forward speed of the cyclone, and the angle between the direction of cyclone movement and the wind direction at a location, using a method that is consistent with the scientific literature.

B. The mean windspeed shall decrease with increasing surface roughness (friction), all other factors held constant.

The mean wind speed of tropical cyclones in the KCC US Hurricane Reference Model depends on the roughness of the underlying surface and decreases with increasing surface roughness, all else held constant. A surface friction model that is based on current scientific and engineering methodologies is used in combination with the LULC data to compute the friction on the hurricane winds.

Disclosures

1. Describe how the asymmetric structure of hurricanes is represented in the hurricane model.

Stationary tropical cyclones can typically be approximated to have symmetrical wind speed profiles along all their radials, but a moving hurricane has an asymmetric wind field. The translational, or forward speed, and direction of tropical cyclones are governed by several factors, including global wind patterns and the location and strength of large-scale high and low-pressure systems. Generally, in the Northern hemisphere, the movement of a tropical cyclone increases the winds on the right side of the track and decreases the winds on the left.

In the KCC US Hurricane Reference Model, the asymmetry in tropical cyclones is evaluated by an asymmetry value, A, which is either added or deducted from the symmetrical windfield depending on the wind direction relative to the motion of the hurricane. This formulation is consistent with the description of hurricane asymmetry from Schwerdt et al. (1979). The asymmetry value is a function of the forward speed and the cosine of the angle between the track direction and the local wind direction. The local wind direction is computed from the inflow angle, which is estimated using the formulation provided in Zhang and Uhlhorn (2012).

2. Discuss the impact of surface roughness on mean windspeeds.

Surface roughness impacts the shape of the vertical mean wind speed profile. In addition, the 10-meter height mean wind speed decreases with increasing surface roughness. In the KCC Reference Hurricane Model, this impact is captured by assigning different roughness lengths to areas with different surface roughness.

3. Provide a completed Form M-3, Radius of Maximum Winds and Radii of Standard Wind Thresholds. Provide a link to the location of the form.

Form M-3: Radius of Maximum Winds and Radii of Standard Wind Thresholds

4. Discuss the radii values for each wind threshold in Form M-3, Radius of Maximum Winds and Radii of Standard Wind Thresholds, with reference to available hurricane observations such as those in HURDAT2. Justify the appropriateness of the databases used in the radii validations.

KCC scientists performed a comparison of modeled wind radii of tropical storm and hurricane force winds to historical reports included in HURDAT2. The analyses showed good agreement of the outer wind radii. The figure below shows comparison of the modeled hurricane force wind radii quantiles (found in Form

M-3) to those derived from the HURDAT2 database. Only hurricanes that impacted Florida were used in this comparison.

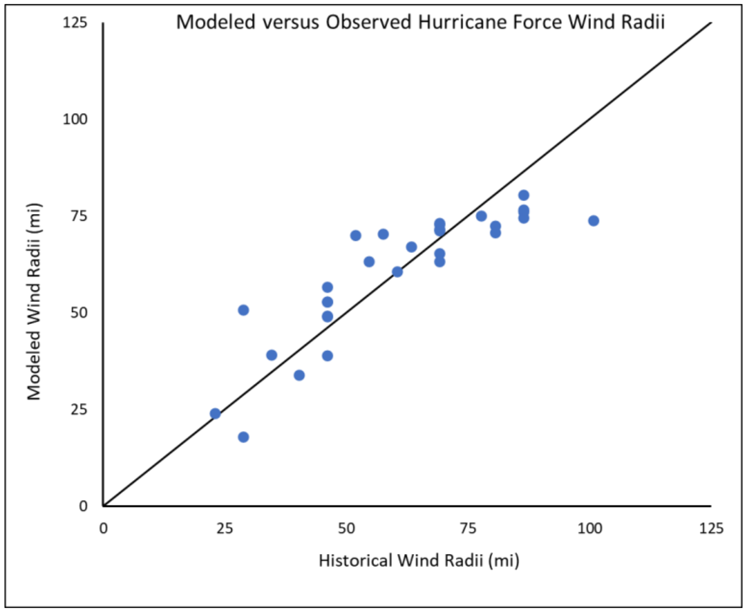


Figure 19 - Modeled versus observed wind radii (miles) for historical hurricane force winds

Statistical Hurricane Standards

S-1 Modeled Results and Goodness-of-Fit

A. The use of historical data in developing the hurricane model shall be supported by rigorous methods published in current scientific and technical literature.

KCC scientists utilized various theoretical distributions and functional forms fit to the historical data to represent the modeled variables. The methods for depicting all modeled hurricane parameters and characteristics are documented under Standards M-2 and M-3 and are supported by current scientific and technical literature.

B. Modeled and historical results shall reflect statistical agreement using current scientific and statistical methods for the academic disciplines appropriate for the various hurricane model components or characteristics

All distributions employed in the KCC US Hurricane Reference Model have been validated against historical observations to ensure statistical agreement. Additionally, the output of each model component has been tested statistically against historical data to ensure good agreement between model output and historical losses.

Disclosures

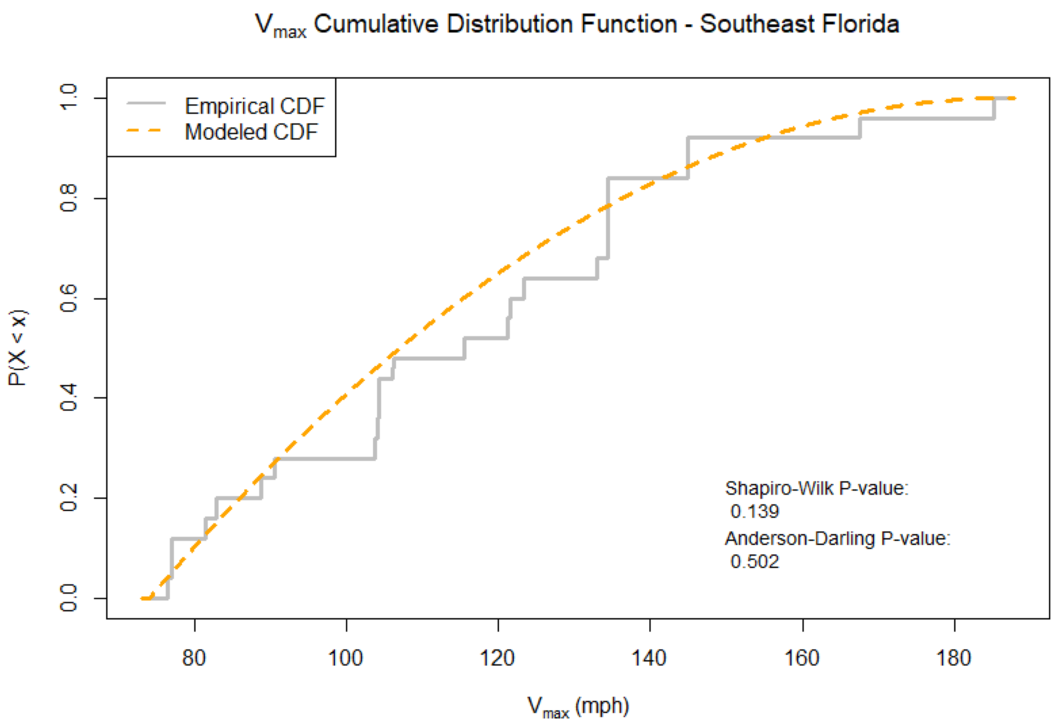
1. Provide a completed Form S-3, Distributions of Stochastic Hurricane Parameters. Identify the form of the probability distributions used for each function or variable, if applicable. Identify statistical techniques used for estimation and the specific goodness-of-fit tests applied along with the corresponding p-values. Describe whether the fitted distributions provide a reasonable agreement with the historical data. Provide a link to the location of the form.

Form S-3: Distributions of Stochastic Hurricane Parameters

Maximum Wind Speed (V_{max})

The peak 1-minute sustained wind speed at landfall (V_{max}) for the simulated event is used as the storm intensity measure. V_{max} is modeled as a random variable following the Generalized Pareto Distribution. The parameters were estimated using Maximum Likelihood Estimation.

Historical and modeled distributions are compared graphically below for two Florida regions. The Shapiro-Wilk and Anderson-Darling goodness-of-fit test p-values indicate there is no evidence for lack of fit at level 0.05.



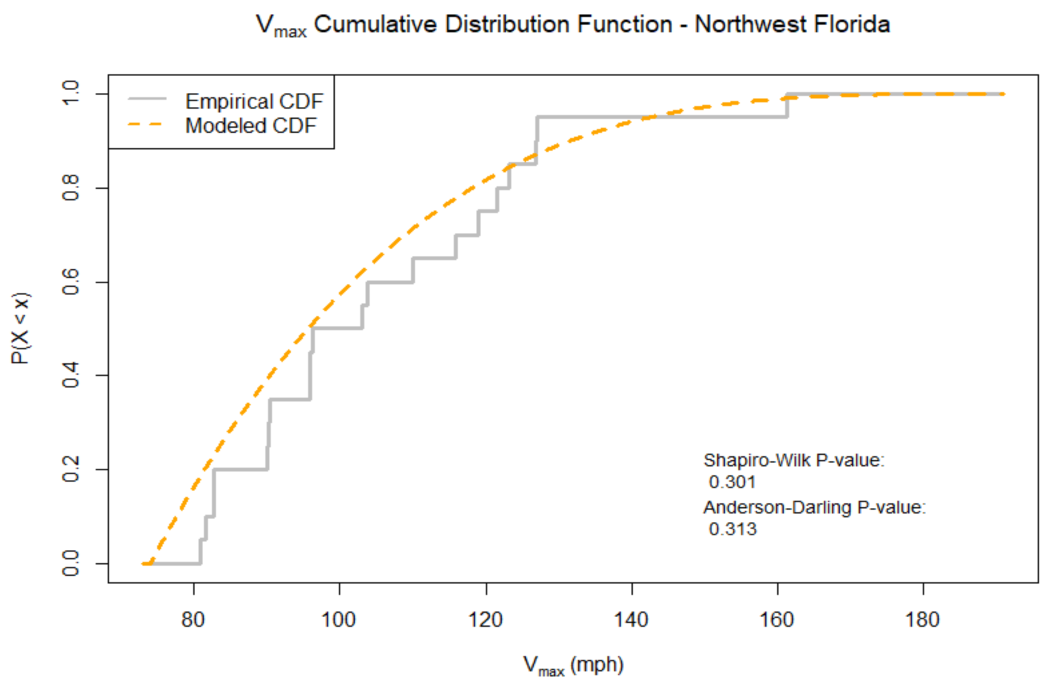


Figure 20 - Historical versus modeled Cumulative Distribution Functions for V_{max}

Radius of maximum winds (R_{max})

The R_{max} is calculated from a regression model that relates it to the maximum sustained wind speed and the latitude, as first developed by Willoughby et al. (2006). The KCC US Hurricane Reference Model uses a modified form of the functional formulation specified in Willoughby et al. (2006) with coefficients estimated using the historical data. Coefficients of this modified Willoughby equation were estimated using the least squares method. The residuals are modeled using a normal distribution. The p-value from the Shapiro-Wilk goodness-of-fit test indicates there is no evidence for lack of fit at level 0.05.

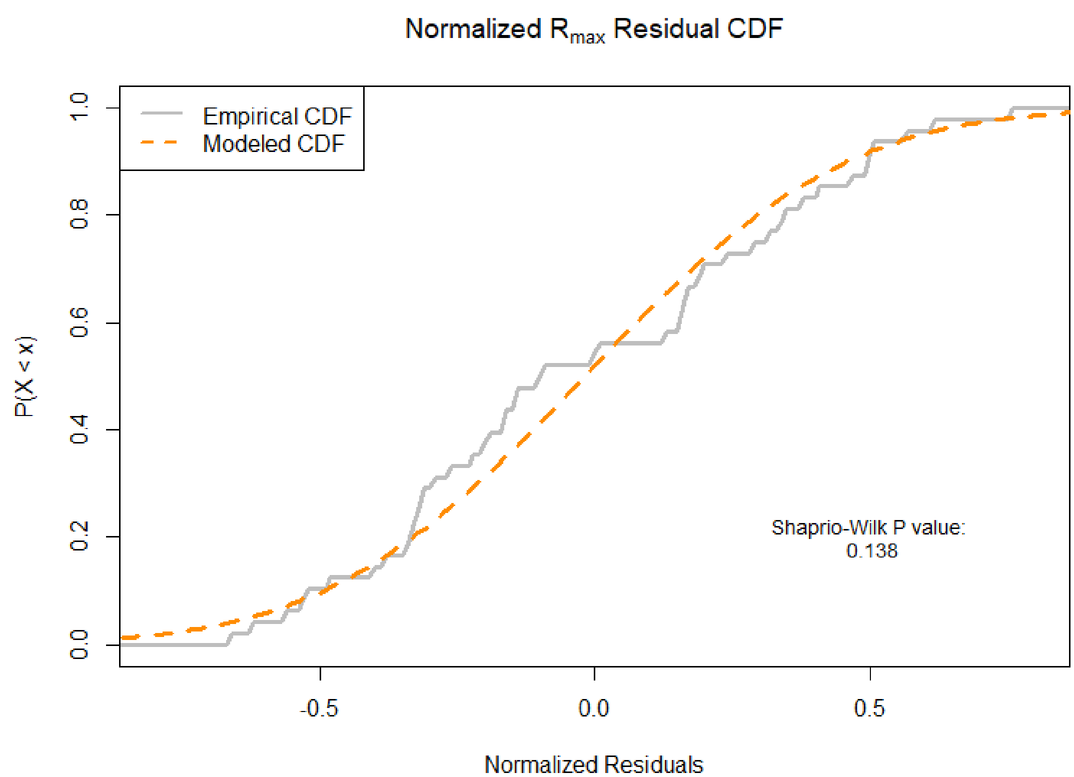


Figure 21 - Historical versus modeled Cumulative Distribution Function for R_{max}

Event day of year

The day of the year for an event is modeled as a random variable using a kernel density estimation with a Gaussian smoother. The fit is based on the occurrence dates of the historical events and represents the observed seasonality in landfalls. Goodness-of-fit testing with the Pearson's Chi-Square test indicates no evidence for lack of fit with a p value of 0.3132.

Annual landfall frequency

The annual landfall frequency is modeled as a random variable following an empirical distribution that is based on a negative binomial distribution fit to historical landfall data. The model accurately represents the historical frequency of years with no landfalls as well as the historical frequency of years with multiple landfalls. Goodness-of-fit testing with the Pearson's Chi-Square test shows no evidence for lack of fit at level 0.05, with a p-value of 0.955.

Forward speed

Forward speed is modeled as a random variable following the Weibull distribution. This distribution was selected based on meteorological expertise and the result of the goodness-of-fit test. The parameters were estimated using maximum likelihood. The p-values from the Shapiro-Wilk and Anderson-Darling goodness-of-fit test indicate it is plausible the distribution of forward speed follows a Weibull distribution at level 0.05.

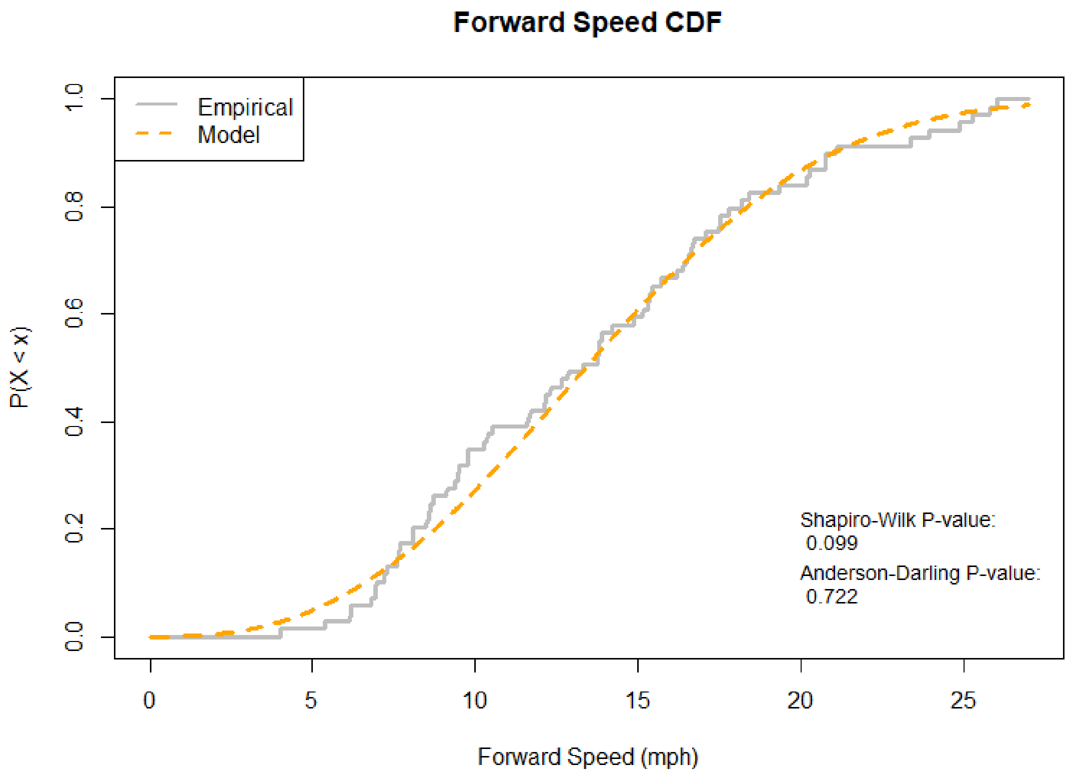


Figure 22 - Historical versus modeled Cumulative Distribution Function for forward speeds

2. ***Describe the nature and results of the tests performed to validate the windspeeds generated.***

The KCC US Hurricane Reference Model wind footprints have been validated against observed wind speeds tabulated by the National Hurricane Center (NHC) as shown in Standard M-4, Disclosure 7. For the validation process, KCC scientists used only the official observations with information on anemometer height and averaging time. The observations were standardized to 1-minute winds at 10-meter height when necessary. The following table shows the root-mean-square deviation (RMSD) and mean bias error (MBE) for Hurricanes Frances and Jeanne.

Storm	Sample Size	RMSD	MBE	Slope of the Fit
Frances	27	6.29 mph	0.61 mph	0.924
Jeanne	19	7.93 mph	0.74 mph	0.947

Table 4 - Validation tests performed for Hurricanes Jeanne and Frances

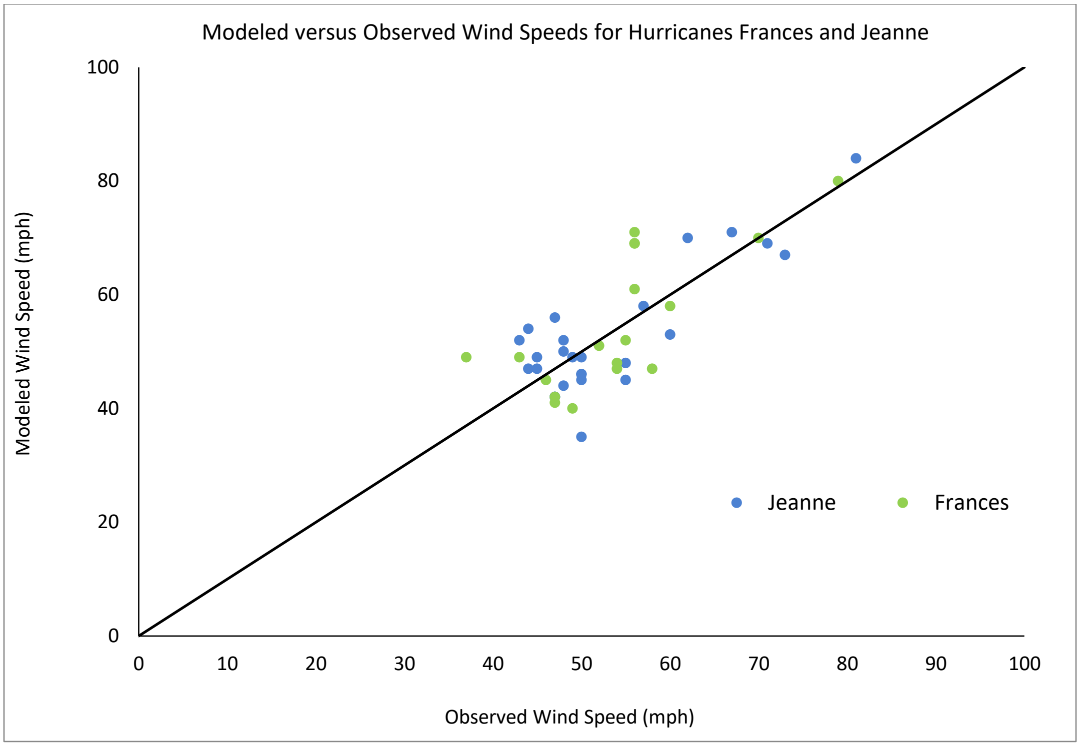


Figure 23 - Modeled versus observed wind speeds for Hurricanes Frances and Jeanne

3. Provide the dates of hurricane loss of the insurance hurricane claims data used for validation and verification of the hurricane model.

- Charley (2004)
- Frances (2004)
- Ivan (2004)
- Jeanne (2004)
- Dennis (2005)
- Katrina (2005)
- Rita (2005)
- Wilma (2005)
- Gustav (2008)
- Ike (2008)
- Irene (2011)
- Isaac (2012)
- Sandy (2012)
- Hermine (2016)
- Matthew (2016)
- Harvey (2017)
- Irma (2017)
- Nate (2017)
- Florence (2018)
- Michael (2018)
- Barry (2019)
- Dorian (2019)
- Delta (2020)

- Isaias (2020)
- Laura (2020)
- Sally (2020)
- Zeta (2020)
- Ida (2021)

4. ***Provide an assessment of uncertainty in hurricane probable maximum loss levels and hurricane loss costs for hurricane output ranges using confidence intervals or other scientific characterizations of uncertainty.***

KCC scientists have examined and studied the contribution of model parameters such as maximum wind speed, radius of maximum winds, forward speed, and the exponential decay length to the uncertainty in modeled probable maximum losses and hurricane loss costs. The results from the uncertainty analysis described in the Standard S-3 disclosure show that maximum wind speed is the largest contributor to the uncertainty in the loss costs. Parameters other than the radius of maximum winds had little contribution to the uncertainty in the loss costs.

5. ***Justify any differences between the historical and modeled results using current scientific and statistical methods in the appropriate disciplines.***

Modeled results, using scientific and statistical methods in the appropriate disciplines, are consistent with historical results.

6. ***Provide graphical comparisons of modeled and historical data and goodness-of-fit tests. Examples to include are hurricane frequencies, tracks, intensities, and physical damage.***

Graphical representations for V_{max}, R_{max}, annual landfall frequency, and forward speed were shown in Standard S-1, Disclosure 1.

Hurricane Landfalls per Year

The following graph compares historical landfall frequencies to the modeled frequencies using an empirical distribution. The agreement between the two distributions is justified graphically, and the Pearson's Chi-Square test produces a p-value of 0.955.

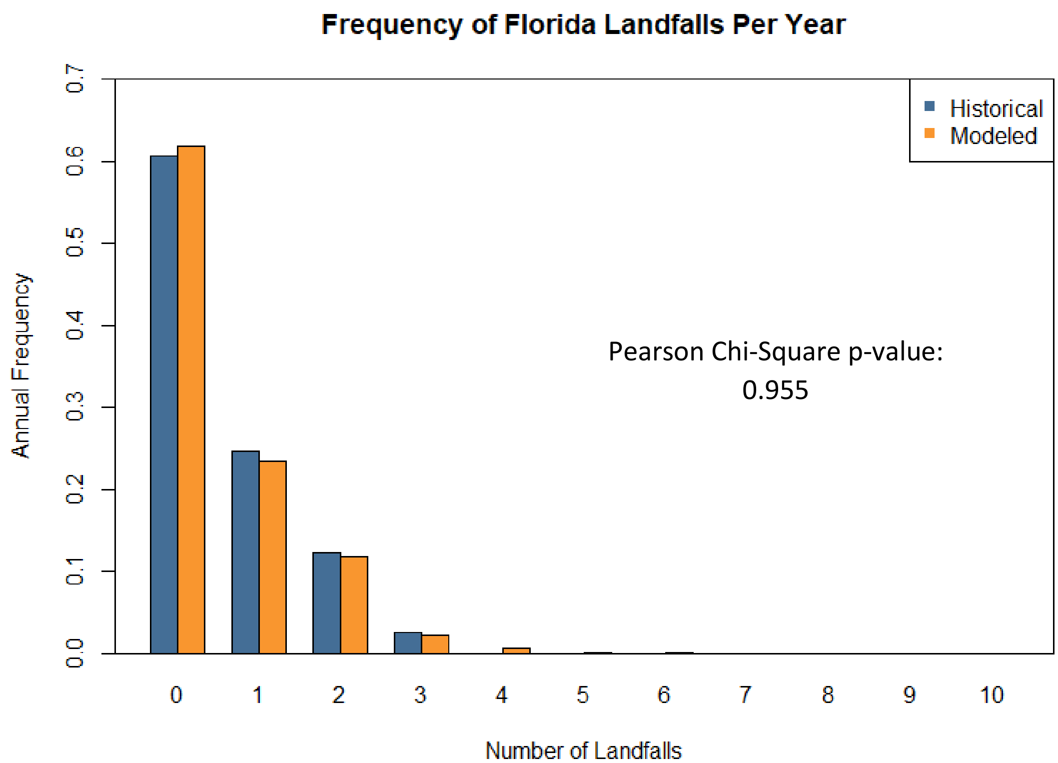


Figure 24 - Comparison of modeled to historical hurricane landfalls in Florida

Physical Damage

The figure below illustrates actual and modeled MDRs. The Pearson's Chi-square test produces a p-value of 0.49, indicating no evidence for lack of fit between the actual and modeled physical damage at level 0.05.

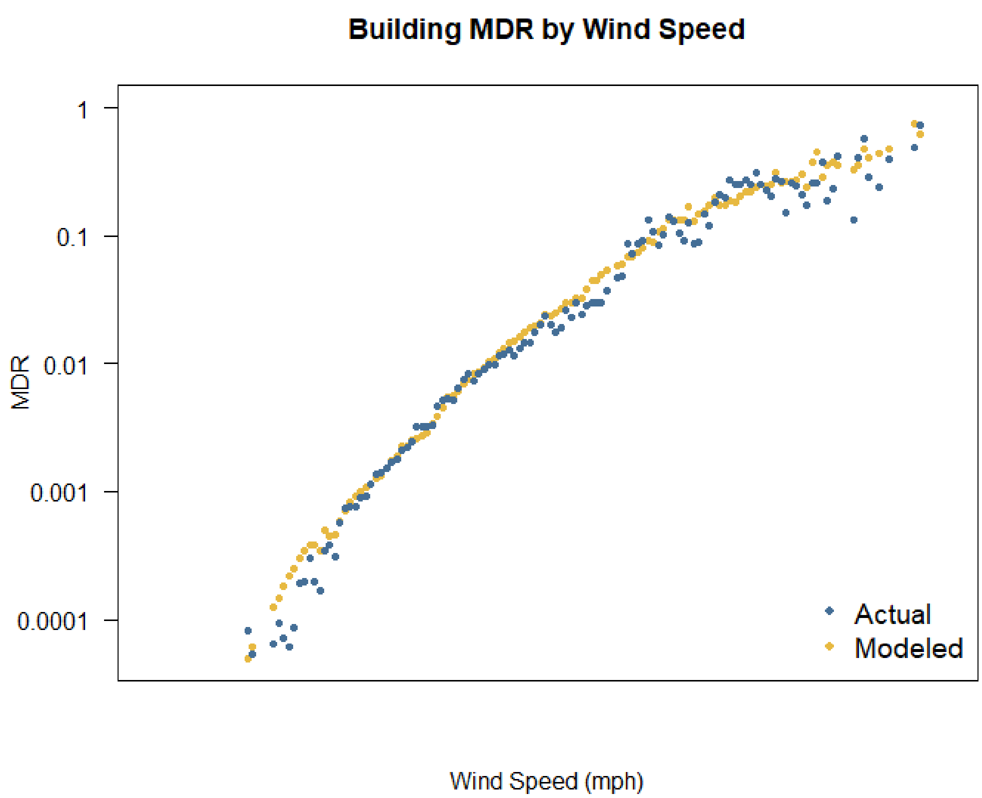


Figure 25 - Actual versus modeled MDRs

7. ***Provide a completed Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year. Provide a link to the location of the form.***

Form S-1: Probability and Frequency of Florida Landfalling Hurricanes per Year

8. ***Provide a completed Form S-2, Examples of Hurricane Loss Exceedance Estimates. Provide a link to the location of the form.***

Form S-2: Examples of Hurricane Loss Exceedance Estimates

S-2 Sensitivity Analysis for Hurricane Model Output

The modeling organization shall have assessed the sensitivity of temporal and spatial outputs with respect to the simultaneous variation of input variables using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action.

The sensitivity of temporal and spatial outputs with respect to the simultaneous variation of input values for the KCC US Hurricane Reference Model has been analyzed using accepted scientific and statistical methods. The results of this analysis are discussed further in Standard S-2, Disclosures 1 through 5. Any appropriate action indicated by the results of these analyses has been taken.

Disclosures

1. Identify the most sensitive aspect of the hurricane model and the basis for making this determination.

The most sensitive aspect of the model is the maximum wind speed (V_{max}). This result is based on studies conducted by KCC scientists and the results demonstrated by the uncertainty analysis described in the Standards S-3 disclosures.

The sensitivity analysis included four model parameters: maximum wind speed, radius of maximum winds, forward speed, and the exponential decay length. The guidelines from the Commission were followed for the sensitivity analysis for the loss cost. The standardized regression coefficient was computed for all four input parameters at three different hurricane intensities (Category 1, Category 3, and Category 5). The result showed that the V_{max} was the greatest contributor to the change in loss costs across all intensities.

Since insured losses are dependent on the final impact from a hurricane event and not the temporal variation, the KCC US Hurricane Reference Model does not output losses on an hourly basis. Consequently, an analysis of the temporal sensitivities of the lost cost was not performed. Instead, the sensitivities of the modeled wind speeds were evaluated both spatially and temporally as described in the Standard S-2 Disclosures.

Temporal and Spatial Analysis

Figures 26, 27, and 28 display the standardized regression coefficients as a function of time (12 hours) for Category 1, 3, and 5 hurricanes at landfall for the point with coordinate (18, 18) on the grid.

For Category 1 and 3 hurricanes, before and immediately following landfall, modeled wind speeds at the grid point are most affected by V_{max}, followed by forward speed (VT), the shape parameter (X1), and the finally R_{max}, which has least impact in the early time periods. As time increases, the impact of the shape parameter (X1) becomes the most impactful, as it has the greatest effect on the spatial extent of the storm beyond the R_{max} in these late time periods. In the later time periods, V_{max} and R_{max} have a relatively similar level of impact, and the effect of forward speed (VT) greatly diminishes.

For Category 5 hurricanes, R_{max} has the greatest impact, and V_{max} has the second greatest impact in the hours before and immediately following landfall, followed by X1 and VT. In later time periods, the impact of the shape parameter again becomes the most impactful, followed by R_{max}, V_{max}, and VT.

The result of this analysis is for the specified coordinate point and could vary significantly depending on which point is selected on the grid.

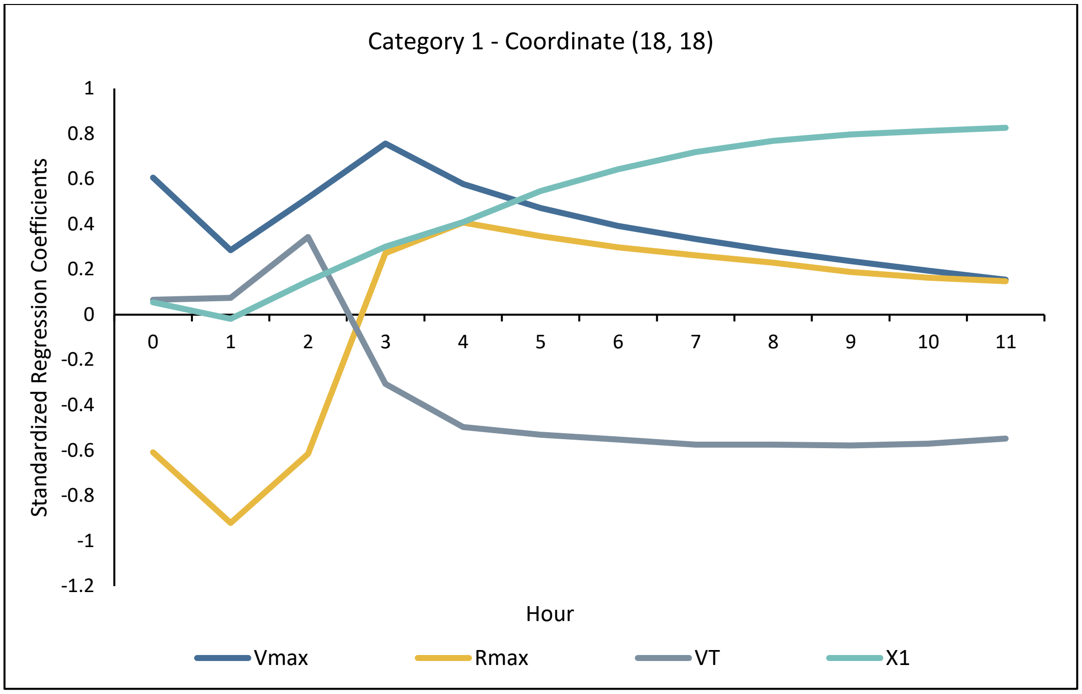


Figure 26 - Time series of standardized regression coefficients at grid coordinates (18,18) for Category 1 hurricanes

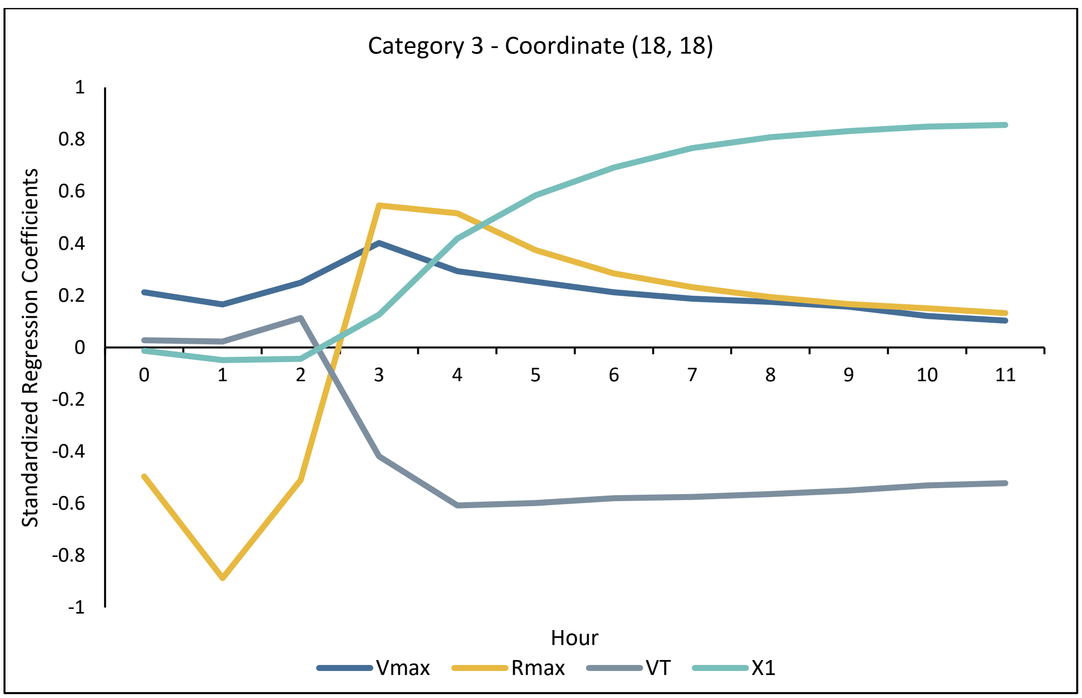


Figure 27 - Time series of standardized regression coefficients at grid coordinates (18,18) for Category 3 hurricanes

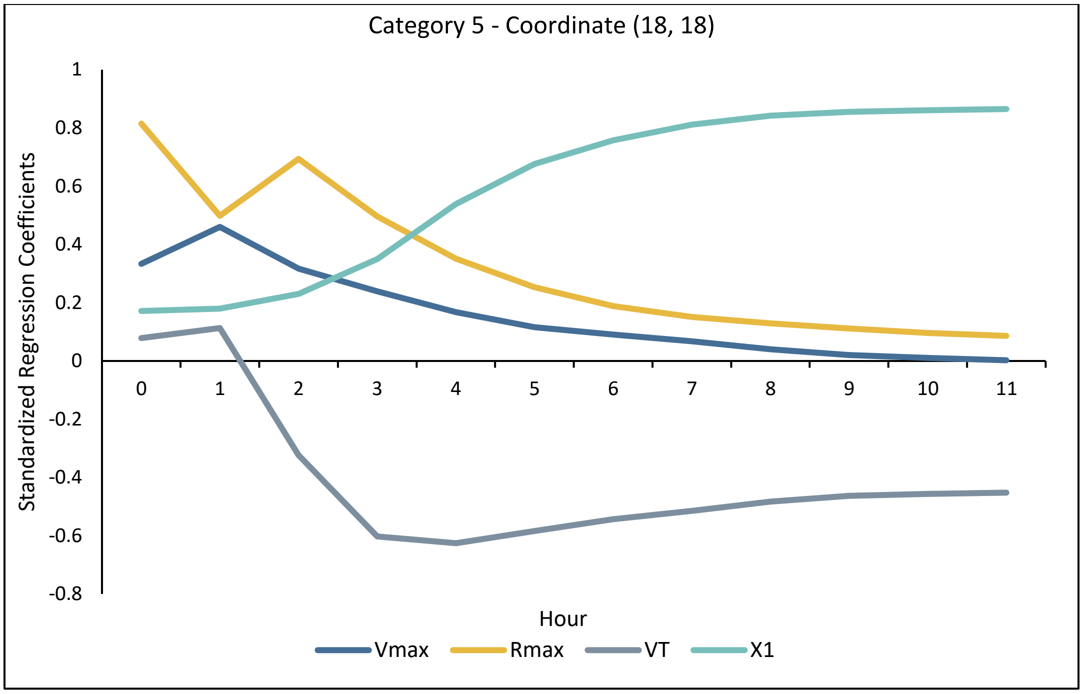


Figure 28 - Time series of standardized regression coefficients at grid coordinates (18,18) for Category 5 hurricanes

2. ***Identify other input variables that impact the magnitude of the output when the input variables are varied simultaneously. Describe the degree to which these sensitivities affect output results and illustrate with an example.***

No other input variables impact the magnitude of the output when the input variables V_{max}, R_{max}, forward speed, and exponential decay length are varied simultaneously.

3. ***Describe how other aspects of the hurricane model may have a significant impact on the sensitivities in output results and the basis for making this determination.***

Other aspects of the hurricane model that have an impact on the sensitivity of the modeled loss costs include the track direction and the landfall location. This determination was made by studies performed by KCC scientists on both uniform exposure and actual exposure.

4. ***Describe and justify action or inaction as a result of the sensitivity analyses performed.***

The sensitivity analyses from Standard S-2 have been reviewed, and the results are reasonable. No action was taken as a result of the analyses performed.

5. ***Provide a completed Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis. (Requirement for hurricane models submitted by modeling organizations which have not previously provided the Commission with this analysis. For hurricane models currently found acceptable, the Commission will determine, at the meeting to review modeling organization submissions, if an existing modeling organization will be required to provide Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, prior to the Professional Team on-site review). If applicable, provide a link to the location of the form.***

Form S-6: Hypothetical Events for Sensitivity and Uncertainty Analysis

S-3 Uncertainty Analysis for Hurricane Model Output

The modeling organization shall have performed an uncertainty analysis on the temporal and spatial outputs of the hurricane model using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action. The analysis shall identify and quantify the extent that input variables impact the uncertainty in hurricane model output as the input variables are simultaneously varied.

KCC scientists and statisticians have conducted uncertainty analyses on the temporal and spatial output of the KCC US Hurricane Reference Model using appropriate statistical and scientific methods. The results, described further in Standard S-3, Disclosures 1 through 4, identify and quantify the extent that input variables impact the uncertainty in the model output. Any appropriate action indicated by the results of the uncertainty analyses were taken.

Disclosures

1. Identify the major contributors to the uncertainty in hurricane model outputs and the basis for making this determination. Provide a full discussion of the degree to which these uncertainties affect output results and illustrate with an example.

The maximum wind speed is the major contributor to the uncertainty in hurricane model loss cost. This outcome is based on studies conducted by KCC scientists and the results demonstrated by the Standard S-3 disclosure.

The uncertainty analysis included four model parameters: maximum wind speed, radius of maximum wind, forward speed, and the exponential decay length. The guidelines from the Commission were followed for the uncertainty analysis for the loss cost. The expected percentage reduction was computed for all four input parameters at three different hurricane intensities (Category 1, Category 3, and Category 5). The result showed that the maximum wind speed is the major contributor the uncertainty in the loss costs for all intensities. For Category 1 hurricanes, radius of maximum winds, forward speed, and the exponential decay length have very little to no contribution. For Category 3 and 5 hurricanes, radius of maximum winds is the second contributor, and the R_{max} contribution to uncertainty increases proportionally with the storm intensity. Forward speed and the exponential decay length still have very little to no contribution to the uncertainty around the modeled lost costs.

Temporal and Spatial Analysis

Since insured losses are dependent on the final impact from a hurricane event and not the temporal variation, the KCC US Hurricane Reference Model does not output losses on an hourly basis. Consequently, an analysis of the temporal uncertainties underlying modeled lost cost was not performed. Instead, the parameters driving the uncertainty of modeled wind speeds were calculated both spatially and temporally described in the Standards S-3 disclosures.

Figures 29, 30, and 31 represent the Expected Percentage Reduction in the variance of the wind speeds as a function of time (12 hours) for Category 1, 3, and 5 hurricanes at landfall for the point with coordinate (18, 18) on the grid.

Before and in the hours immediately following landfall, the largest contribution to the uncertainty in modeled wind speed is R_{max} for all categories of hurricanes. For Category 1 and 3 hurricanes, V_{max} and VT have the second and third largest contribution to the uncertainty in modeled wind speeds, followed by the shape parameter (X1). Across all categories of hurricanes, as time increases, the shape parameter (X1) has the largest contribution to the uncertainty in modeled wind speeds followed by the forward speed (VT), and at the later hours, R_{max} and V_{max} have the least contribution to the uncertainty.

The result of this analysis is for the specified coordinate point and could vary significantly depending on which point is selected on the grid.

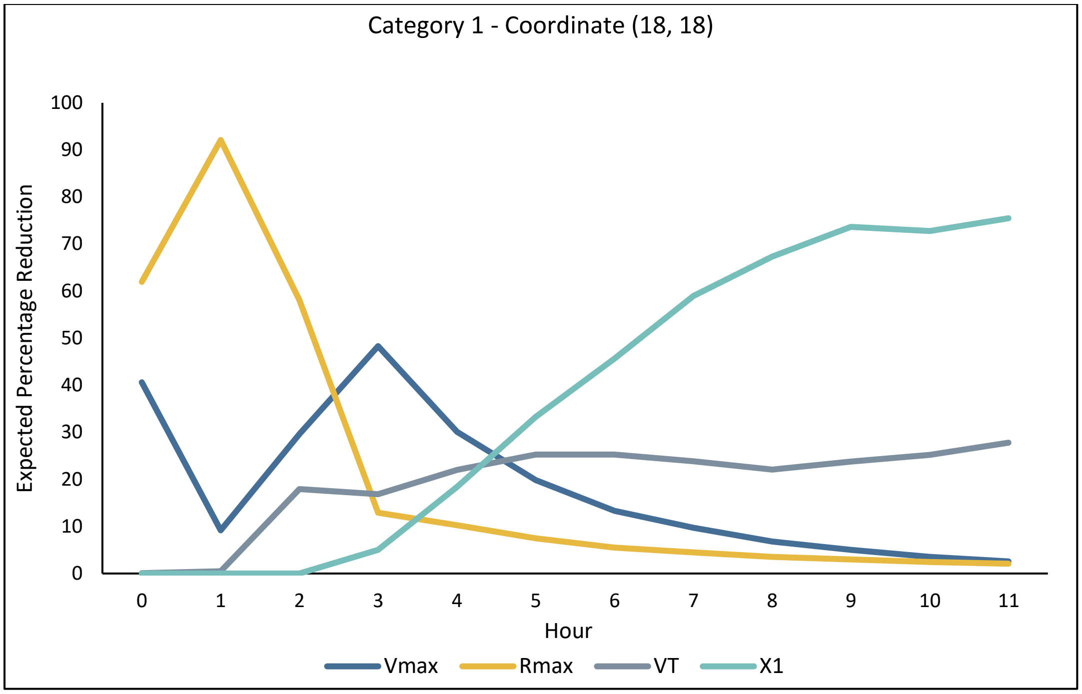


Figure 29 - Time series of expected percentage reduction at grid coordinates (18,18) for Category 1 hurricanes

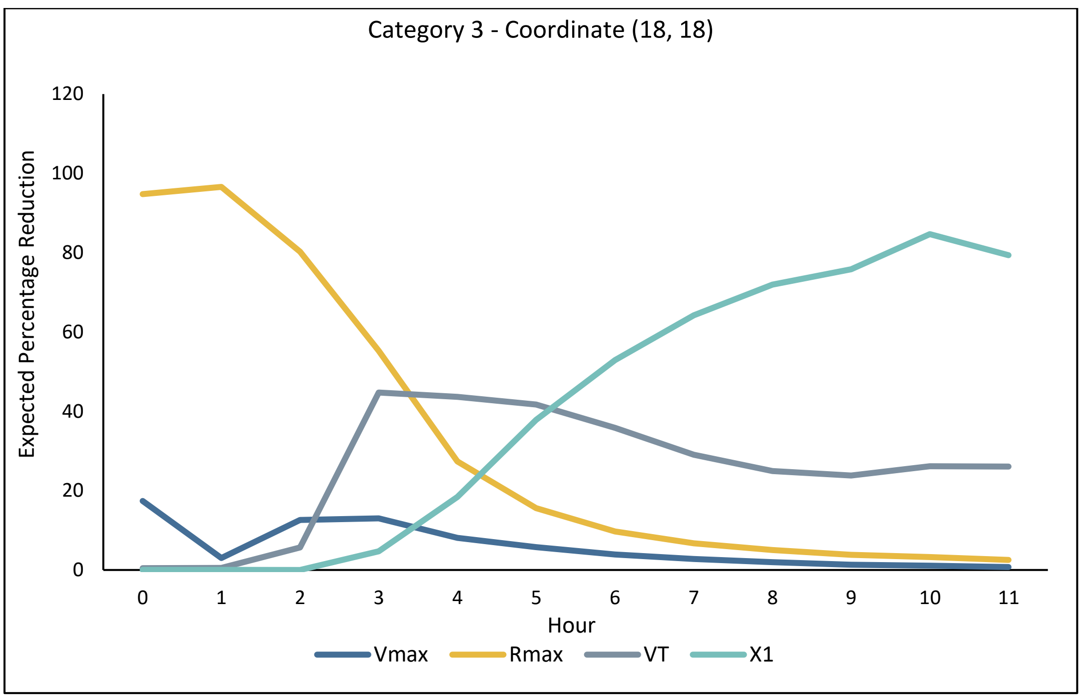


Figure 30 - Time series of expected percentage reduction at grid coordinates (18,18) for Category 3 hurricanes

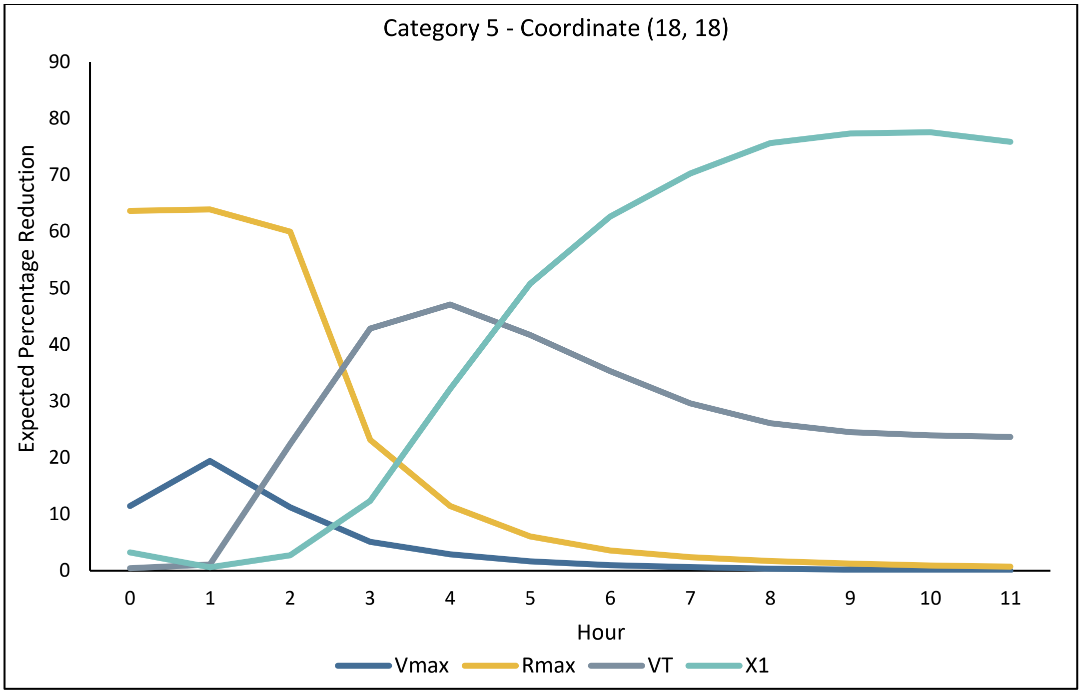


Figure 31 - Time series of expected percentage reduction at grid coordinates (18,18) for Category 5 hurricanes

2. ***Describe how other aspects of the hurricane model may have a significant impact on the uncertainties in output results and the basis for making this determination.***

Other aspects of the hurricane model that may have a significant impact on the uncertainties in loss costs model output include the track direction and the landfall location. The basis of this determination is studies performed by KCC scientists on both uniform and actual exposure.

3. ***Describe and justify action or inaction as a result of the uncertainty analyses performed.***

The uncertainty analyses performed have been thoroughly reviewed, and the results obtained were found to be reasonable. No action was taken as a result of the analyses performed.

4. ***Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, if disclosed under Hurricane Standard S-2, Sensitivity Analysis for Hurricane Model Output, will be used in the verification of Hurricane Standard S-3, Uncertainty Analysis for Hurricane Model Output.***

Form S-6 was included in the previous submission for the 2017 Report of Activities and found acceptable. There have been no changes to the sensitivity or uncertainty analyses.

S-4 County Level Aggregation

At the county level of aggregation, the contribution to the error in hurricane loss cost estimates attributable to the sampling process shall be negligible.

KCC has conducted tests to ensure that the expected hurricane loss projections resulting from the sampling methodology meet the performance requirements. These statistical tests performed on the KCC US Hurricane Reference Model verify that errors in the loss cost estimates due to sampling are negligible at the county level.

Disclosure

1. Describe the sampling plan used to obtain the average annual hurricane loss costs and hurricane output ranges. For a direct Monte Carlo simulation, indicate steps taken to determine sample size. For an importance sampling design or other sampling scheme, describe the underpinnings of the design and how it achieves the required performance.

The sampling plan selected is of significant importance for a catastrophe model. Along with the appropriate number of events and characteristics for the events in the stochastic catalog, the simulated sample must provide complete and consistent spatial coverage. The added dimension of geography makes the catastrophe modeling sampling problem more complex than many other applications.

The stochastic hurricane event set must represent the following:

- The expected frequency by location
- The expected distribution of intensities by location
- Distributions of other hurricane characteristics

Commonly used simulation techniques, such as the Monte Carlo method, introduce undesirable “noise” into the stochastic storm set due to the random sampling process. Millions of events are required to eliminate the noise at the location-level resolution. Bootstrapping methods, reliant on empirical distributions fit closely to the historical data, do not provide the appropriate sample in the opinion of KCC scientists because future events are not likely to mirror past events.

This standard specifies county-level resolution, but the KCC US Hurricane Reference Model is designed to provide credible loss cost estimates at the location level because insurers use the model for individual account underwriting and pricing. In order to develop a stochastic event set that provides robust average annual losses and loss costs at a location-level resolution, a more efficient and intelligent sampling procedure was required.

The first step of the sampling process is to utilize the landfall frequency distribution and Generalized Pareto Distribution parameters to generate the number of events for each landfall point and the intensity of each event, represented by V_{max}. KCC scientists conducted sensitivity tests to determine that a five mph increment is sufficient for representing the V_{max} distributions for each landfall point.

Another important sampling criterion was for the 1-in-500-year hurricane to be represented at each landfall point. This resulted in a 100,000-year simulation sample with nearly 60,000 events and approximately 2,500 unique V_{max} and landfall point combinations for Florida.

The image below illustrates the simulated V_{max} distribution for each landfall point along a segment of Florida coastline. Note the smooth and desired transition along the coast relative to a Monte Carlo simulation.

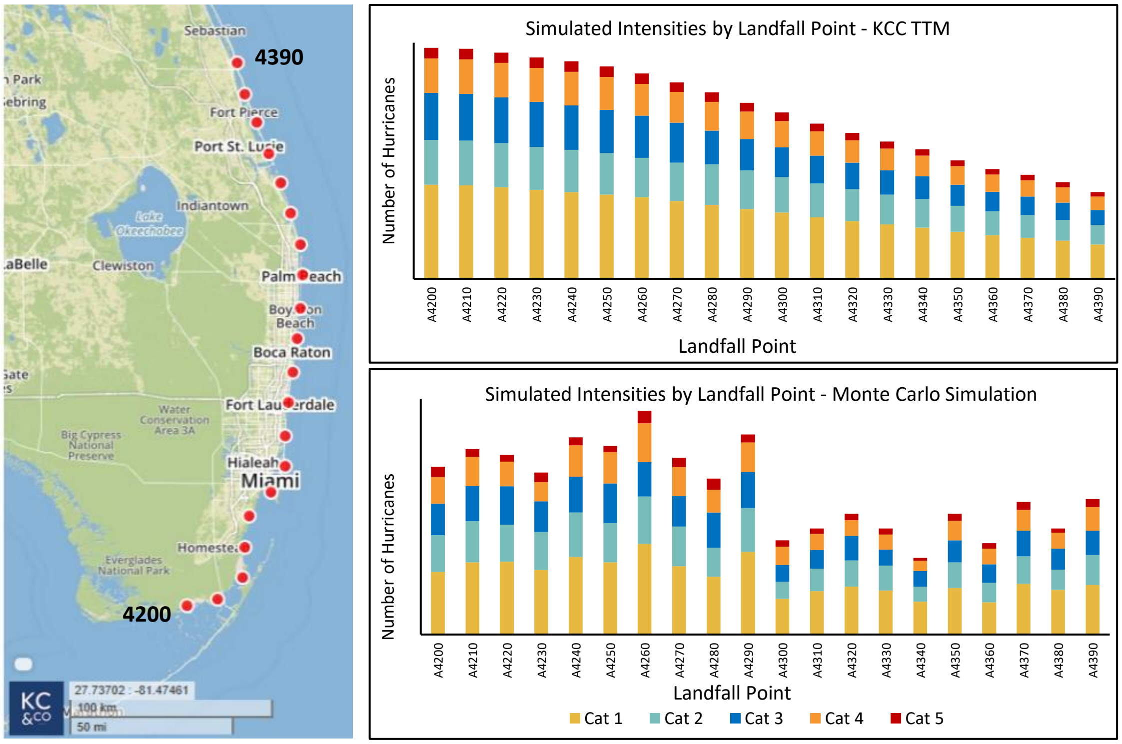


Figure 32 - Landfall points used in simulation analyses (left), and KCC US Hurricane Reference Model intensities by landfall point (top right) versus intensities generated using Monte Carlo simulation (bottom right)

After the V_{max} values are assigned, values for the other important hurricane parameters are selected following the Joint Probability Method (JPM) and using a ternary tree structure to maintain symmetry. This method has several advantages over other simulation techniques, the most important of which is that it provides a stochastic catalog representing the entire range of potential future storm characteristics along with complete and consistent spatial coverage. This method does not introduce noise into the sample.

The method starts with defining the hierarchy of importance for the parent nodes. For insured losses, the hierarchy is:

- Track over land (TD)
- Radius of maximum winds (Rmax)
- Forward speed (F)

This hierarchy determines the design of the ternary tree as shown in the tree structure below.

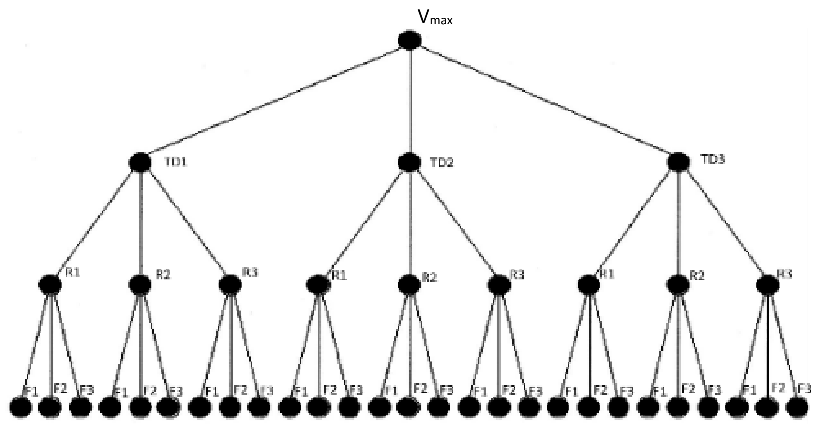


Figure 33 - Hierarchal structure for parameter value selection

At the root of the tree is the V_{max}, the parent node. The first set of child nodes represent the three track directions (TD1, TD2, TD3). Each TD node will have its own three child nodes for R_{max} (R1, R2, R3). Finally, each R_{max} has three nodes for forward speed (F1, F2, F3). This tree structure and a set of branching rules, including the requirement to maintain tree symmetry, produces the set of hurricane characteristics assigned to each event. A few examples are shown below.

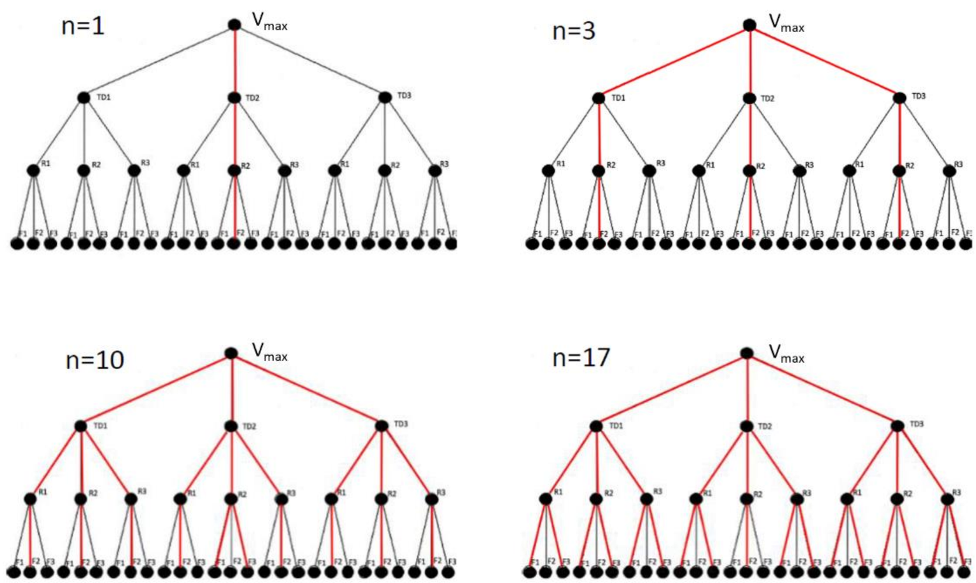


Figure 34 - Scenario selection for one (top left), three (top right), 10 (bottom left), and 17 (bottom right) events.

KCC scientists used this methodology to produce a spatially unbiased and reproducible sample of nearly 30,000 landfalling events in Florida and the two adjacent regions. Additional justification for this methodology includes:

- Every event in the KCC catalog has meaning and is named by its event characteristics. In the RiskInsight® application, insurers can readily identify which events and event characteristics are contributing to their largest losses.

- For every landfall point and V_{max}, there is an event representing the expected values of all other characteristics. This enables insurers to obtain the Characteristic Event (CE) losses for selected hazard levels (i.e., return period wind speeds).
- No event in the catalog would be considered “suspect” by meteorological standards. There are no events in the stochastic catalog not likely to occur in nature.

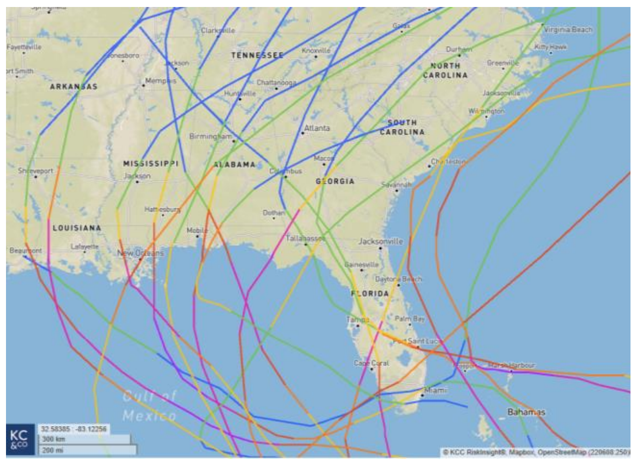
KCC has conducted tests to ensure that the event catalog resulting from this methodology has met performance requirements. KCC scientists have evaluated high-resolution wind speed maps generated from the catalog to verify logical relationships to risk are achieved and that no localized anomalies are present. Statistical tests were also performed on the KCC US Hurricane Reference Model Version 4.0 loss costs to verify that the errors in the loss cost estimates due to sampling are negligible.

S-5 Replication of Known Hurricane Losses

The hurricane model shall estimate incurred hurricane losses in an unbiased manner on a sufficient body of past hurricane events from more than one company, including the most current data available to the modeling organization. This standard applies separately to personal residential and, to the extent data are available, to commercial residential. Personal residential hurricane loss experience may be used to replicate structure-only and contents-only hurricane losses. The replications shall be produced on an objective body of hurricane loss data by county or an appropriate level of geographic detail and shall include hurricane loss data from Hurricane Irma (2017) and Hurricane Michael (2018), to the extent data are available for these storms.

KCC has been provided with detailed claims data from insurance companies for 28 historical hurricanes going back to 2004. Fourteen of these hurricanes impacted the state of Florida. The list of storms is shown below, along with the amount of total insured value (TIV) by personal residential, commercial residential, and manufactured homes. For all but one insurer, individual claims were provided by location along with the contemporaneous policy-level exposure data.

Storm Name	Storm Year	Storm Name	Storm Year
Charley	2004	Matthew	2016
Frances	2004	Harvey	2017
Ivan	2004	Irma	2017
Jeanne	2004	Nate	2017
Dennis	2005	Florence	2018
Katrina	2005	Michael	2018
Rita	2005	Barry	2019
Wilma	2005	Dorian	2019
Gustav	2008	Delta	2020
Ike	2008	Isaias	2020
Irene	2011	Laura	2020
Isaac	2012	Sally	2020
Sandy	2012	Zeta	2020
Hermine	2016	Ida	2021



Policy Type	Total TIV
Personal Residential	32,600,581,567,143
Commercial Residential	2,427,826,378,042
Manufactured Homes	13,721,089,235

Table 5 - Storms included in KCC estimated claims and loss validation (left), spatial distribution of event tracks (top right), and TIV by residential policy types included in the data (bottom right)

Disclosures

1. Describe the nature and results of the analyses performed to validate the hurricane loss projections generated for personal and commercial residential hurricane losses separately. Include analyses for the 2017 and 2018 hurricane seasons, to the extent data are available.

KCC scientists and engineers have conducted rigorous analyses of insurer high-resolution claims data. KCC engineers mapped each individual claim amount to the policy generating that claim so the claims data could be analyzed separately by construction, occupancy, year built, and other property characteristics.

Most of the claims were also identified by coverage. The contemporaneous exposure data was provided for all policies in force on the date of the storm (not just those with claims), which is required for estimating the MDRs (mean damage ratios) by wind speed. For each storm, each claim was matched to the wind speed experienced at that location according to the modeled and validated high-resolution wind footprints. The modeled and actual losses were compared by wind speed and building attribute, such as construction type and year built.

An excess litigation factor of 15 percent has been applied to Florida single family home modeled losses for Irma and Michael.

Company	Event	Actual Loss	Modeled Loss
Company A	Charley	301,163,304	268,886,082
Company B	Charley	368,913,436	349,497,253
Total	**Charley**	**670,076,739**	**618,383,335**
Company A	Frances + Jeanne	130,840,560	143,376,198
Company B	Frances + Jeanne	495,792,220	490,575,173
Total	**Frances + Jeanne**	**626,632,780**	**633,951,370**
Company A	Wilma	88,613,991	169,488,779
Company B	Wilma	586,432,881	696,556,696
Company C	Wilma	387,872,015	430,062,682
Total	**Wilma**	**1,062,918,887**	**1,296,108,158**
Company A	Hermine	5,220,286	8,230,274
Company D	Hermine	6,877,223	7,100,140
Company E	Hermine	11,443,767	10,011,141
Total	**Hermine**	**23,541,275**	**25,341,555**
Company A	Matthew	39,003,279	68,821,391
Company B	Matthew	52,964,560	49,118,242
Company D	Matthew	38,819,330	41,644,033
Company E	Matthew	187,444,459	115,913,522
Company F	Matthew	15,296,891	10,640,396
Company G	Matthew	46,578,331	37,948,563
Total	**Matthew**	**380,106,851**	**324,086,146**
Company A	Irma	981,231,729	828,342,736
Company B	Irma	442,199,875	370,446,421
Company D	Irma	761,125,324	602,285,057
Company E	Irma	958,202,384	867,680,063
Company F	Irma	254,630,398	334,607,400
Company G	Irma	685,047,955	680,021,477
Company H	Irma	114,099,639	61,928,910
Total	**Irma**	**4,082,437,665**	**3,683,383,154**

Company	Event	Actual Loss	Modeled Loss
Company A	Michael	526,295,265	397,860,793
Company B	Michael	714,196,488	483,323,289
Company D	Michael	257,139,296	260,582,112
Company E	Michael	469,948,329	346,276,662
Company H	Michael	14,428,495	8,442,077
Total	**Michael**	**1,967,579,378**	**1,488,042,855**
Company A	Delta + Zeta	101,319,470	108,259,303
Company H	Delta + Zeta	65,303,220	70,507,002
Company B	Delta + Zeta	359,411,957	411,028,459
Total	**Delta + Zeta**	**526,034,647**	**589,794,764**
Company A	Laura	206,068,529	206,015,606
Company H	Laura	57,237,596	54,408,736
Company B	Laura	595,788,769	630,787,401
Total	**Laura**	**859,094,894**	**891,211,743**
Company A	Ida	716,234,988	770,023,653
Company H	Ida	350,125,905	364,669,269
Company I	Ida	814,572,504	819,379,188
Company B	Ida	843,871,632	880,124,545
Total	**Ida**	**2,724,805,029**	**2,834,196,655**
Total	**All Events**	**13,051,756,279**	**12,454,870,721**

Table 6 - Actual versus modeled losses (disguised insurer data) for Florida and non-Florida hurricanes

2. Provide a completed Form S-4, Validation Comparisons. Provide a link to the location of the form.

Form S-4: Validation Comparisons

S-6 Comparison of Projected Hurricane Loss Costs

The difference, due to uncertainty, between historical and modeled annual average statewide hurricane loss costs shall be reasonable, given the body of data, by established statistical expectations and norms.

The difference between historical and modeled annual average statewide hurricane loss costs is reasonable and expected. Given the length of the historical record—122 years—it's to be expected that the modeled annual average statewide hurricane loss cost will be higher than the historical loss cost. The hurricane model must account for hurricanes that haven't happened yet but that could occur in the future, and this includes more extreme events than observed in the historical record. In general, the hurricane annual average loss costs are dominated by the largest loss-producing events, and these occur when a major hurricane strikes a highly populated area. In the historical record, the three Category 5 hurricanes that made landfall in Florida did not impact the most highly populated areas of the state. The hurricane model must account for the possibility of major hurricanes with observed and higher wind speeds impacting all regions of coastline for which these storms are meteorologically feasible.

Disclosures

1. Describe the nature and results of the tests performed to validate the expected hurricane loss projections generated. If a set of simulated hurricanes or simulation trials was used to determine these hurricane loss projections, specify the convergence tests that were used and the results. Specify the number of hurricanes or trials that were used.

KCC scientists and engineers first validate all the model components independently to compare expectations with the results produced by the model:

- For every landfall point along the Florida coastline, the frequency of storms by intensity is verified along with the expected transition between landfall points. The historical frequencies by intensity are also compared to the simulated frequencies by intensity for larger regions within Florida.
- The return period wind speeds from the stochastic model are compared to the historical wind speeds to verify expectations, i.e., the 100-year return period wind speeds should be comparable (although smoothed) relative to the maximum wind speeds from the historical events. The 250-year return period wind speeds from the stochastic model should be higher than the maximum wind speeds from the historical storms.
- The modeled losses for historical events are compared to actual losses to validate the vulnerability functions.

Once the individual components are validated and verified, the overall losses are compared between the historical events and the stochastic model. Along with the average annual loss costs, the return period losses from the stochastic model are compared to the historical losses. It was verified that the 1-in-100-year loss from the stochastic model is consistent with the largest loss in the historical catalog and the 1-in-50-year loss from the stochastic model is consistent with the second largest historical loss (as demonstrated in Standard S-5, Disclosure 1). Lower return period losses were similarly reviewed to validate the losses projected by the model. Historical losses were adjusted to today's values using a method similar to that developed by Pielke et al. (2008).

2. Identify and justify differences, if any, in how the hurricane model produces hurricane loss costs for specific historical events versus hurricane loss costs for events in the stochastic hurricane set.

Historical event loss costs are determined using the unadjusted historical wind speed data whereas the stochastic hurricane set is based on intensity distributions that account for the impacts of climate change on hurricane wind speeds.

The update to the intensity distributions underlying the stochastic wind speeds ensures that the model loss costs are representative of hurricanes in the current climate which, according to the generally accepted scientific consensus, has a higher potential for more intense hurricanes due to warming global temperatures.

Historical loss costs include storms that occurred decades in the past during a cooler climate and are lower as a result.

3. Provide a completed Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled. Provide a link to the location of the form.

Form S-5: Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled

Vulnerability Hurricane Standards

V-1 Derivation of Building Hurricane Vulnerability Functions

A. Development of the building hurricane vulnerability functions shall be based on at least one of the following: (1) insurance claims data, (2) laboratory or field testing, (3) rational structural analysis, and (4) post- event site investigations. Any development of the building hurricane vulnerability functions based on rational structural analysis, post-event site investigations, and laboratory or field testing shall be supported by historical data.

The building vulnerability functions are developed based on all of the above: rational structural engineering analysis, data from laboratory and field testing on building component capacities, and post-event surveys and site investigations. KCC engineers have conducted laboratory experiments on building component performance under wind loading. Insurance claims data for historical hurricanes are used to validate the building vulnerability functions. Throughout the process, KCC engineers referred to current scientific research and accepted wind engineering principles.

B. The derivation of the building hurricane vulnerability functions and the treatment of associated uncertainties shall be theoretically sound and consistent with fundamental engineering principles.

KCC engineers ensure that the vulnerability functions comply with fundamental engineering principles. The functions are developed and validated by experts in wind and structural engineering and are based on published research, post-disaster site surveys, and claims data. The uncertainties associated with each damage level were developed based on sound statistical and engineering principles and have been validated using insurance claims data.

C. Residential building stock classification shall be representative of Florida construction for personal and commercial residential buildings.

The building inventory and stock information was compiled from published studies on the Florida residential building stock, census and tax appraiser’s data, damage survey observations, and the Florida Hurricane Catastrophe Fund (FHCF). These data were then used to identify and classify the relevant building construction types. The KCC building stock classification is representative of the personal and commercial residential properties found in Florida.

D. Building height/number of stories, primary construction material, year of construction, location, building code, and other construction characteristics, as applicable, shall be used in the derivation and application of building hurricane vulnerability functions.

The KCC US Hurricane Reference Model classifies buildings based on a set of primary characteristics: primary construction materials, building occupancy, number of stories, year built, and building location/region (applicable building codes and enforcement are included here). Unique vulnerability functions are then developed for each combination of these characteristics.

At the start of a loss analysis, the vulnerability function for each building is selected based on its primary characteristics. The selected vulnerability function can then be modified based on building secondary characteristics and mitigation measures. This is explained in detail in Standard V-4.

E. Hurricane vulnerability functions shall be separately derived for commercial residential building structures, personal residential building structures, manufactured homes, and appurtenant structures.

Vulnerability functions for personal residential buildings, commercial residential buildings, manufactured homes, as well as appurtenant structures are derived separately.

F. The minimum windspeed that generates damage shall be consistent with fundamental engineering principles.

The minimum wind speed at which damage begins in the KCC US Hurricane Reference Model is 25 mph (1-minute sustained wind speed at 10-meter height). This is consistent with fundamental engineering principles and has been verified using observations from post-disaster damage surveys and insurance claims data.

G. Building hurricane vulnerability functions shall include damage as attributable to windspeed and wind pressure, water infiltration, and missile impact associated with hurricanes. Building hurricane vulnerability functions shall not include explicit damage to the building due to flood (including hurricane storm surge and wave action).

The KCC US Hurricane Reference Model wind vulnerability functions include the damage from wind speed and pressure, water infiltration, and missile impact. Damage from flood, storm surge, or wave action is not explicitly included in the wind vulnerability functions.

Disclosures

1. Describe any modifications to the building vulnerability component in the hurricane model since the currently accepted hurricane model.

The changes since the currently accepted hurricane model are

- Modified vulnerability functions for site-built homes with respect to Very-New year-built band
- Modified vulnerability functions for manufactured homes with respect to year-built bands
- Updated vulnerability functions for commercial residential, renters, and condos occupancy types when building height is unknown.

2. Provide a flowchart documenting the process by which the building hurricane vulnerability functions are derived and implemented.

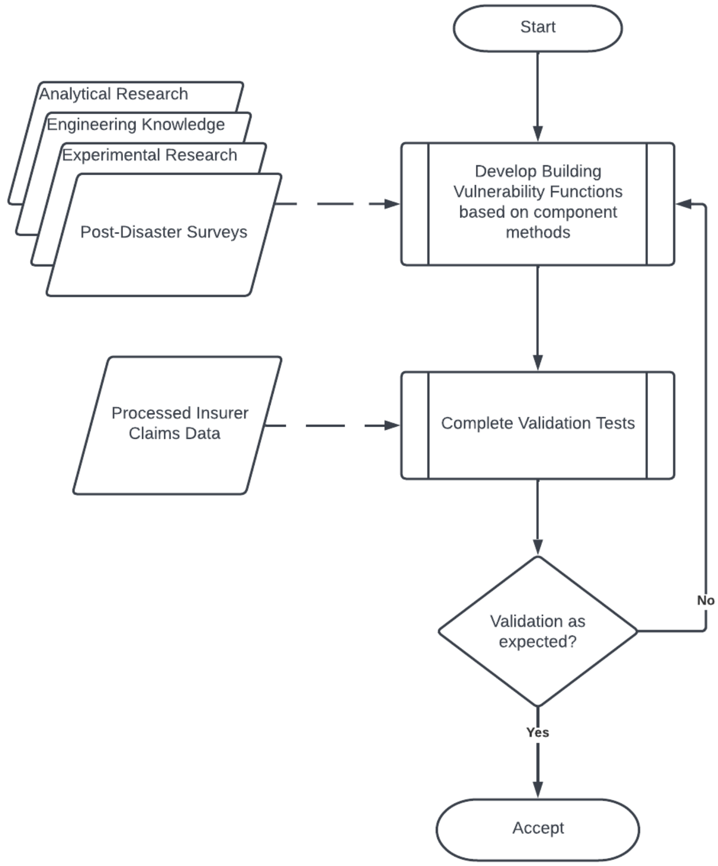


Figure 35 - Development and implementation of hurricane vulnerability functions

3. Describe the nature and extent of actual insurance company hurricane claims data used to develop the building hurricane vulnerability functions. Describe in detail the breakdown of data into number of policies, number of insurers, dates of hurricane loss, amount of hurricane loss, and amount of dollar exposure; separated into personal residential, commercial residential, and manufactured homes.

KCC has been provided with detailed claims data from 11 insurance companies for 28 historical hurricanes going back to 2004. Fifteen of these hurricanes impacted the state of Florida. The number of policies and the amount of exposure by policy type is summarized in the following table.

Policy Type	Number of Policies	Exposure ($)
Personal Residential	61,557,330	32,600,581,567,143
Commercial Residential	20,571,234	2,427,826,378,042
Manufactured Homes	140,600	13,721,089,235

Table 7 - Number of policies and amount of dollar exposure used for detailed claims analyses

The amount of loss data analyzed can be separated by line of business as follows: $7.1 billion for personal residential, $469 million for commercial residential and $44 million for manufactured homes.

For one insurer, the claims data was provided by five-digit ZIP Code, and for all other insurers, individual claims were provided by location along with the contemporaneous policy-level data. KCC engineers mapped each claim amount to the policy generating that claim so the claims data could be analyzed separately by construction, occupancy, year built, and other property characteristics. Most of the claims were also identified by coverage. The contemporaneous exposure data was provided for all policies in force on the date of the storm (not just those with claims), which is required for estimating the MDRs (mean damage ratios) by wind speed.

For each storm shown below, each claim was matched to the wind speed experienced at that location according to the modeled and validated high-resolution wind footprints. The claims MDRs were then compared to the modeled MDRs by wind speed to check the accuracy of the building vulnerability functions. In general, the engineering-based vulnerability functions performed well, and the claims data did inform a few refinements to the vulnerability functions.

Storm Name	Storm Year	Storm Name	Storm Year
Charley	2004	Matthew	2016
Frances	2004	Harvey	2017
Ivan	2004	Irma	2017
Jeanne	2004	Nate	2017
Dennis	2005	Florence	2018
Katrina	2005	Michael	2018
Rita	2005	Barry	2019
Wilma	2005	Dorian	2019
Gustav	2008	Delta	2020
Ike	2008	Isaias	2020
Irene	2011	Laura	2020
Isaac	2012	Sally	2020
Sandy	2012	Zeta	2020
Hermine	2016	Ida	2021

Table 8 - Hurricanes included in KCC estimated claims and loss validation

4. Describe any new insurance company hurricane claims datasets reviewed since the currently accepted hurricane model.

KCC has been provided with several new detailed claims datasets since the currently accepted hurricane model, totaling $1.9 billion of hurricane loss. Additionally, KCC has received updated claims information for several datasets since the currently accepted model submission. The new insurance claims datasets consist of 33 new datasets from seven insurance companies across six historical hurricanes.

Policy Type	Number of Policies	Exposure ($)
Personal Residential	27,197,687	16,823,617,290,199
Commercial Residential	10,669,722	1,300,544,470,628
Manufactured Homes	0	0

Table 9 - Number of new policies and new amount of dollar exposure used for detailed claims analyses

5. Describe the assumptions, data (including insurance claims data), methods, and processes used for the development of the building hurricane vulnerability functions.

KCC engineers use a component-based methodology to develop the building vulnerability functions. Each base vulnerability function is representative of a specific construction and occupancy type. Each distinct combination of construction and occupancy type has a base vulnerability function.

In the engineering analysis, a building is assumed to be composed of several components, such as the roof covering, openings, and roof-to-wall connections, that have distinct damage modes. A damage function is developed for each component by considering direct and progressive damages while addressing the complex interaction between the building components. The component damage functions thus developed are then combined to produce the vulnerability function for the entire building structure. Scientific literature, post-disaster survey observations, experimental aerodynamic load and component resistance data, and engineering judgment are the backbone of this methodology. The theory behind this approach is well documented in published engineering studies including Unanwa et al. (2000), Cope (2004), Li and Ellingwood (2006), and Huang et al. (2015).

This methodology provides an understanding of building performance during a hurricane along with the contribution of individual building components to the vulnerability of the entire building. This enables different combinations of components to be weighted to create vulnerability functions for rare or unique building configurations that will be consistent with engineering principles. The assumptions employed in this method are validated using insurance claims data from past hurricanes.

Once the base vulnerability functions are developed, relativities between other building characteristics, such as the number of stories, year built, and region, for the various construction types are established using scientific literature, post-disaster survey observations and reports, engineering judgment, and wind engineering analysis. The base vulnerability functions are then broken down into the distinct combinations of all primary building characteristics. KCC engineers thoroughly inspect each vulnerability function during the development process to ensure consistency and logical relativities. Moreover, the process of vulnerability function development and the vulnerability functions themselves have been peer reviewed internally and externally by experts in structural engineering.

6. Describe the treatment of uncertainties associated with the building hurricane vulnerability functions.

The vulnerability functions provide estimates of the mean damage in response to 1-minute sustained wind speeds experienced at the location. For each structure type (construction, occupancy, year built, etc.) there are four vulnerability functions representing the Mean Damage Ratios (MDRs) for building, appurtenant structure, contents, and time element coverages.

The MDRs from the vulnerability functions are expressed as percentages of the coverage replacement values. For each MDR, the RiskInsight® Financial Module considers the full range of damage levels around the mean (the secondary uncertainty) with empirical distributions. Empirical distributions are chosen because actual hurricane losses do not exhibit a simple central behavior, and these distributions better correlate with reality and actual claims experience.

RiskInsight® represents the secondary uncertainty distributions as discrete bins, where each bin corresponds to the probability of experiencing a specific damage level, and every distribution includes a non-zero probability mass at 0 and at 100 percent loss. Secondary uncertainty is always considered in the loss calculations.

There are 100,000 secondary uncertainty distributions for MDRs ranging from .00001 to 1. KCC scientists developed a complex iterative process to create these distributions so that the following mathematical constraints are met:

- The probabilities add up to 1
- The MDRs are maintained

- The probability mass at 0 falls as the MDR increases
- The probability mass at 1 rises as the MDR increases

The diagram below illustrates the implementation of secondary uncertainty in the KCC US Hurricane Reference Model.

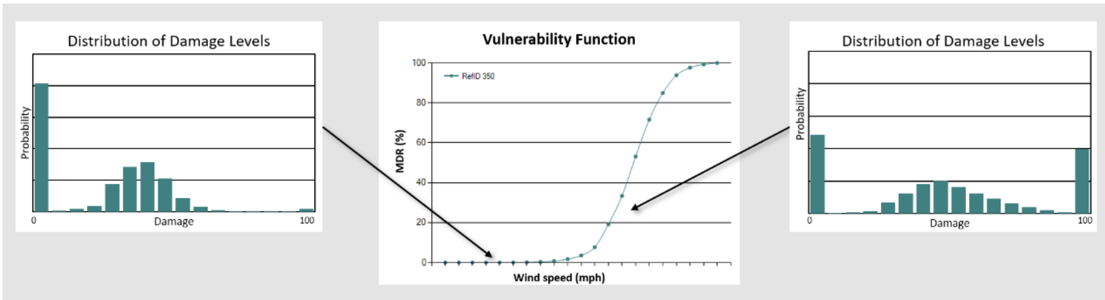


Figure 36 - Illustration of secondary uncertainty for different MDRs

7. ***Summarize post-event site investigations, including the sources, and provide a brief description of the resulting use of these data in the development or validation of building hurricane vulnerability functions.***

Post-disaster surveys and site inspections provide important information for vulnerability function development. KCC professionals have decades of collective experience in hurricane post-event data collection, starting with Hurricane Hugo in 1989 and encompassing most of the significant landfalling hurricanes since then, including Andrew, Katrina, Rita, Wilma, Ike, and Sandy. The most recent hurricane post-event damage surveys conducted by KCC engineers include Matthew, Harvey, Irma, Maria, Florence, Michael, Laura, Ida, and Ian. Four types of information are collected and analyzed post-event.

Neighborhood damage surveys. KCC engineers have implemented a standardized process and forms for collecting information on claim frequency and severity by wind speed regime. Areas are selected to cover the range of wind speeds experienced by the storm. Neighborhoods with similar properties and construction practices are surveyed to determine how many properties experienced damage and the distribution of damage levels. The information collected using this method can be analyzed statistically.

Detailed site investigations. KCC engineers select a sample of properties covering different construction and occupancy types to conduct more detailed damage observations—typically covering the interior as well as the exterior of the properties. These observations provide additional insight into the nature of the damage and cause of loss.

Site visits with claims adjusters. Since the MDRs represent the cost to repair the damage divided by the replacement cost of the properties, the vulnerability functions must reflect the claims handling practices of insurers. KCC engineers travel with client insurer claims adjusters to damaged properties to observe how the claims costs are estimated and the claims are settled.

Review of desktop claims systems and files. Reviewing a larger number of claims provides more insight into the costs of more frequent repairs required after a hurricane and enables the verification of material and labor costs across a large volume of claims. Damage observed in the field can then be validated against the ultimate paid claim.

8. ***Describe the categories of the different building hurricane vulnerability functions. Specifically, include descriptions of the building types and characteristics, building height, number of stories, regions within the state of Florida, year of construction, and occupancy types for which a unique building hurricane vulnerability function is used. Provide the total number of building hurricane vulnerability functions available for use in the hurricane model for personal and commercial residential classifications.***

There are about 4,200 total building vulnerability functions in Florida for personal and commercial residential classifications based on the following primary building characteristics:

- Construction
- Occupancy
- Number of stories
- Year built
- Location/Region

Primary construction materials influence a structure's potential vulnerability when exposed to hurricane winds. Manufactured homes, light metal, and wood frame structures are generally more vulnerable than buildings constructed of concrete and steel. The following construction types form the base construction types.

Construction Type	Description
Residential Buildings, Apartments, and Condominiums	
Wood Frame	Buildings where the exterior walls and roof frame are constructed using wood studs. The wall sidings are constructed using wood or other combustible materials, including wood iron-clad, stucco on wood, or plaster on combustible supports. Also includes aluminum or plastic siding over frame.
Masonry Veneer	Buildings where the exterior walls and roof frame are constructed using wood studs. The exterior wall siding is primarily composed of non-combustible materials, including non-load bearing concrete, masonry, or brick.
Unreinforced Masonry	Buildings where the exterior (and some interior) walls are load-bearing and constructed of masonry, non-combustible, or fire resistive materials such as adobe, brick, concrete, gypsum block, hollow concrete block, stone, tile or other non-combustible materials. No steel reinforcement. The roofs are typically made of wood frame construction.
Reinforced Masonry	Buildings where the exterior walls are load-bearing and constructed of masonry, non-combustible, or fire resistive materials such as adobe, brick, concrete, gypsum block, hollow concrete block, stone, tile or other non-combustible materials. The wall material is reinforced in-plane and out-of-plane with steel bars. The roofs are typically made of wood frame construction.
Reinforced Concrete	Buildings where the beams and columns are constructed of reinforced concrete. Infill walls are typically constructed of masonry. Floors are constructed of concrete slabs, steel or wooden joists.
Steel	Buildings where the beams and columns are constructed using steel.
Light Metal	Buildings constructed of light gauge steel frames. The walls can be constructed of brick veneer, EIFS, plywood, corrugated metal sheets, etc. Roof covering can be corrugated steel or similar to wood frame buildings. Here columns and beams are not rigidly connected and do not act as a frame. Lateral resistance is made by braces.
Masonry	Used when information on wall reinforcement in Masonry Buildings is not provided and represented by a weighted average of Reinforced Masonry and Unreinforced Masonry.
Unknown	Represented by an exposure-weighted average of the above.

Construction Type	Description
Manufactured homes	
Mobile Home -Fully Tie-Downs	Mobile/Manufactured Housing, which has anchors and tie-downs as required by Section 320.8325, Florida Statutes, and Florida Administrative Code rules promulgated thereunder.
Mobile home - Partial Tie-Downs	Mobile/Manufactured Housing, which has anchors and tie-downs but not to the level required by Section 320.8325, Florida Statutes, and Florida Administrative Code rules promulgated thereunder.
Mobile home - No Tie-Downs	Mobile home is not tied down.
Unknown	Represented by an exposure-weighted average of the above.

Table 10 - Construction types in the KCC US Hurricane Reference Model applicable to personal and commercial residential classifications

Occupancy type is also an indicator of building vulnerability. This is mainly due to differences in architectural requirements, construction practices and level of engineering attention. Site built homes are grouped into either single-family home, multi-family home, or condo unit (owner or condo unit-association).

The number of stories of a building impacts its vulnerability. Wind speed increases with height exposing taller buildings to higher wind pressure; however, taller buildings are typically designed and constructed under more stringent requirements and receive more attention to detail than their low-rise counterparts. KCC US Hurricane Reference Model height classifications are shown in the table below.

Description	Number of Stories
Single Family Home	1
	2
	≥ 3
	Unknown
Manufactured/Mobile Home	1
	2
	Unknown
Multi-Family homes, apartments, and Condominiums	1
	2
	3 - 6
	7 - 12
	≥ 13
	Unknown

Table 11 - Height bands for personal and commercial residential classifications

Post-disaster surveys and claims data consistently confirm that newer properties, particularly residential structures, are less vulnerable to strong winds than older properties. This is due not only to updated building codes, but also to improvements in construction techniques and building materials and the impact of aging. Over time, more stringent building codes require new properties to be built with wind and storm surge mitigation features that should reduce potential losses, such as window protection and wind-rated roof shingles. Structural aging also impacts both the building component resistances and the structural integrity of the building. Site-built homes are grouped into one of the year-built bands shown in the table below. These bands are selected to capture major changes in building design codes, particularly the Florida Building Code (FBC). Different year-built bands are used for manufactured homes since they are designed as per the requirements of the US Department of Housing and Urban Development (HUD). The year-built bands and vulnerability used for manufactured homes capture the evolution of the HUD design requirements, particularly the requirements on tie-down anchors.

Year-built band	
Site-Built	Manufactured Homes
<1995	<1976
1995-2001	1976 - 1994
2002-2011	1995 - 2008
>2011	>2008
Unknown	Unknown

Table 12 - Year-built bands for personal and commercial residential classifications in Florida

Different regions of Florida exhibit different vulnerabilities due to factors including difference in code stringency and level of enforcement. The regional differences in design for wind speed and debris impacts set forth by the FBC are used as guides for categorizing Florida into different regions. In the KCC US

Hurricane Reference Model, Florida is categorized into four regions: High Velocity Hazard Zone (HVHZ), Wind-Borne Debris Region (WBDR), Central, and North Florida.

9. Describe the process by which local construction practices and statewide and county building code adoption and enforcement are considered in the development of the building hurricane vulnerability functions.

The KCC vulnerability functions vary by region within the state of Florida and account for the stringency of design wind speeds and debris impact requirements in those different regions. Historically, Miami-Dade and Broward Counties have experienced the most intense hurricanes, and in recognition of this fact, the most stringent building codes in the state have been implemented in those regions. In those counties, which are referred to as the High Velocity Hazard Zones, relatively high design wind speeds and more stringent impact resistance are in place. Moreover, design for terrain exposure C is only allowed.

The minimum design wind speeds requirements, High-velocity Hazard Zones (HVHZ) requirements, and Wind-Borne Debris Region (WBDR) requirements in the FBC are used as guides for categorizing Florida into four different vulnerability regions. The differences in vulnerability in those different regions is corroborated by insurance claims data and post-disaster surveys. Changes in the building codes over time are accounted for by the appropriate year-built bands.

10. Describe the relationship between building structure and appurtenant structure hurricane vulnerability functions and their consistency with insurance claims data.

In the KCC US Hurricane Reference Model, the losses for appurtenant structures are calculated separately from other coverages. The default construction code will be the same as that used for the main building unless a separate vulnerability function is selected.

The relationship between building and appurtenant structure vulnerability functions used in the KCC Hurricane Reference Model is consistent with insurance claims data.

11. Describe the assumptions, data (including insurance claims data), methods, and processes used to develop building hurricane vulnerability functions when:

a. residential construction types are unknown, or

b. one or more primary building characteristics are unknown, or

c. one or more secondary characteristics are known, or

d. building input characteristics are conflicting.

Separate building vulnerability functions have been developed for construction, region, year built, occupancy, and number of stories. Beside the distinct applicable combinations of those characteristics, vulnerability functions for cases where one or more of these building attributes is unknown/missing were developed by exposure weighted-averaging the known vulnerability functions to create composite vulnerability functions to handle cases where one or more attribute is unknown.

Prior to running a loss analysis, exposure information must be imported into RiskInsight. During import, RiskInsight performs validation on all input exposure attributes, and the valid data types and input options are detailed in the *RiskInsight OEF2 Database Schema* user documentation. An initial level of validation ensures that on an individual risk characteristic resolution, such as window protection, only valid and non-conflicting information is entered. For example, for an individual building, only one option for window protection is permitted, such as “Engineered Shutters,” and the exposure import process will not allow input of two conflicting values, such as both “No protection” and “Engineered Shutters.” An additional validation is performed to ensure combinations of risk characteristics do not conflict, such as a ten-story wood frame building. All exposure locations contained in the input file that do not pass the validation rules due to conflicting input characteristics are reported in the Exposure Import Log, are not imported into RiskInsight, and are not available for loss analysis.

12. Identify the one-minute average sustained windspeed and the windspeed reference height at which the hurricane model begins to estimate damage.

A 1-minute average sustained wind speed of 25 mph at a 10-meter height is the start of damage estimation.

13. Describe how the duration of windspeeds at a particular location over the life of a hurricane is considered.

The building vulnerability functions and MDRs are based on the maximum wind speed experienced at each location. Duration of wind is not explicitly modeled. Analyses of insurer claims data do not provide evidence of a duration effect.

14. Describe how the hurricane model addresses wind-borne missile impact damage and water infiltration.

Wind-borne missile impact damage and water infiltration are both accounted for implicitly in the vulnerability functions to the extent that this damage is included in the insurer claims data. Secondary modifiers can also be used to explicitly account for mitigation features designed to reduce the damage from wind-borne missiles and water infiltration.

15. Provide a completed Form V-1, One Hypothetical Event. Provide a link to the location of the form.

Form V-1: One Hypothetical Event

V-2 Derivation of Contents Hurricane Vulnerability Functions

A. Development of the contents hurricane vulnerability functions shall be based on at least one of the following: (1) insurance claims data, (2) tests, (3) rational engineering analysis, and (4) post-event site investigations. Any development of the contents hurricane vulnerability functions based on rational engineering analysis, post-event site investigations, and tests shall be supported by historical data.

The contents vulnerability functions were developed based on engineering judgement informed by rational structural analysis and post-event damage surveys. Vulnerability functions were then validated using insurance claims data.

B. The relationship between the hurricane model building and contents hurricane vulnerability functions shall be consistent with, and supported by, the relationship observed in historical data.

The relationship between modeled building vulnerability functions and modeled contents vulnerability functions is reasonable and has been validated with insurance claims data. The modeled MDRs are in good agreement with MDRs developed from claims data.

Disclosures

1. Describe any modifications to the contents vulnerability component in the hurricane model since the currently accepted hurricane model.

The KCC contents vulnerability functions are derived from building vulnerability functions using contents damage to building damage relationships, and these relationships have not been modified since the currently accepted hurricane model. The only modifications to contents vulnerability functions are due to modifications of the building vulnerability functions described in V-1, Disclosure 1.

2. Provide a flowchart documenting the process by which the contents hurricane vulnerability functions are derived and implemented.

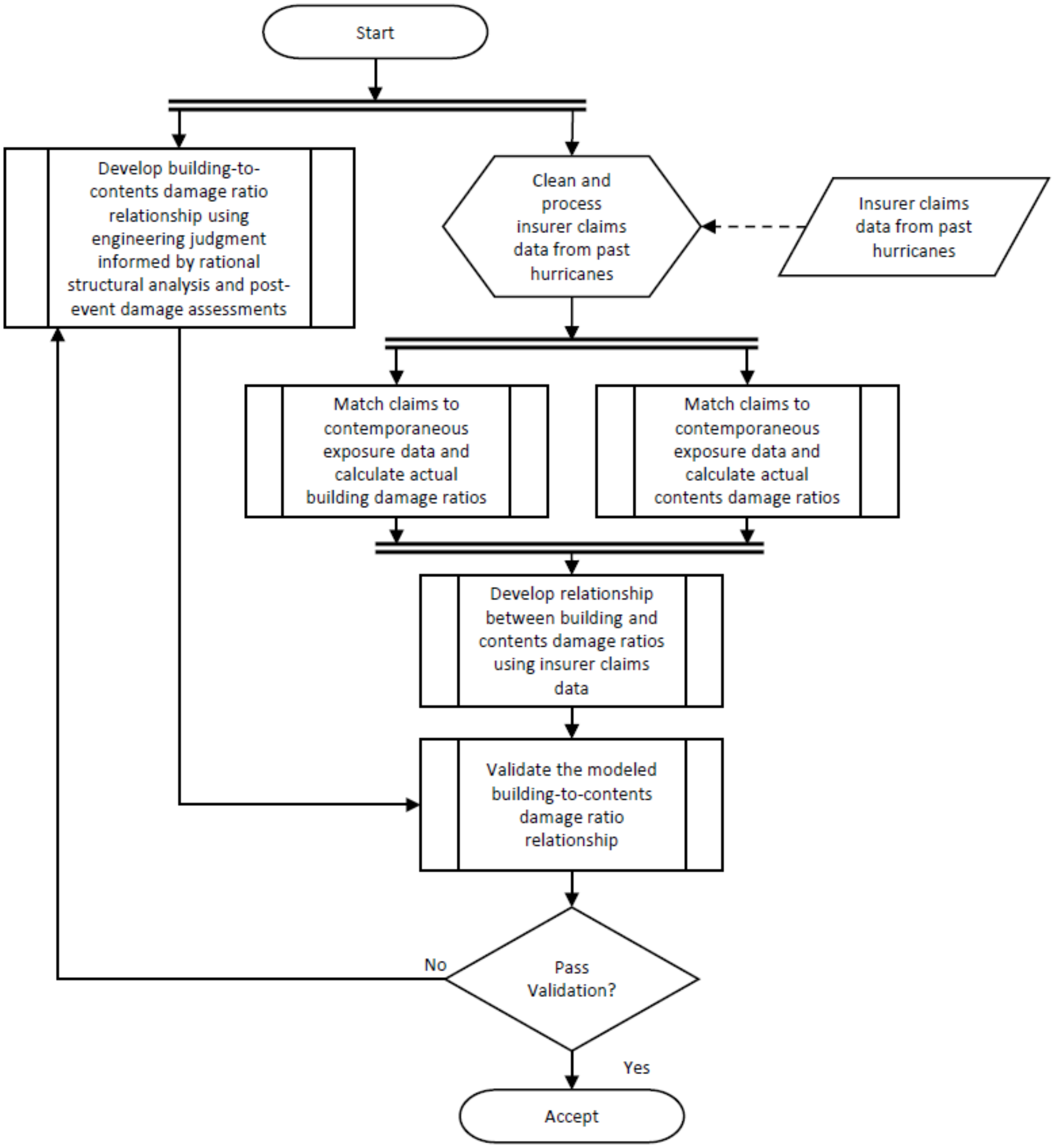


Figure 37 - Derivation and implementation of contents vulnerability functions

3. Describe the assumptions, data, methods, and processes used to develop and validate the contents hurricane vulnerability functions.

The process of developing the contents vulnerability functions is shown in Figure 37. Contents damage depends on the level of damage to the building; hence, the KCC US Hurricane Reference Model uses a building-to-contents relationship to estimate the contents losses. Contents are damaged only after a threshold level of building damage is reached.

The initial building-to-contents relationship was developed based on engineering judgement informed by rational structural analysis and post-event damage surveys. Insurance claims data were then used to validate the relationship between building and contents damage.

4. Provide the total number of contents hurricane vulnerability functions. Describe whether different contents hurricane vulnerability functions are used for personal residential, commercial residential, manufactured homes, unit location for condo owners and apartment renters, and various building classes.

There are about 4,200 content vulnerability functions applied to contents. For each combination of distinct building characteristics, a unique building vulnerability function is developed from which the contents vulnerability function is derived. As a result, different contents vulnerability functions correspond to different building characteristics.

5. Describe the relationship between building structure and contents hurricane vulnerability functions.

Contents damage depends on the damage to the building structure. Therefore, the contents hurricane vulnerability functions correspond to building vulnerability functions so that as the building damage increases (or decreases) so does the contents damage. However, the relationship between building damage and contents damage is not constant. A smaller proportion of the contents are damaged at lower levels of building damage because at low levels of building damage the envelope elements are still intact and the damage to contents is minimal. As the building damage increases, the contents become more vulnerable to damage, and the proportion of contents damaged increases. Because some contents are salvageable or non-destructible, when a building sustains complete damage, the contents damage ratio is less than 100%. This relationship is confirmed by analyses of insurance claims data.

V-3 Derivation of Time Element Hurricane Vulnerability Functions

A. Development of the time element hurricane vulnerability functions shall be based on at least one of the following: (1) insurance claims data, (2) tests, (3) rational engineering analysis, and (4) post-event site investigations. Any development of the time element hurricane vulnerability functions based on rational engineering analysis, post- event site investigations, and tests shall be supported by historical data.

The time element vulnerability functions were developed based on engineering judgement informed by rational structural analysis and post-event damage surveys. Vulnerability functions were then validated using insurance claims data.

B. The relationship between the hurricane model building and time element hurricane vulnerability functions shall be consistent with, and supported by, the relationship observed in historical data.

The time element vulnerability functions are derived from building vulnerability functions using time element damage to building damage relationships. These relationships were derived based on analytical analysis and expert judgement and have been verified using insurance claims data.

C. Time element hurricane vulnerability function derivations shall consider the estimated time required to repair or replace the property.

The time element vulnerability functions in the KCC US Hurricane Reference Model were derived by taking into account both event-related losses (this includes indirect time element losses such as evacuation and processing times), and time required to repair/replace the damage to the associated property. Hence, the KCC time element vulnerability functions explicitly capture the estimated time to repair or replace the damaged properties.

D. Time element hurricane vulnerability functions shall include time element hurricane losses associated with damage to the infrastructure caused by a hurricane.

The KCC time element damage to building damage relationships used to derive time element vulnerability functions have been verified using insurance claims data, which inherently include the losses generated by these sources. Hence, the KCC time element losses due to wind, missile impact, flood, and damage to infrastructure are included in the time element vulnerability functions.

Disclosures

1. Describe any modifications to the time element vulnerability component of the hurricane model since the currently accepted hurricane model.

The KCC time element vulnerability functions are derived from building vulnerability functions using time element damage to building damage relationships, and these relationships have not been modified. The only modifications to time element vulnerability functions are due to modifications of the building vulnerability functions described in V-1, Disclosure 1.

2. Provide a flowchart documenting the process by which the time element hurricane vulnerability functions are derived and implemented.

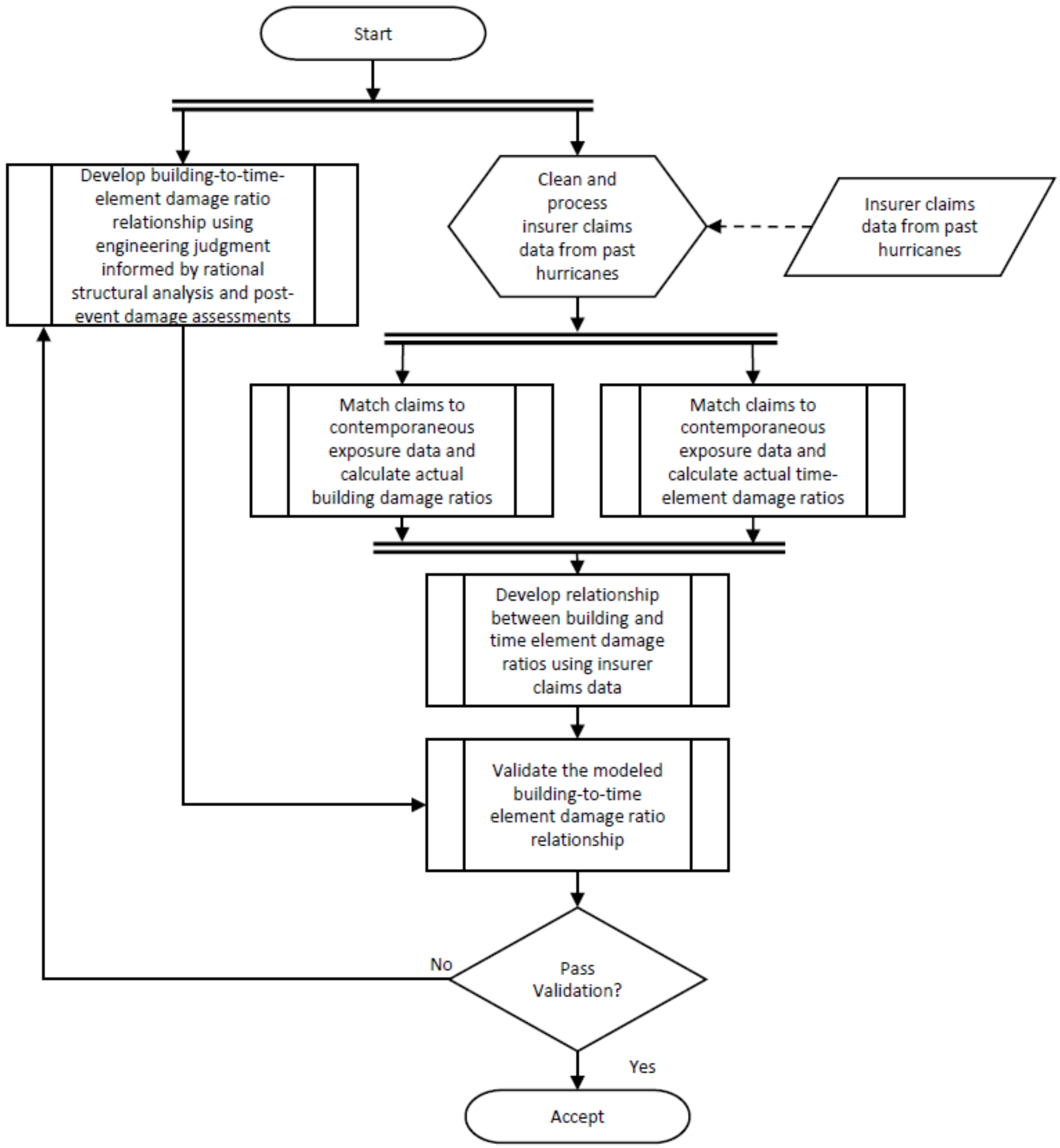


Figure 38 - Derivation and implementation of the time element vulnerability function

3. Describe the assumptions, data, methods, and processes used to develop and validate the time element hurricane vulnerability functions.

The process for developing the hurricane vulnerability functions for time element losses is shown in Figure 38. The central assumption used in the derivation of time element losses vulnerability functions is that time element related losses are proportional to building damage related losses. Hence, building-to-time-element relationships are developed and used to derive the time element vulnerability functions from the building vulnerability functions. Losses causing time element claims can be divided into direct losses (time to repair a damaged building) and indirect losses (e.g., infrastructure disruption, mandatory evacuation, claims processes). Both losses are captured in the KCC US Hurricane Reference Model, which uses a building-to-time-element relationship to estimate the time element losses.

The initial building-to-time-element relationship was developed based on engineering judgement informed by rational structural analysis, cost and repair analysis, and post-event damage surveys. Insurance claims data were then used to validate the relationship between buildings and time element losses.

4. Describe how time element hurricane vulnerability functions take into consideration the damage to local and regional infrastructure.

One of the components reliant on engineering judgement is the effect that local and regional infrastructure disruption has on the amount of time between a building being uninhabitable and occupants returning. This effect could be independent of the repair time (for example, a building with no damage but located in an area with infrastructure disruption) or coincide with the repair time (such as if infrastructure disruption delayed repairs to a damaged building). The time element vulnerability functions do not explicitly distinguish between the direct loss (repair time) and indirect loss (infrastructure disruption due to storm surge, flood, and wind); however, since insurance claims data from historical events are used to validate the time element vulnerability functions, the effects of local and regional infrastructure disruption, which are included in the insured claims data sets, are implicitly accounted for by the time element vulnerability functions.

5. Describe the relationship between building structure and time element hurricane vulnerability functions.

Time element vulnerability functions reflect the time required for a building to be repaired, which is largely dependent on the building's damage state. Therefore, the time element vulnerability functions generally follow the building vulnerability functions so that as the building damage level increases (or decreases) so does the time element. Additional factors, such as infrastructure disruption, also impact the time element losses and are incorporated by validating the time element vulnerability functions with insurer claims data.

Similar to the relationship between building damage and contents damage, for low level building damage states, the time element increases at a relatively slow rate, and as the building damage states become more severe, the time element increases at a faster rate. At lower building damage states, the repairs are not significant enough to force the occupants to leave the dwellings, and most of the time element losses are due to indirect losses, such as infrastructure disruption and mandatory evacuations. However, as the building damage increases, the repair times become progressively longer.

V-4 Hurricane Mitigation Measures and Secondary Characteristics

A. Modeling of hurricane mitigation measures to improve a building's hurricane wind resistance, the corresponding effects on hurricane vulnerability and associated uncertainties shall be theoretically sound and consistent with fundamental engineering principles. These measures shall include fixtures or construction techniques that affect the performance of the building and the damage to contents and shall include:

- ***Roof strength***
- ***Roof covering performance***
- ***Roof-to-wall strength***
- ***Wall-to-floor-to-foundation strength***
- ***Opening protection***
- ***Window, door, and skylight strength.***

The impact of mitigation measures and secondary characteristics on a building's hurricane wind resistance is captured through the use of modification factors that increase or decrease the building vulnerability functions. The default vulnerability functions are those developed for the distinct combinations of primary building characteristics described in Standard V-1. The secondary characteristics relevant to building hurricane vulnerability include roof strengths, roof covering, roof-to-wall connections, wall-to-floor-to-foundation connections, opening protection, and window, door, and skylight strengths. For each secondary characteristic, detailed wind engineering analysis, supported by post-disaster damage survey data, and engineering judgement are used to determine its effects on overall building performance.

B. The modeling organization shall justify all hurricane mitigation measures and secondary characteristics considered by the hurricane model.

The hurricane wind mitigation measures and building secondary characteristics identified to impact building performance have been selected based on the analysis of the aerodynamic sensitivity of buildings (e.g., Stathopoulous and Baskarakan, 1987; Ho et al., 2005; Kopp et al., 2005; Habte et al., 2017), experiments on the performance of buildings under high wind speeds (Habte et al., 2015, 2017; Li, 2012), and observations of damage modes during post-disaster damage surveys. The mitigation measures and secondary building characteristics included in the KCC US Hurricane Reference Model have been well documented with respect to their impacts on building performance during hurricanes.

C. Application of hurricane mitigation measures that affect the performance of the building and the damage to contents shall be justified as to the impact on reducing damage whether done individually or in combination.

The application of hurricane mitigation measures is justified by sound wind and structural engineering analysis. Each mitigation measure impacts the vulnerability function of a related building component(s) and consequently modifies the composite building vulnerability function. The effect of each hurricane mitigation measure is estimated separately. If more than one mitigation measure is present, the effects of multiple mitigation measures are combined systematically, as described in Standard V-4, Disclosure 6. The application of individual or a combination of hurricane mitigation measures and the resulting vulnerability functions are reasonable and in agreement with engineering principles.

D. ***Treatment of individual and combined secondary characteristics that affect the performance of the building and the damage to contents shall be justified.***

The effect of each secondary characteristic on building performance is derived using wind engineering analysis. The treatment of individual or a combination of secondary characteristics and the resulting building and contents vulnerability functions are in agreement with rational structural analysis, post-disaster damage survey results, and insurer claims data.

Disclosures

1. Describe any modifications to hurricane mitigation measures and secondary characteristics in the hurricane model since the currently accepted hurricane model.

Hurricane mitigation measures and secondary characteristics have not been modified since the currently accepted hurricane model.

2. Describe the procedures used to calculate the impact of hurricane mitigation measures and secondary characteristics, including software, its identification, and current version. Describe whether or not such procedures have been modified since the currently accepted hurricane model.

The procedure used to derive the impact of mitigation measures and secondary characteristics has not changed since the currently accepted hurricane model. KCC engineers use the component-based methodology to develop the building vulnerability functions and to calculate the impact of mitigation measures and secondary characteristics. The development of hurricane mitigation and secondary characteristic modifiers is based on extensive wind engineering analyses of the wind load that a building and its components experience as well as the wind resistance of building components at different wind speeds.

The mitigation measures and secondary building characteristics included in the KCC US Hurricane Reference Model are first categorized into one of two categories: 1) those that impact the aerodynamic load a structure experiences, for example the roof slope or roof shape, and 2) those that impact the resistance of the building to wind pressure and debris impact load, for example the roof cover type or age. Using the aerodynamic load/resistance (ALR) component method, the impact of each secondary characteristic is estimated using the resistance of a building component (such as changing the uplift resistance of the roof deck depending on the roof deck attachments) or the change in wind loading (for example, with different roof shapes). The secondary characteristics can increase or decrease the building vulnerability functions, and the effects will vary with wind speed.

The software identification used to calculate the impact of mitigation measures and secondary characteristics is RiskInsight 4.11.1.7. The software has not been updated since the previous-accepted hurricane model associated with the impact of mitigation measures and secondary characteristics.

3. Provide a completed Form V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage. Provide a link to the location of the form.

Form V-2: Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage

4. Provide a description of the hurricane mitigation measures and secondary characteristics used by the hurricane model, whether or not they are listed in Form V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage.

The following tables summarize the secondary characteristics and hurricane mitigation measures included in the KCC US Hurricane Reference Model.

Secondary Characteristic / Mitigation Measures	Options	In Form V2	Description
Roof Cover Age	> 18 years		New roof coverings perform better than older roof coverings.
	10 - 18 years		
	< 10 years		
	Unknown		
Roof Cover Type	Shingle, Class D		The type of roof covering impacts the uplift capacity and debris impact resistance of the roof. Hurricane rated shingles, tiles with adhesive attachment, and standing seam metal roofs are among the strongest roof coverings. Unrated shingles and clay tiles with mortar attachment are the most vulnerable to high wind speeds. The shingle ratings specified are according to the ASTM D7158 testing protocol.
	Shingle, Class F		
	Shingle, Class G		
	Shingle, Class H	✓	
	Shingle, Hurricane Rated		
	Shingle, Not Hurricane Rated		
	Shingle, Unknown		
	Tile, Clay, Mortar Attachment		
	Tile, Clay, Adhesive Attachment		
	Tile, Concrete, Mortar Attachment		
	Tile, Concrete, Adhesive Attachment		
	Tile, Concrete, Mechanical/Nail Attachment		
	Tile, Unknown		
	Light Metal Panels		
	Standing Seam Metal Roof	✓	
	Built Up Roof		
	Single Ply Membrane	✓	
	Wood Shakes		
	Unknown		
Roof Decking	Plywood - 6d Nails @ 6/12		The type of roof decking material and the nailing pattern significantly affects the damageability of buildings by hurricane winds. Damage to roof decking coincides with damage to roof covering, but it also exposes the building interior to damage and can lead to total
	Plywood - 8d Nails @ 6/12		
	Plywood - 8d Nails @ 6/6	✓	
	Plywood - Unknown		
	OSB - 6d Nails @ 6/12		
	OSB - 8d Nails @ 6/12		
	OSB - 8d Nails @ 6/6		
	OSB - Unknown		
	Wood Planks		

Secondary Characteristic / Mitigation Measures	Options	In Form V2	Description
	Metal Deck		loss. Wood planks, metal decks, and wood decks with 8d nails are the least vulnerable while smaller nails or scattered nailing can result in weaker roof decks.
	Unknown		
Roof-to-Wall Connections	Anchor Bolts		Roof-to-wall connections are vital in maintaining the load path continuity from the roof to the walls. Damaged roof-to-wall connections will lead to total roof loss and expose the building interior to rain and wind. Nails without any straps are among the weakest, while wrap type roof-to-wall connections have the highest uplift resistance.
	Toe-nail		
	Clips/Ties	✓	
	Single Wrap	✓	
	Double Wrap		
	Unknown		

Table 13 - Secondary characteristics and mitigation measures relating to roof strength

Secondary Characteristic / Mitigation Measures	Options	In form V-2	Description
Roof Geometry	Shed		For equal roof pitches, hip roofs experience the least uplift suction forces, followed by gable and flat roofs. The differences could be as high as 40%, and this characteristic makes hip roofs less damageable during high wind events. Although it depends on the wind direction, shed roofs can be assumed as equivalently vulnerable as flat roofs. Mansard and Complex roofs fall between gable and hip roofs. Roof geometry mainly impacts the wind uplift experienced by roof covering, roof decking, and roof-to-wall connections.
	Flat Roof		
	Gable - With gable end bracing	✓	
	Gable - No gable end bracing		
	Hip	✓	
	Mansard		
	Complex		
	Gambrel		
	Pyramid		
	Stepped		
	Unknown		

Secondary Characteristic / Mitigation Measures	Options	In form V-2	Description
Parapets	Parapet > 5’		Parapets can either increase or decrease the wind loading on roofs predominantly near roof corners and edges, which are the regions where damage typically starts. Short parapets (i.e., less than 5’ height) have experimentally been shown to increase suction pressure by up to 15%, while tall parapets decreased the corner suction pressure by up to 50%.
	Parapet < 5’		
	Parapet – Unknown		
	No Parapet		
	Unknown		
Roof Slope	Slope < 10 deg		For the same roof shape, as the roof slope increases, the overall uplift suction at the roof corners and edges decreases. Roof slopes less than 10° have similar aerodynamic behaviors, and a steeper roof slope leads to a significant reduction in suction pressures at the leading edge of the building because of the earlier flow reattachment.
	Slope 10 – 20 deg		
	Slope 20 – 30 deg		
	Slope > 30 deg		
	Unknown		
Roof Top Equipment	Yes – Adequately Fastened		Chimneys and roof top equipment can slightly affect the aerodynamic load on a roof as they change the geometry of the roof. Additionally, they can weaken the roof covering if they are not braced properly.
	Yes – Inadequately Fastened		
	Yes – Unknown		
	No		
	Unknown		

Table 14 - Secondary characteristics and mitigation measures relating to building geometry

Secondary Characteristic / Mitigation Measures	Options	In Form V-2	Description
Skylight	No Skylight		The presence of skylights can increase the vulnerability of a building unless they are protected during hurricanes. A skylight breach exposes the building interior to direct damage from rain and wind pressures.
	Skylight Cover	✓	
	No Skylight Cover		
	Skylight – Unknown Cover		
	Unknown		
Window Protection	Window Shutters	✓	Window shutters are one of the most important mitigation measures. If a window is breached, the internal pressure will induce additional pressure on the building envelope. Additionally, the building interior will be subjected to heavy damage from rain and wind.
	No window Shutter		
	Engineered Shutters		
	Non-engineered Shutters		

Secondary Characteristic / Mitigation Measures	Options	In Form V-2	Description
	Unknown		
Door Protection	Has Covering	✓	Door protection is most important for doors that are not rated for impact. Door damage from debris impact can have the same devastating effects as a window breach.
	No Covering		
	Unknown		
Door Type	Single-Double/Impact Rated	✓	The door type affects the resistance of doors to high wind pressure during hurricanes. Sliding doors have been observed to be most susceptible to high pressures. Impact rated doors are less vulnerable to debris impact damage than those that are not impact rated.
	Single-Double/Not Impact Rated		
	Single-Double/Unknown		
	Sliding/Impact Rated	✓	
	Sliding/Not impact Rated		
	Sliding/Unknown		
	Unknown		
Garage Door	Impact Rated	✓	Garage doors rated for impact perform better than those not rated for impact during hurricanes.
	Not Impact Rated	✓	
	Unknown		
Glass Percentage	< 10%		Glass is particularly susceptible to debris damage, and if not properly installed, glass can also sustain damage from high wind pressures. Large glazing is particularly susceptible to debris impact and pressure loads. Hence, the vulnerability of a building will increase as the percentage of glass increases.
	10% - 20%		
	20% - 50%		
	> 50%		
	Unknown		
Glass / Glazing Type	Annealed		In cases where the opening is not protected from debris impact, the type of glass used governs the vulnerability of buildings to debris impact damage. Annealed/regular glass is the most vulnerable, while laminated and impact rated are the least vulnerable glazing types.
	Insulated Glass Units		
	Tempered		
	Heat Strengthened		
	Laminated		
	Non-Impact Rated		
	Impact Rated		
	Unknown		

Table 15 - Secondary characteristics and mitigation measures relating to building openings

Secondary Characteristic / Mitigation Measures	Options	In Form V2	Description
Wall Siding	Aluminum Vinyl		The strength of the attachment and connections between the wall material and wall siding impacts the vulnerability of wall sidings to hurricane winds. Brick and stone veneer are among the least vulnerable, while aluminum, vinyl siding, EIFS, and stucco are commonly observed to sustain damage during hurricanes.
	EIFS		
	Stucco		
	Brick Veneer		
	Stone		
	Glass Siding		
	Wood Shingle		
	Metal Sheathing		
	Unknown		
Wall to Floor to Foundation Connection	Anchorage Bolts	✓	There is very limited damage to wall-to-foundation connections during hurricanes. Other parts of the building typically fail well before the foundation connections. However, it is important that a building have an integrated load-path from the wall to the foundation. Structurally connected connections are the strongest, while nails are the weakest.
	Nails		
	Straps	✓	
	Clips		
	Structurally connected		
	Unknown		
IBHS Designation	Bronze - 1		IBHS building rating is a very good indicator of the vulnerability of a building to hurricane wind speeds. If this data is available, it overrides all other secondary characteristics and mitigation measures.
	Bronze - 2		
	Silver		
	Gold		
	Fortified for Safer Living		
	Unknown		

Table 16 - Secondary characteristics and mitigation measures relating to other factors

5. Describe how hurricane mitigation measures and secondary characteristics are implemented in the hurricane model. Identify any assumptions.

In the KCC US Hurricane Reference Model, the impact of hurricane mitigation measures and secondary characteristics on building vulnerability is captured using modification factors. These modification factors vary by wind speeds; for example, the impact of roof cover type or roof cover age is more pronounced at low wind speeds, while the impact of building-to-foundation connections is more pronounced at high wind speeds.

For each secondary characteristic or mitigation measure listed in Standard V-4, Disclosure 4, there is a set of options that modify the building vulnerability functions based on user input data. If there is no input for a certain secondary characteristic (if it is unknown), no modification is applied to the vulnerability function. If there are multiple secondary characteristic inputs, the combined effect is first calculated before modifying the vulnerability function.

6. Describe how the effects of multiple hurricane mitigation measures and secondary characteristics are combined in the hurricane model and the process used to ensure that multiple hurricane mitigation measures and secondary characteristics are correctly combined.

The process of combining the effects of multiple hurricane mitigation measures and secondary characteristics is based on the ALR component-based wind engineering analysis. In cases where multiple secondary modifiers impact the same building component, for example the roof cover age and roof cover type, they are combined by multiplying the ratios of the modified vulnerabilities to the original vulnerability. For example, if mitigation measure “a” decreases the vulnerability by 2%, and mitigation “b” decreases the vulnerability by 3%, the combined effect would be a decrease of [100%-(98%*97%)] in the vulnerability.

In cases where the secondary characteristics impact different building components, for example window shutters and roof deck type, the combined effect is computed by adding the percent of impact that each modifier has on the vulnerability function. For example, if mitigation measure “a” decreases the vulnerability by 2% and mitigation “b” decreases the vulnerability by 3%, the combined effect would be a decrease of 5% in the vulnerability.

In cases where three or more secondary characteristics are present, modifiers that affect the same building component are first combined before their combined percent of impact is incorporated into the vulnerability function. This approach was observed to be consistent with the wind engineering analysis used to develop the secondary modifiers and produces reasonable combinations of any number of secondary building characteristics and mitigation measures.

7. Describe how building and contents damage are affected by performance of hurricane mitigation measures and secondary characteristics. Identify any assumptions.

Building damage decreases with the implementation of hurricane mitigation measures as the relative vulnerability decreases. Secondary characteristics can increase or decrease the building vulnerability. Contents damage changes in proportion with the building damage as the contents vulnerability functions are derived from the building vulnerability functions.

8. Describe how hurricane mitigation measures and secondary characteristics affect the uncertainty of the vulnerability. Identify any assumptions.

In the KCC US Hurricane Reference Model, the uncertainty around vulnerability is a function of the level of damage. During loss calculation, the mitigation measures and secondary characteristics will modify the MDRs, hence modifying the secondary uncertainty of the vulnerability. No other assumptions are made with respect to the mitigation measures and secondary characteristics.

9. Provide a completed Form V-3, Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item), if not considered as Trade Secret. Provide a link to the location of the form [insert hyperlink here].

Form V-3, Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item) is considered a Trade Secret.

10. Provide a completed Form V-4, Differences in Hurricane Mitigation Measures and Secondary Characteristics. Provide a link to the location of the form.

Form V-4: Differences in Hurricane Mitigation Measures and Secondary Characteristics

11. Provide a completed Form V-5, Differences in Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item), if not considered as Trade Secret. Provide a link to the location of the form [insert hyperlink here].

Form V-5, Differences in Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item) is considered a Trade Secret.

Actuarial Hurricane Standards

A-1 Hurricane Model Input Data and Output Reports

A. Adjustments, edits, inclusions, or deletions to insurance company or other input data used by the modeling organization shall be based upon generally accepted actuarial, underwriting, and statistical procedures.

All adjustments, edits, inclusions, or deletions to insurance company input or other input data are based upon accepted actuarial, underwriting, and statistical procedures.

B. All modifications, adjustments, assumptions, inputs and input file identification, and defaults necessary to use the hurricane model shall be actuarially sound and shall be included with the hurricane model output report. Treatment of missing values for user inputs required to run the hurricane model shall be actuarially sound and described with the hurricane model output report.

Model input data is provided by the user for each catastrophe loss analysis. RiskInsight® performs validation tests during exposure data import and includes exposure data validation tools within the user interface that assist users in verifying data integrity. All modifications, adjustments, assumptions, inputs and input file identification, and defaults necessary to use the hurricane model are actuarially sound and are included with the hurricane model output report and in the RiskInsight® documentation. Treatment of missing values required to run the hurricane model are actuarially sound and described in the RiskInsight® documentation.

Disclosures

1. Identify insurance-to-value assumptions and describe the methods and assumptions used to determine the property value and associated hurricane losses. Provide a sample calculation for determining the property value.

The model makes no insurance-to-value assumptions. The KCC US Hurricane Reference Model assumes that the Replacement Value input is the true property value. The model has separate inputs for replacement values and policy limits.

Users can account for underinsured policies by adjusting the exposure data outside of the model.

As an example, a policy with an insured value of $200,000 that is 20% underinsured would be entered as:

Replacement value field: $200,000 / (1- 20%) = $250,000

Limit field: $200,000

2. Identify depreciation assumptions and describe the methods and assumptions used to reduce insured hurricane losses on account of depreciation. Provide a sample calculation for determining the amount of depreciation and the actual cash value (ACV) hurricane losses.

The KCC US Hurricane Reference Model makes no depreciation assumptions and does not reduce hurricane losses on account of depreciation. As such, no sample calculation has been provided.

3. Describe the methods and input data used to distinguish among policy form types (e.g., homeowners, dwelling property, manufactured homes, tenants, condo unit owners) and their deductibles and coverage limits.

Modeling input data is provided by the user, and during import input exposure attributes are used to distinguish between policy form types and their deductibles and coverage limits. The valid data types and input options are detailed in the *RiskInsight OEF2 Database Schema* user documentation, including the distinct input fields used to identify the construction material, occupancy type, policy form, deductible type, and coverage limits for each input location.

The selection of construction material and occupancy type determines the vulnerability of each location. The construction code "MH" is used to identify Manufactured Homes, and the occupancy codes "ATC-01", "ATC-02", "ATC-42", and "ATC-43" are used to identify Owners, Renters, Commercial Residential, and Condo Unit Owners respectively in the input data.

The Policy Form type is not explicitly modeled but is used for reporting purposes. In the input data the user can input Policy Form types "Owners", "Renters", "Condo Unit Owners", "Manufactured Homes", and "Commercial Residential" as well as "HO3", "HO4", and "HO6" to meet the user's reporting needs. For all policy form types, input options support deductibles and coverage limits that can be applied to the site or any combination of individual coverages A, B, C, and D.

4. Provide a copy of the input form(s) used by the hurricane model with the hurricane model options available for selection by the user for the Florida hurricane model under review. Describe the process followed by the user to generate the hurricane model output produced from the input form. Include the hurricane model name, version identification, and platform identification on the input form. All items included in the input form should be clearly labeled and defined.

Tab Separated Values (TSV) are used to import exposure information into the KCC exposure database. The RiskInsight® OEF Import Guide documents the input file names, field names, and data types that are supported during import, including the required fields for generating loss estimates.

KCC utilizes an analysis input form to record and set loss analysis specifications including: model and model version, loss analysis resolution, and demand surge, among other options. As described further below, by selecting the "Florida Hurricane Rate Filing v4.0" analysis option, all of the settings required for a Florida rate filing are automatically selected, and Standard A-1, Disclosure 6 identifies each of the automatic selections. The contents of this analysis input form are recorded in the hurricane model output report, a sample of which is provided in Standard A-1, Disclosure 5.

The table below shows the analysis option settings that are required for ratemaking purposes.

Analysis Option	Required Setting for Florida Ratemaking	Available Options	Description
Exposure Set			
Job Name	n/a	n/a	A text description meaningful to the user that uniquely identifies each analysis.
Database	n/a	n/a	The name of the OEF 2.3 SQL exposure database on which losses will be run.
Portfolio	n/a	n/a	The portfolio within the exposure database on which losses will be run.
Job Template	Florida Hurricane Rate Filing v4.0	Florida Hurricane Rate Filing v4.0; user defined templates	Selecting the Florida Hurricane Rate Filing v4.0 job template auto populates all settings required for rate making in Florida. This template cannot be changed by users.
Reinsurance	n/a	n/a	Users may include reinsurance treaties in an analysis. Inclusion/exclusion of treaties does not impact gross loss used in Florida rate filings.

Analysis Option	Required Setting for Florida Ratemaking	Available Options	Description
Loss Analysis Options			
Save Losses by	n/a	Event Totals Only, Losses by Location, Losses by Layer, Losses by LOB, Losses by Country, Losses by State, Losses by County, Losses by ZIP, Losses by CRESTA, Losses by Country and LOB, Losses by State and LOB, Losses by County and LOB, Losses by ZIP and LOB, and Losses by CRESTA and LOB	The level at which event losses will be saved in the results database. A variety of resolutions are supported including location, policy, LOB, State, and State and LOB. This selection does not impact loss costs.
Want AAL by	n/a	Geography: None, Country, State, ZIP, County, CRESTA Business: None, Account, Policy, Location By LOB: On, Off	The resolution average annual losses will be stored in the database. User may elect to use AALs calculated at a location, ZIP, or other resolution in rate filings.
Model	KCC_TropicalCyclone_NAT-US_v4.0	KCC_TropicalCyclone_NAT_v4.0	By selecting the Florida Hurricane Rate Filing v4.0 Job Template in a previous input step, the KCC US Hurricane Reference Model version 4.0 is automatically populated in the input form.
Job Options			
Priority	n/a	High, Normal, and Low	Multiple analyses can be run in parallel on independent clusters of hardware resources. Users can select between High, Normal, and Low analysis queues to prioritize analyses. This setting does not impact loss costs.
Email	n/a	n/a	Entering an email address will trigger an automated email once an analysis is completed. This setting does not impact loss costs.

Table 17 – RiskInsight® analysis options available through the user interface for Florida rate filing

A representative sample input file supported by the model is shown below. The RiskInsight® import functionality detects field names in the input file and automatically maps them into the required KCC OEF exposure database field.

LocationID	AccountID	PostalCode	BuildingValue	OtherValue	ContentsValue	TimeElementValue	RiskCount	ConstructionCodeType	ConstructionCode	OccupancyCodeType
17387	2	32712	1043100	0	0	0	2	KCC	MS10	ATC
17388	2	32751	4076383	0	0	0	2	KCC	MS10	ATC
17389	2	32751	0	96563	0	0	5	KCC	MS10	ATC
17390	2	32751	13587077	126126	0	0	18	KCC	MS10	ATC
17391	2	32751	40000	0	0	0	1	KCC	MS10	ATC
17392	2	32751	4193018	159540	0	0	8	KCC	MS10	ATC
17393	2	32751	814100	76575	0	0	2	KCC	MS10	ATC
17394	2	32751	940899	0	0	0	1	KCC	MS10	ATC
17395	2	32751	11823132	0	0	0	15	KCC	MS10	ATC
17396	2	32751	0	78600	0	0	1	KCC	MS10	ATC

Figure 39 – Sample input file imported into RiskInsight® for exposure mapping

As an initial step in the import process, the user selects import options, including the destination exposure database and the location of the import files, which are illustrated in the image below.

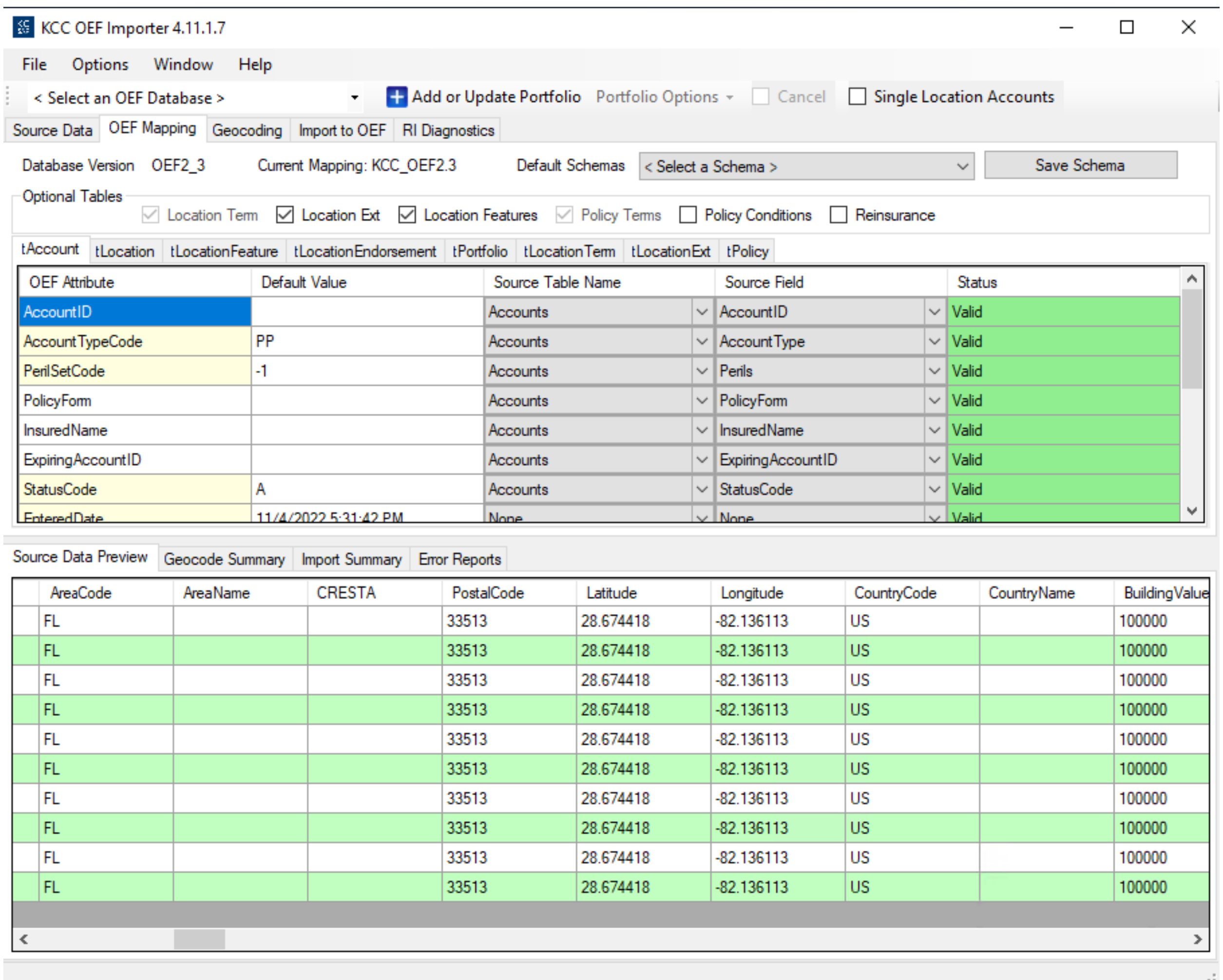


Figure 40 – Options available on exposure data import

After the exposure data is imported and prior to generating results, the user selects a number of analysis options that specify the type and resolution for the model output. The process followed by the user to generate the model output produced from the exposure input is provided below.

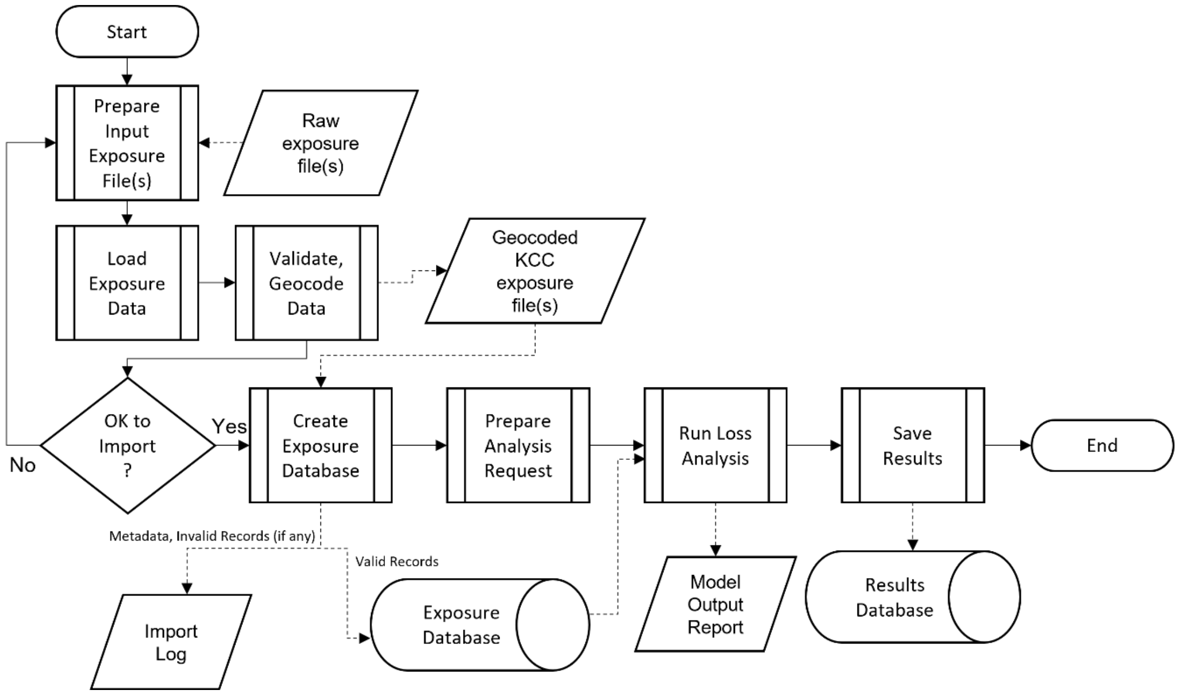


Figure 41 – Process to generate model output from initial exposure input

5. ***Disclose, in a hurricane model output report, the specific inputs required to use the hurricane model and the options of the hurricane model selected for use in a residential property insurance rate filing in Florida. Include the hurricane model name, version identification, and platform identification on the hurricane model output report. All items included in the hurricane model output report should be clearly labeled, highlighted, and defined.***

The inputs required to use the hurricane model and the options required for residential property insurance rate filing are detailed in Standard A-1, Disclosure 4.

A sample hurricane model output report is shown below, which includes the hurricane model name and version. Definitions for the hurricane model output report labels are included in Standard A-1, Disclosure 4 and Standard A-1, Disclosure 6.

Attribute Value

RiskInsight Version 4.11.1.7

RI Results Database Version 4.11

Analysis Type Loss

Analysis Ceding Company Florida Rate Filing Analysis 11/03/2022 09:36:40.098

Analysis Name 11/03/2022 09:36:40.098

Analysis Notes

Analysis ID 3

Analysis Parent Analysis ID 0

Analysis Queue ID 2

Analysis Job ID 11

Analysis Job Priority High

Analysis User KCC\adminsv

Analysis Time Submitted 11/3/2022 10:08:09 PM

Analysis Time Started 11/3/2022 10:08 PM

Analysis Time Ended 11/3/2022 10:17 PM

Analysis Duration 0:08:57

Analysis Status Completed in 8.6 minutes at 2022-11-03 22:17

Analysis Error Summary False

Exposure SQL Server Version Microsoft SQL Server 2019 (RTM-CU17) (KB5016394) - 15.0.4249.2 (X64)

Exposure SQL Server Name FLCO21WD-2-SQL

Job Submission Template Florida Hurricane Rate Filing v4.0

Job Analysis Template

Exposure Type KCC_OEF2

Exposure Version KCC_OEF2.3

Exposure Filter [Country] = 'US' AND [State] NOT IN ('HI','AK','WA','OR','CA','ID','NV','MT','WY','UT','AZ','ND','SD','NE','CO','MN','IA','WI','MI')

Locations Filter [Country] = 'US' AND [State] = 'FL'

Accounts Filter

Exposure Database KCC_OEF2_NotionalDataset_FormA6_2021FLCOM_Final_221031_WindPeril

Exposure PortfolioID 1

Exposure Portfolio Name NotionalSet1

Exposure Accounts 1880

Exposure Policies 1880

Exposure Locations 1880

Exposure Sublimits 0

Exposure Reinsurance 0

Exposure Total Replacement Value 6,427,600,000

Model Event Set Type STOC

Model Secondary Peril 0

Model Secondary Qualifier

Analysis Demand Surge True

Analysis Used Cached Exposures False

Analysis Custom Demand Surge False

Secondary Modifiers Applied True

Analysis Plugins used in Analysis KCC TropicalCyclone_NAT-US_v4.0 - Wind:'1001005,1001007,1001008'

IPR Files Applied KCC TropicalCyclone_NAT-US_v4.0 - Wind:''

Model Peril Set Codes Wind_Storm

Model Peril IDs Wind_Storm

Model ID 1001061980

Model Name KCC TropicalCyclone_NAT-US_v4.0

Model Version 221027:2009

Model Catalog \\flco21wd-2-jcm\KCC_Public\RI_Hazard\KCC_NAT-US_TC_V4\USHUv4_EventIDLink_STOC_221024.txt

Model Events 83,021

Model Catalog Version 1.0

Model DF Version 1.0

Model Rates Version 1.0

Analysis Intra-policy correlation setting 0.6

Analysis Simulation Count 1000

Analysis Apply Residential Location Terms False

Analysis Reinsurance Program name

Exposure FAC reinsurance count

Exposure Treaty reinsurance count

Analysis Loss Perspectives GR

Analysis Event Losses by Event_Totals_Only

Analysis AAL Resolution

ASC Job Server FLCO21WD-2-SQL

ASC Number of workers 5

ASC Workers i-0b2ab3e640108096c,i-03c3a2f953087d9aa,i-0fa5f78962dd2dcb0,i-07f713b669fc0c5eb,i-0df003c1728ee0f0a

ASC Worker cores 32,32,32,32,32

ASC Worker RAM (GB) 528,528,528,528,528

Results SQL Server FLCO21WD-2-SQL

Results Database KCC_OEF2_NotionalDataset_FormA6_2021FLCOM_Final_221031_WindPeril_ResultsRI4

Analysis Results Currency USD

Model is MultiPeril True

Model Secondary Uncertainty File \\flco21wd-2-jcm\KCC_Public\RI_Hazard\KCC_NAT-US_TC_V4\SecUncV2\KCCLoss_MDR_Beta_Probs_00001.bin

Model Minimum Intensity Threshold KCC TropicalCyclone_NAT-US_v4.0 - Wind:'25.0'

6. Provide a list of all options available (e.g., base storm set, vulnerability functions) to the user. Identify the specific options acceptable for a Florida rate filing.

As described in Standard A-1, Disclosure 4, selecting the Job Template "Florida Hurricane Rate Filing v4.0" auto populates all the required analysis settings for a Florida rate filing. The table below identifies the available options and the settings pre-selected when the "Florida Hurricane Rate Filing v4.0" template is selected.

Analysis Option	Pre-Selected Setting for Florida Ratemaking	Available Options	Description
Loss Analysis Options			
Analysis Templates Drop Down	n/a	n/a	Selecting an analysis template auto populates Loss Analysis options with a predetermined value. When the "Florida Hurricane Rate Filing v4.0" is selected, this field cannot be modified.
Loss Analysis Currency Drop Down	USD: Dollars	USD, and over 100 international currency options	Currency for loss estimates.
Event Set	STOC	STOC, HIST, RICE, LIVE, CUST	When selected, the model includes loss estimates from the stochastic event set.
Secondary Modifier Radio Button	On	On and Off	When selected, loss estimates reflect hurricane mitigation measures
Plugins Table	Excess Litigation Plugin v4.0: Check	Excess Litigation Plugin v4.0; user defined plugins	The set of plugins that are available to be used during the loss analysis. Checking the Include check box will make a plugin active during an analysis.
Demand Surge Radio Button	On	On and Off	When selected, loss estimates are increased to reflect increases in material and labor costs associated with repairing properties after significant catastrophe events.
Model Options			
Model	KCC_TropicalCyclone_NAT-US_v4.0	KCC_TropicalCyclone_NAT-US_v4.0, KCC SevereConvectiveStorm_NAM-US_v3.0, KCC Wildfire_NAM-US_v1.0, KCC US Earthquake, KCC WinterStorm_NAM-US_v2.0, and multiple International Models	Model RiskInsight® will use for running losses.

Analysis Option	Pre-Selected Setting for Florida Ratemaking	Available Options	Description
Model Sub-perils	Wind: Check Storm Surge: Uncheck Inland Flood: Uncheck	Wind, Storm Surge, Inland Flood	For the tropical cyclone model, it is possible to estimate losses due to the wind, storm surge and hurricane-induced inland flood perils. Unselecting the storm surge and inland flood options limits loss estimates to the wind peril only.
Job Options			
Exposure Filters	[Country] = 'US' and [State] = 'FL'	SQL string that defines a geographic filter	The SQL string is applied to the input exposure data for the database and portfolio selected for analysis.
Use Cached Exposure	Unchecked	Checked, unchecked	If a prior analysis was performed for the same exposure database and portfolio, a check allows the analysis to directly leverage local cache files, and unchecked requires the exposure to be extracted from exposure database with the Exposure Filters.

Table 18 - Analysis options available in RiskInsight® through the user interface

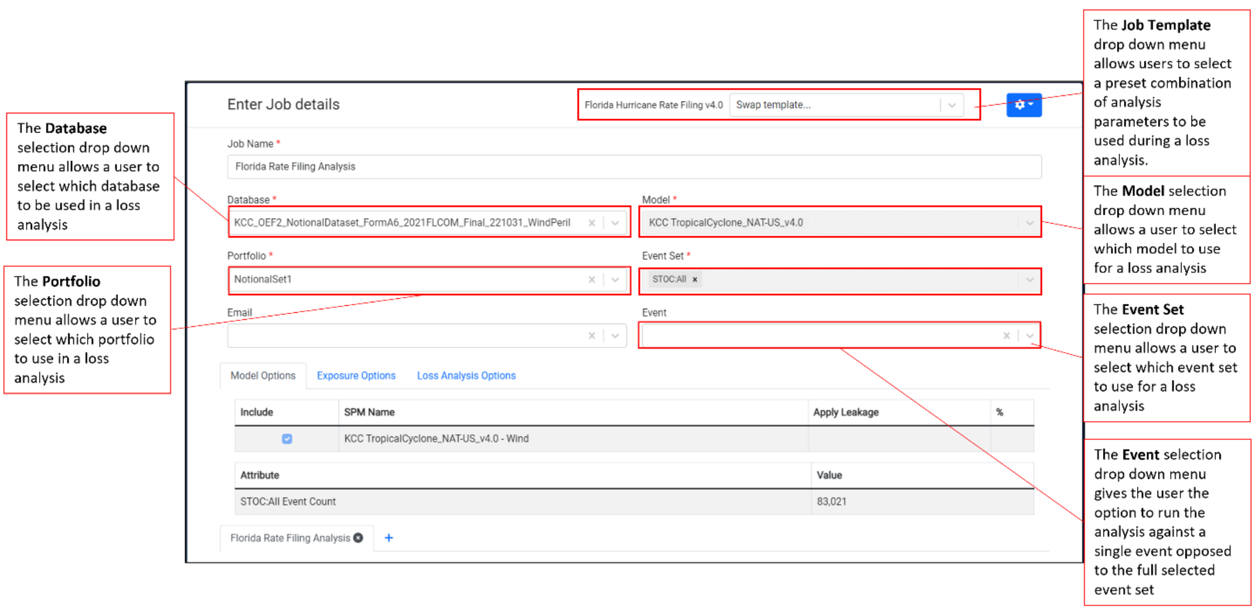


Figure 42 - Selecting analysis options within the user interface

7. Describe actions performed to ensure the validity of insurer or other input data used for hurricane model inputs or for validation/verification.

RiskInsight® performs validation tests during exposure data import and also provides exposure data validation tools within the user interface that assist users in verifying data integrity. Validation testing includes confirming postal codes are in a 5 digit or 5+4 digit format, and construction and occupancy codes match supported options. When a validation error occurs during exposure data import, the offending input record is flagged and reported to the user in the Exposure Import Log and is not imported into the KCC exposure database. The user has the opportunity to correct the error, and if the augmented record passes all import exposure validation tests, it can then be imported into the exposure database.

8. Disclose if changing the order of the hurricane model input exposure data produces different hurricane model output or results.

Changing the order of the KCC US Hurricane Reference Model input exposure data does not produce different hurricane model output or results.

9. Disclose if removing or adding policies from the hurricane model input file affects the hurricane model output or results for the remaining policies.

Removing or adding policies from the KCC US Hurricane Reference Model input file will not affect the hurricane model output for the remaining policies.

A-2 Hurricane Events Resulting in Modeled Hurricane Losses

A. Modeled hurricane loss costs and hurricane probable maximum loss levels shall reflect all insured wind related damages from hurricanes that produce minimum damaging windspeeds or greater on land in Florida.

Modeled hurricane loss costs and hurricane probable maximum loss levels reflect all insured wind-related damages from storms classified as landfalling or by-passing hurricanes, consistent with the definitions stated in the *Hurricane Standards Report of Activities as of November 1, 2021* developed by the FCHLPM, that produce minimum damaging wind speeds or greater on land in Florida.

B. The modeling organization shall have a documented procedure for distinguishing wind-related hurricane losses from other peril losses.

KCC has a documented procedure for distinguishing wind-related hurricane losses from other peril losses which will be available for review by the Professional Team during the on-site visit.

Disclosures

1. Describe how damage from hurricane model generated storms (landfalling and by-passing hurricanes) is excluded or included in the calculation of hurricane loss costs and hurricane probable maximum loss levels for Florida.

The calculation of hurricane loss costs and hurricane probable maximum loss levels for Florida include damage from landfalling and by-passing model-generated storms.

2. Describe how damage resulting from concurrent or preceding flood (including hurricane storm surge) is treated in the calculation of hurricane loss costs and hurricane probable maximum loss levels for Florida.

In the KCC US Hurricane Reference Model, the model supports the option to include or exclude storm surge and hurricane-induced inland flood losses. If the storm surge and inland flood model options are not selected, no storm surge or inland flood losses are included in the calculations. As described in Standard A-1, Disclosure 4, when the required Florida Hurricane Rate Filing v4.0 template is selected, storm surge and inland loss losses are not included. The hurricane loss costs and hurricane probable maximum loss levels in this submission do not include storm surge or inland flood losses.

A-3 Hurricane Coverages

A. The methods used in the calculation of building hurricane loss costs, including the effect of law and ordinance coverage, shall be actuarially sound.

The KCC US Hurricane Reference Model calculates building hurricane loss costs separately from appurtenant structures, contents, and time element hurricane loss costs. The methods used in the calculation of building hurricane loss costs, including the effect of law and ordinance coverage, are actuarially sound.

B. The methods used in the calculation of appurtenant structure hurricane loss costs shall be actuarially sound.

The KCC US Hurricane Reference Model calculates appurtenant structure hurricane loss costs separately from building, contents, and time element hurricane loss costs. The methods used in the calculation of appurtenant structure hurricane loss costs are similar to the methods used for the calculation of building hurricane loss costs and are actuarially sound.

C. The methods used in the calculation of contents hurricane loss costs shall be actuarially sound.

The KCC US Hurricane Reference Model calculates contents hurricane loss costs separately from building, appurtenant structures, and time element hurricane loss costs. The methods used in the calculation of contents hurricane loss costs are similar to the methods used for the calculation of building hurricane loss costs and are actuarially sound.

D. The methods used in the calculation of time element hurricane loss costs shall be actuarially sound.

The KCC US Hurricane Reference Model calculates time element hurricane loss costs separately from building, appurtenant structures, and contents hurricane loss costs. The methods used in the calculation of time element hurricane loss costs are similar to the methods used for the calculation of building hurricane loss costs and are actuarially sound.

Disclosures

1. Describe the methods used in the hurricane model to calculate hurricane loss costs for building coverage associated with personal and commercial residential properties.

When the exposure data is read into the model, each location is assigned a reference vulnerability function code appropriate for the attributes of that property. Personal residential properties are identified by occupancy codes that are different from the commercial residential occupancy codes. The reference vulnerability function code is used to assign the appropriate vulnerability function to the individual location property. The appropriate building vulnerability function is used to estimate the building ground-up loss from each event in the simulated catalog using the wind speed from that event at the property location. The gross losses are calculated by applying secondary uncertainty and the policy terms. Annual hurricane losses are calculated by multiplying losses by their respective event rates and summing them across all events. Annual hurricane loss costs are calculated by dividing the average annual hurricane losses by the appropriate exposure and multiplying by 1,000.

2. Describe the methods used in the hurricane model to calculate hurricane loss costs for appurtenant structure coverage associated with personal and commercial residential properties.

The KCC US Hurricane Reference Model uses the methodology described in Standard A-3, Disclosure 1 to calculate hurricane loss costs for appurtenant structure coverage associated with personal and commercial residential properties.

3. Describe the methods used in the hurricane model to calculate hurricane loss costs for contents coverage associated with personal and commercial residential properties.

The KCC US Hurricane Reference Model uses the methodology described in Standard A-3, Disclosure 1 to calculate hurricane loss costs for contents coverage associated with personal and commercial residential properties.

4. Describe the methods used in the hurricane model to calculate hurricane loss costs for time element coverage associated with personal and commercial residential properties.

The KCC US Hurricane Reference Model uses the methodology described in Standard A-3, Disclosure 1 to calculate hurricane loss costs for time element coverage associated with personal and commercial residential properties.

5. Describe the methods used in the hurricane model to account for law and ordinance coverage associated with personal residential properties.

Law and ordinance coverage associated with personal residential properties is not explicitly considered. However, to the extent law and ordinance coverage associated with personal residential policies is present in the historical claims information, it is implicitly included in base vulnerability functions and accounted for in the model.

A-4 Modeled Hurricane Loss Cost and Hurricane Probable Maximum Loss Level Considerations

A. Hurricane loss cost projections and hurricane probable maximum loss levels shall not include expenses, risk load, investment income, premium reserves, taxes, assessments, or profit margin.

Expenses, risk load, investment income, premium reserves, taxes, assessments, or profit margin are not included in the KCC US Hurricane Reference Model hurricane loss cost projections and hurricane probable maximum loss levels.

B. Hurricane loss cost projections and hurricane probable maximum loss levels shall not make a prospective provision for economic inflation.

The KCC US Hurricane Reference Model does not make a prospective provision for economic inflation in the hurricane loss cost projections and hurricane probable maximum loss levels.

C. Hurricane loss cost projections and hurricane probable maximum loss levels shall not include any explicit provision for direct flood losses (including those from hurricane storm surge).

In the KCC US Hurricane Reference Model, the model users have the option to include or exclude storm surge and hurricane-induced inland flood losses. If the storm surge and inland flood model options are not selected, no storm surge or inland flood losses are included in the calculations. As described in Standard A-1, Disclosure 4, when the required Florida Hurricane Rate Filing v4.0 template is selected, storm surge and inland loss losses are not included. The hurricane loss costs and hurricane probable maximum loss levels in this submission do not include storm surge and inland flood losses.

D. Hurricane loss cost projections and hurricane probable maximum loss levels shall be capable of being calculated from exposures at a geocode (latitude-longitude) level of resolution.

In the KCC US Hurricane Reference Model, the hurricane loss cost projections and hurricane probable maximum loss levels can be calculated from exposures at a geocode (latitude-longitude) level of resolution.

E. Demand surge shall be included in the hurricane model's calculation of hurricane loss costs and hurricane probable maximum loss levels using relevant data and actuarially sound methods and assumptions.

Demand surge is included in the KCC US Hurricane Reference Model's calculation of hurricane loss costs and hurricane probable maximum loss levels. Demand surge has been developed using relevant data and actuarially sound methods and assumptions.

Disclosures

1. Describe the method(s) used to estimate annual hurricane loss costs and hurricane probable maximum loss levels and the treatment of associated uncertainties. Identify any source documents used and any relevant research results.

The KCC hurricane event catalog represents a 100,000-year sample. Annual hurricane losses are calculated by multiplying losses by their respective event rates and summing them across all events. Annual hurricane loss costs are calculated by dividing the average annual hurricane losses by the appropriate exposure and multiplying by 1,000. The one percent probable maximum losses are calculated as the 1,000th largest annual loss from the sample.

As described in the response to Disclosure S-4.1, a Joint Probability Method determines catalog event rates based on the stochastic hurricane parameter distributions identified in Form S-3 including for the maximum sustained wind speed, radius of maximum winds, and forward speed. Catalog events are then assigned to model years based on the empirical annual landfall frequency distribution described in Form

S-3, with some years containing no events and other years containing one or more events. The resulting catalog represents the primary uncertainty in the model, and the relative frequency and severity of storms making landfall in or bypassing different Florida locations.

As explained in the response to Disclosure G-1.2, empirical distributions consider the full range of damage levels (the secondary uncertainty) that can occur around the MDR in the vulnerability functions. The secondary uncertainty is always considered in loss calculations for each location and each coverage.

2. Identify all possible resolutions available for the reported hurricane output ranges. Identify the finest level of resolution (i.e., the most granular level) for which hurricane loss costs and hurricane probable maximum loss levels can be provided.

In the KCC US Hurricane Reference Model, available resolutions for hurricane loss costs reported in the hurricane output ranges include all combinations of LOB (or policy form if stored in the LOB input field) and location (street address), ZIP, county, CRESTA, state, and portfolio. The most granular resolution hurricane loss costs and hurricane probable maximum loss levels can be provided is at a specific location level (the latitude and longitude coordinates associated with a property).

3. Describe how the hurricane model incorporates demand surge in the calculation of hurricane loss costs and hurricane probable maximum loss levels.

In the KCC US Hurricane Reference Model, demand surge is applied to ground-up losses based on the industry-wide loss amount for each event. Larger industry losses are expected and assumed to generate more demand surge.

4. Provide citations to published papers, if any, or modeling-organization studies that were used to develop how the hurricane model estimates demand surge.

No published papers on demand surge were used to develop how the KCC US Hurricane Reference Model quantifies demand surge.

5. Describe how economic inflation has been applied to past insurance experience to develop and validate hurricane loss costs and hurricane probable maximum loss levels.

When validating the KCC US Hurricane Reference Model using insurer claims data, no adjustments were made to the exposure or loss data because KCC clients have been able to provide high-resolution claims data that could be matched to their contemporaneous exposure data. When validating the KCC US Hurricane Reference Model using industry data, historical event losses going back to 1900 were trended and adjusted to today's population and property values using methods similar to those described in Pielke et al. (2008). A refinement over the Pielke method was to use construction cost indices by region rather than a CPI measure in trending the past losses. Construction cost indices are a better reflection of the current costs to repair or replace hurricane damaged properties.

A-5 Hurricane Policy Conditions

A. The methods used in the development of mathematical distributions to reflect the effects of deductibles and policy limits shall be actuarially sound.

The methods used in the development of mathematical distributions to reflect the effects of deductibles and policy limits are actuarially sound.

The model generates mean damage ratios (MDRs), which represent the cost to repair the damage divided by the replacement value of the property. For each MDR, the model considers the secondary uncertainty, which is the full probability distribution of damage levels around the mean, using empirical distributions. The secondary uncertainty distribution is used to apply the effects of deductibles and limits.

Expected Insured Loss = $\int_{x=0}^{1} f_{\overline{D}}(x)\{Coins\% * max\,[0, min(PL, x * RV - DED)]\}dx$

where

$f_{\overline{D}}(x)$ = Secondary Uncertainty Distribution

Coins% = Coinsurance Percentage

x = Damage Ratio Variable

RV = Replacement Value

PL = Policy Limit

DED = Deductible

In application, $f_{\overline{D}}(x)$ is discretized and numerical integration is used to estimate the expected insured loss.

B. The relationship among the modeled deductible hurricane loss costs shall be reasonable.

The relationship among the modeled deductible hurricane loss costs is reasonable. Hurricane loss costs decrease as deductibles increase.

C. Deductible hurricane loss costs shall be calculated in accordance with s. 627.701(5)(a), F.S

Deductible hurricane loss costs are calculated in accordance with the hurricane deductible specifications defined in s. 627.701(5)(a), F.S.

Disclosures

1. Describe the methods used in the hurricane model to treat deductibles (both flat and percentage), policy limits, and insurance-to-value criteria when projecting hurricane loss costs and hurricane probable maximum loss levels. Discuss data or documentation used to validate the method used by the hurricane model.

Percentage deductibles are converted into flat deductibles by multiplying them by the appropriate coverage amount. Flat deductibles are used directly. The model estimates a mean damage ratio, to which a secondary uncertainty function is applied. The model caps the losses at the policy limits. If desired by the user, insurance-to-value assumptions can be made to the input data prior to the user importing the data into the KCC database. KCC validated the hurricane model by performing detailed analysis on client claims data, including ground-up and gross losses.

2. Describe if and how the hurricane model treats policy exclusions and loss settlement provisions.

Policy exclusions are implicitly factored into the model to the extent that they are included in claims data. Loss settlement provisions are not included in the hurricane model loss estimates. The insurer claims data used to validate the model excludes loss adjustment expenses.

3. Describe how the hurricane model treats annual deductibles.

For the first event loss within a simulated year, the applied deductible amount is the full value of the annual hurricane deductible. If the ground-up loss amount is less than the hurricane deductible, a "residual hurricane deductible" is estimated for each secondary uncertainty scenario. The expected residual hurricane deductible is estimated based on the probability of the secondary uncertainty scenarios. For the second event loss within a simulated year, the applied deductible amount is the maximum of either the expected residual hurricane deductible or all other perils deductible. For each subsequent event within a simulated year, the applied deductible amount will never be less than the all other perils deductible. For the next simulated year, the residual hurricane deductible amount resets, as the hurricane deductible would be at its full value.

A-6 Hurricane Loss Outputs and Logical Relationships to Risk

A. The methods, data, and assumptions used in the estimation of hurricane loss costs and hurricane probable maximum loss levels shall be actuarially sound.

The methods, data, and assumptions used in the estimation of the hurricane probable maximum loss levels in the KCC US Hurricane Reference Model are actuarially sound. No alternate relationship has been observed in the loss costs.

B. Hurricane loss costs shall not exhibit an illogical relation to risk, nor shall hurricane loss costs exhibit a significant change when the underlying risk does not change significantly.

The KCC US Hurricane Reference Model produces hurricane lost costs that exhibit a logical relation to risk and that do not exhibit a significant change when the underlying risk does not change significantly. No alternate relationship has been observed in the loss costs.

C. Hurricane loss costs produced by the hurricane model shall be positive and non-zero for all valid Florida ZIP Codes.

The KCC US Hurricane Reference Model produces hurricane lost costs that are positive and non-zero for all valid Florida ZIP Codes. No alternate relationship has been observed in the loss costs.

D. Hurricane loss costs cannot increase as the quality of construction type, materials, and workmanship increases, all other factors held constant.

All other factors held constant, the hurricane loss costs do not increase as the quality of construction type, materials, and workmanship increases. No alternate relationship has been observed in the loss costs.

E. Hurricane loss costs cannot increase as the presence of fixtures or construction techniques designed for hazard mitigation increases, all other factors held constant.

All other factors held constant, the hurricane loss costs do not increase as the presence of fixtures or construction techniques designed for hazard mitigation increases. No alternate relationship has been observed in the loss costs.

F. Hurricane loss costs cannot increase as the wind resistant design provisions increase, all other factors held constant.

All other factors held constant, the hurricane loss costs do not increase as the wind resistant design provisions increase. No alternate relationship has been observed in the loss costs.

G. Hurricane loss costs cannot increase as building code enforcement increases, all other factors held constant.

All other factors held constant, the hurricane loss costs do not increase as the building code enforcement increases. No alternate relationship has been observed in the loss costs.

H. Hurricane loss costs shall decrease as deductibles increase, all other factors held constant.

All other factors held constant, the hurricane loss costs decrease as deductibles increase. No alternate relationship has been observed in the loss costs.

I. The relationship of hurricane loss costs for individual coverages (e.g., building, appurtenant structure, contents, and time element) shall be consistent with the coverages provided.

The relationship of hurricane loss costs for individual coverages is consistent with the coverages provided. No alternate relationship has been observed in the loss costs.

J. Hurricane output ranges shall be logical for the type of risk being modeled and apparent deviations shall be justified.

Hurricane output ranges are logical for the type of risk being modeled. There are no deviations, and any counterintuitive relationships are a result of the characteristics of the underlying data, as described in Standard A-6, Disclosure 17.

K. All other factors held constant, hurricane output ranges produced by the hurricane model shall in general reflect lower hurricane loss costs for:

1. masonry construction versus frame construction,

All other factors held constant, hurricane output ranges produced by the KCC US Hurricane Reference Model reflect lower hurricane loss costs for masonry construction versus frame construction. No alternate relationship has been observed in the loss costs.

2. personal residential risk exposure versus manufactured home risk exposure,

All other factors held constant, hurricane output ranges produced by the KCC US Hurricane Reference Model reflect lower hurricane loss costs for personal residential risk exposure versus manufactured home risk exposure. No alternate relationship has been observed in the loss costs.

3. inland counties versus coastal counties,

All other factors held constant, hurricane output ranges produced by the KCC US Hurricane Reference Model reflect lower hurricane loss costs for inland counties versus coastal counties. No alternate relationship has been observed in the loss costs.

4. northern counties versus southern counties, and

All other factors held constant, hurricane output ranges produced by the KCC US Hurricane Reference Model reflect lower hurricane loss costs for northern counties versus southern counties. No alternate relationship has been observed in the loss costs.

5. newer construction versus older construction.

All other factors held constant, hurricane output ranges produced by the KCC US Hurricane Reference Model reflect lower hurricane loss costs for newer construction versus older construction. No alternate relationship has been observed in the loss costs.

L. For hurricane loss cost and hurricane probable maximum loss level estimates derived from and validated with historical insured hurricane losses, the assumptions in the derivations concerning (1) construction characteristics, (2) policy provisions, (3) coinsurance, and (4) contractual provisions shall be appropriate based on the type of risk being modeled.

KCC professionals maintain ongoing relationships with our client companies, particularly primary insurers who have shared their detailed claims data. Along with conducting independent post-event damage surveys, KCC scientists and engineers accompany our clients' claims adjusters after hurricanes to obtain firsthand knowledge on how policy provisions and exclusions and other contractual provisions are applied during the claims adjusting process. To the extent possible, these factors are captured in the KCC US Hurricane Reference Model. With respect to insurer claims data, hurricanes from 2004 to 2021 are used in the model validation process. This means the validation data are relatively current with respect to capturing today's construction practices and characteristics. The following workflow chart shows the KCC process for analyzing client data.

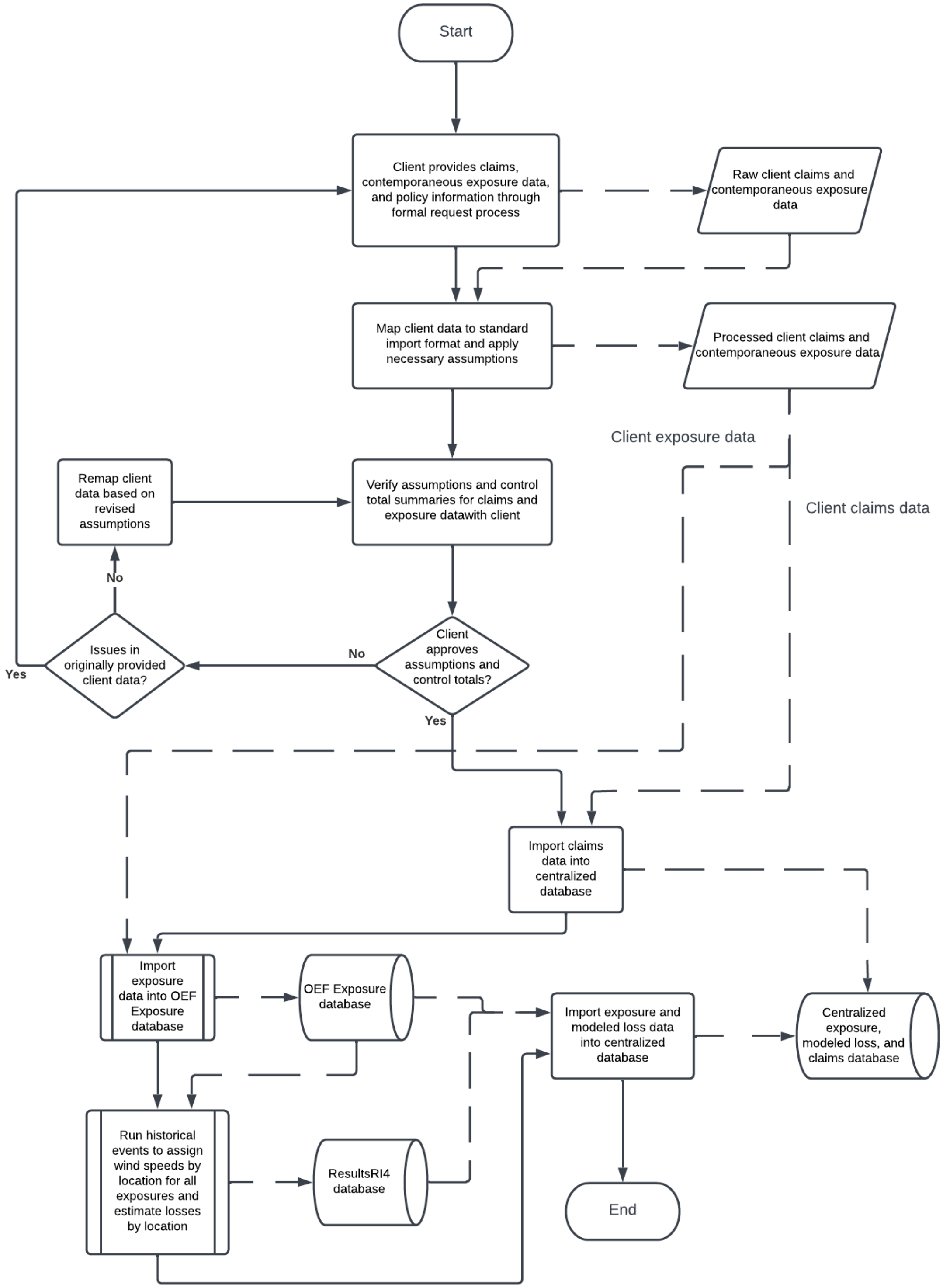


Figure 43 - Workflow diagram for analyzing insurer claims data and preparing the data for model validation

Disclosures

1. ***Provide a completed Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code. Provide a link to the location of the form.***

   Form A-1: Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code

2. ***Provide a completed Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses. Provide a link to the location of the form.***

   Form A-2: Base Hurricane Storm Set Statewide Hurricane Losses

3. ***Provide a completed Form A-3, Hurricane Losses. Provide a link to the location of the form.***

   Form A-3: Hurricane Losses

4. ***Provide a completed Form A-4, Hurricane Output Ranges. Provide a link to the location of the form.***

   Form A-4: Hurricane Output Ranges

5. ***Provide a completed Form A-5, Percentage Change in Hurricane Output Ranges. Provide a link to the location of the form.***

   Form A-5: Percentage Change in Hurricane Output Ranges

6. ***Provide a completed Form A-6, Logical Relationship to Hurricane Risk (Trade Secret Item), if not considered as Trade Secret. Provide a link to the location of the form [insert hyperlink here].***

   Form A-6, Logical Relationship to Hurricane Risk (Trade Secret Item) is considered a Trade Secret.

7. ***Provide a completed Form A-7, Percentage Change in Logical Relationship to Hurricane Risk. Provide a link to the location of the form.***

   Form A-7: Percentage Change in Logical Relationship to Hurricane Risk

8. ***Explain any assumptions, deviations, and differences from the prescribed exposure information in Form A-6, Logical Relationship to Hurricane Risk (Trade Secret Item), and Form A-7, Percentage Change in Logical Relationship to Hurricane Risk. In particular, explain how the treatment of unknown is handled in each sensitivity exhibit.***

   All assumptions used to create the import file for OEF2 generation are documented in our Exposure Assumption Input Form.

   When a primary building characteristic is defined as unknown in the exposure data, the model code for that attribute is set to unknown in the model. The model vulnerability functions for cases where a primary building characteristic is unknown were developed by exposure weighted-averaging of the known vulnerability functions for that attribute, as described in Standard V-1 of the submission. When a secondary building characteristic is set to unknown, no secondary modifier is applied to the primary vulnerability function for that secondary building attribute.

9. ***Provide a completed Form A-8, Hurricane Probable Maximum Loss for Florida. Provide a link to the location of the form.***

   Form A-8: Hurricane Probable Maximum Loss for Florida

10. ***Describe the calculation of uncertainty intervals.***

    As explained in the response to Disclosure G-1.2, the hurricane vulnerability functions include empirical distributions that consider the full range of damage levels (the secondary uncertainty) that can occur around the MDR. This secondary uncertainty is always considered in loss calculations.

    To calculate the uncertainty intervals for an event, the expected value and variance in loss experienced at each location (as defined by the location's secondary uncertainty distribution) within the event footprint is aggregated to determine the event's expected loss and variance. The 10% (lower bound) and 90% (upper bound) hurricane loss levels are estimated from each event's expected loss and variance using properties of sums of random variables and Chebyshev's theorem.

11. ***Describe how the hurricane model produces hurricane probable maximum loss levels.***

    The method used to produce hurricane probable maximum loss levels is described in Standard A-4, Disclosure 1.

12. ***Provide citations to published scientific and technical literatures, if any, or modeling-organization studies that were used to estimate hurricane probable maximum loss levels.***

No published scientific or technical papers were used to estimate hurricane probable maximum loss levels.

13. Describe how the hurricane probable maximum loss levels produced by the hurricane model include the effects of personal and commercial residential insurance coverage.

The hurricane probable maximum loss levels produced by the KCC US Hurricane Reference Model include the effects of personal and commercial residential insurance coverage based on the input provided by the user.

14. Explain any differences between the values provided on Form A-8, Hurricane Probable Maximum Loss for Florida, and those provided on Form S-2, Examples of Hurricane Loss Exceedance Estimates.

There are no differences between the values provided on Form A-8 and those provided on Form S-2.

15. Provide an explanation for all hurricane loss costs that are not consistent with the requirements of this standard.

The hurricane loss costs provided are logical, and they are consistent with the requirements of this standard. Some relationships might appear counterintuitive due to the variation of the exposure mix by ZIP Code but are in agreement with the data provided.

16. Provide an explanation of the differences in hurricane output ranges between the currently accepted hurricane model and the hurricane model under review.

Event Catalog Module updates:

- Inclusion of 2019-2021 events
- Consideration of climate change impacts on hurricane intensity distributions
- Updated storm tracks including re-intensification over the Gulf of Mexico

Intensity Footprint Module updates:

- Updated the land cover dataset used to calculate wind speed over land

Vulnerability Module updates:

- Updated site-built building vulnerability functions associated with Very-New year-built band
- Updated manufactured home vulnerability functions associated with year-built bands
- Updated vulnerability functions for commercial residential, renters, and condos occupancy types when building height is unknown

Other changes impacting loss costs:

- Updated ZIP codes and population-weighted centroids and related databases
- Inclusion of excess litigation factor for Florida site built single family homes
- Demand surge factors have been updated to reflect increased property values in the 2022 KCC Industry Exposure Database

17. Identify the assumptions used to account for the effects of coinsurance on commercial residential hurricane loss costs.

The KCC US Hurricane Reference Model accounts for the effects of coinsurance by applying a participation percentage to the estimated losses. This data field is provided by the user and represents the percentage of the loss assumed by the insured.

Computer/Information Hurricane Standards

CI-1 Hurricane Model Documentation

A. Hurricane model functionality and technical descriptions shall be documented formally in an archival format separate from the use of correspondence including emails, presentation materials, and unformatted text files.

KCC maintains two sets of documents on model functionality and technical descriptions: one for external client use and the other set for internal use. All KCC documentation is managed through a version control system.

B. A primary document repository shall be maintained, containing or referencing a complete set of documentation specifying the hurricane model structure, detailed software description, and functionality. Documentation shall be indicative of current model development and software engineering practices.

KCC maintains a primary document repository containing a complete set of documentation aligned with software engineering practices. KCC uses generally accepted procedures to ensure the documents are readable, self-contained, and easy to understand. All system components are documented with requirement statements, class, data flow, and sequence diagrams as appropriate and provide relevant detail on the structure and flow of data between the components and subcomponents.

C. All computer software (i.e., user interface, scientific, engineering, actuarial, data preparation, and validation) relevant to the hurricane model shall be consistently documented and dated.

KCC maintains pertinent computer software documents based on documentation templates that are consistently dated and that will be available for review by the Professional Team.

D. The following shall be maintained: (1) a table of all changes in the hurricane model from the currently accepted hurricane model to the initial submission this year, and (2) a table of all substantive changes since this year's initial submission.

KCC maintains a table of all changes to the software and data files associated with the hurricane model, and this document will be available for review by the Professional Team.

E. Documentation shall be created separately from the source code.

The model, software, and database schema are documented separately from the source code.

F. A list of all externally acquired, currently used, hurricane model-specific software and data assets shall be maintained. The list shall include (1) asset name, (2) asset version number, (3) asset acquisition date, (4) asset acquisition source, (5) asset acquisition mode (e.g., lease, purchase, open source), and (6) length of time asset has been in use by the modeling organization.

KCC maintains a list of all externally acquired software and data assets, and this document will be available for review by the Professional Team.

CI-2 Hurricane Model Requirements

A complete set of requirements for each software component, as well as for each database or data file accessed by a component, shall be maintained. Requirements shall be updated whenever changes are made to the hurricane model.

KCC maintains requirement statements for each software component and schema documentation for each database and file accessed by the component. These documents, as appropriate, are updated when pertinent changes are made to the hurricane model and will be available for review by the Professional Team.

Disclosure

1. Provide a description of the hurricane model and platform(s) documentation for interface, human factors, functionality, system documentation, data, human and material resources, security, and quality assurance.

KCC maintains documents provided to all clients that describe the specifications, product requirements, installation requirements, user interfaces, database schema, security considerations, and test databases for ensuring that all major components of the installation are functioning properly. These documents will be available for review by the Professional Team.

KCC developers also maintain comprehensive documentation on RiskInsight® and all KCC Reference Models. A documentation set for major components within RiskInsight® includes requirement specifications, software design documentation, code documentation, data schemas, test plans and test cases, and end-user documentation. Documents maintained by the KCC software development team for RiskInsight® components include:

- Software Requirement Specification
- Software Design Documentation
- Source Code Documentation
- Data Format Schema
- Test Plans and Test Cases
- Installation and Configuration Guide
- End-User Guide
- Database Reference Manual
- Component Reference Manual (e.g., WindfieldBuilder)
- End-User Workflow Specific Guides
- Coding Standards
- Technical Writing Guide
- Software Documentation Templates
- Security Documentation

CI-3 Hurricane Model Organization and Component Design

A. The following shall be maintained and documented: (1) detailed control and data flowcharts and interface specifications for each software component, (2) schema definitions for each database and data file, (3) flowcharts illustrating hurricane model-related flow of information and its processing by modeling organization personnel or consultants, (4) network organization, and (5) system model representations associated with (1)-(4) above. Documentation shall be to the level of components that make significant contributions to the hurricane model output.

KCC maintains documents that describe the flow of data between all relevant components of the software as well as the schema of the databases that host the exposures and results and the supporting API. These documents will be available for review by the Professional Team.

B. All flowcharts (e.g., software, data, and system models) in the submission or in other relevant documentation shall be based on (1) a referenced industry standard (e.g., UML, BPMN, SysML), or (2) a comparable internally-developed standard which is separately documented.

All flowcharts developed and maintained by KCC conform to the ISO 5807 standard, including the KCC Appendix to the standard. A sample is provided below.

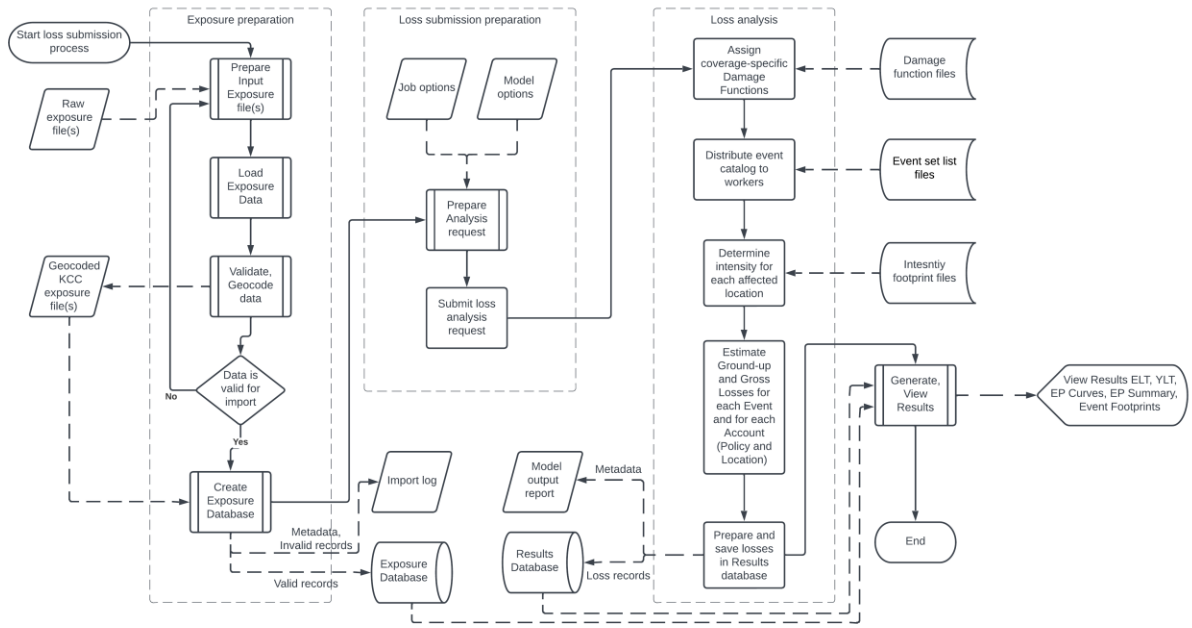


Figure 44 – Flowchart for loss analysis process

CI-4 Hurricane Model Implementation

A. A complete procedure of coding guidelines consistent with accepted software engineering practices shall be maintained.

KCC maintains implementation procedures and coding guidelines to ensure all software components comply with our coding standards.

B. Network organization documentation shall be maintained.

KCC maintains diagrams and documentation on the organization of the networks where the hurricane model is installed. These documents will be available for review by the Professional Team.

C. A complete procedure used in creating, deriving, or procuring and verifying databases or data files accessed by components shall be maintained.

KCC maintains procedures for creating and verifying databases and data files accessed by the software.

D. All components shall be traceable, through explicit component identification in the hurricane model representations (e.g., flowcharts) down to the code level.

KCC guidelines require all components to be explicitly and clearly identified and traceable from scientific documentation down to the code level.

E. A table of all software components affecting hurricane loss costs and hurricane probable maximum loss levels shall be maintained with the following table columns: (1) component name, (2) number of lines of code, minus blank and comment lines, and (3) number of explanatory comment lines.

KCC maintains a table meeting the requirement, which will be available for review by the Professional Team.

F. Each component shall be sufficiently and consistently commented so that a software engineer unfamiliar with the code shall be able to comprehend the component logic at a reasonable level of abstraction.

KCC coding guidelines require the code (e.g. projects, modules, classes, methods, variables, constants, enumerated constants) for all components to be clearly named and documented for efficient transfer of knowledge between any two software engineers broadly familiar with the subject matter. KCC standards also require all code changes to pass a formal code review process.

G. The following documentation shall be maintained for all components or data modified by items identified in Hurricane Standard G-1, Scope of the Hurricane Model and Its Implementation, Disclosure 7 and Audit 7:

1. A list of all equations and formulas used in documentation of the hurricane model with definitions of all terms and variables, and

This list is maintained and will be available for review by the Professional Team.

2. A cross-referenced list of implementation source code terms and variable names corresponding to items within G.1 above.

This list is maintained and will be available for review by the Professional Team.

H. Hurricane model code and data shall be accompanied by documented maintenance, testing, and update plans with their schedules. The vintage of the code and data shall be justified.

KCC maintains procedures for updating data and software used for hurricane model development. These documents will be available for review by the Professional Team.

Disclosure

1. Specify the hardware, operating system, and essential software required to use the hurricane model on a given platform.

The hardware and operating system requirements for the KCC US Hurricane Reference Model and RiskInsight® Loss Modeling Platform for each tier include:

- Application Tier
    - Windows 10 - 11
    - Windows Server 2012 – 2022
    - CPU: 3.0 GHz, 8 cores
    - RAM: 32 GB
    - Disk: 1 TB
- Loss Analysis Tier
    - Windows Server 2012 – 2022
    - CPU: 3.0 GHz, 12 cores
    - RAM: 128 GB
    - Disk: 1 TB
- Database Tier
    - Windows Server 2012 – 2022
    - CPU: 3.0 GHz, 8 cores
    - RAM: 64 GB
    - Disk: 1 TB
    - SQL Server: 2014 – 2019

Additional software requirements and programming languages include:

- Microsoft .NET 4.8 and .NET 5.0 required on all systems
- Transact-SQL (SQL Server 2014 – 2019) required for queries
- XML 1.0 (eXtensible Markup Language) required for configuration files
- Internet Explorer 10.0 or later required for viewing maps
- LeafletJS v0.7 required to render maps
- Microsoft Edge WebView2 runtime required to render React JS (JavaScript) user interface
- WebGL 1.0 required to render windfields on maps
- Background map imagery provided by Mapbox
- JSON.NET C# library for serializing and deserializing RiskInsight data in JSON format
- PGRestAPI Node.js REST API for serving thematic map shapes
- FastColoredTextBox.dll for improved diagnostics reports

- SharpZipLib.dll for opening data stored in the zip archive file format
- DotNetZip dll for opening data stored in the zip archive file format
- JacksonSoft.CustomTabControl.dll for customized tab styles (deprecated)
- Npgsql.dll access PostgreSQL from C# to retrieve thematic map objects from sds.kccriskinsight.co
- Mono.Security.dll used by Npgsql to access PostgreSQL
- PdfSharp.dll for creating PDF documents
- SharpKml.dll for reading and writing files in the KML file format
- BitMiracle.LibTiff.NET.dll for reading and writing files in Tiff format
- Natural Earth Source data for thematic map shapes

CI-5 Hurricane Model Verification

A. General

For each component, procedures shall be maintained for verification, such as code inspections, reviews, calculation crosschecks, and walkthroughs, sufficient to demonstrate code correctness. Verification procedures shall include tests performed by modeling organization personnel other than the original component developers.

KCC employs multiple procedures to verify code correctness. Members of the model development team independently develop prototypes and worked examples of the desired software implementation for key components. The prototypes and worked examples are shared with the KCC software team, including the component software developer, along with representative output prior to implementation. KCC does not outsource/offshore any development. All members of KCC's teams are US-based and organized for active, direct interaction and collaboration.

All code implementations as well as the principal outputs are subject to code reviews, tests by the primary developers, and by experienced developers using appropriate combinations of hand calculations, unit tests, and visual inspection of graphical representations (using charts, maps, and tables) before being released from the DEV to the QA environment. The QA environment is then used by other KCC professionals (not software engineers) to independently verify the model's intermediate and final outputs and, where pertinent, to perform regression tests.

During implementation, the component software developer cross-references the provided input and output examples to verify that the code accurately reproduces intended results. Once the cross-reference verification is met, the software developer submits the code for peer review. The peer review is performed by other members of the software development team and includes checks of component inputs, outputs, code inspection, and adherence to KCC coding guidelines. Upon successful completion of the peer review, the component code is made available for the next build of the software.

KCC professionals other than the original component developer conduct rigorous quality assurance (QA) checks of the model output for each build of the software, including reviews of any component that has changed from the previous build. The QA checks include construction of purpose-built input files designed to isolate the behavior and output of an individual component, such as simulated wind speed or a vulnerability function. The results of the QA checks are verified against expected outputs with relevant members of the software and research teams to ensure code correctness.

KCC uses both Microsoft Team Foundation Server and Git / GitHub for managing source code, documentation, test plans and project management. Automated tests are written using the NUnit testing framework and automated tests are run using JetBrains TeamCity Build Server and Test Runner.

Unit tests are written using NUnit and are executed by TeamCity. A history for each Unit Test is maintained on TeamCity. The software development team is notified immediately when a test fails. Team City provides access to the build history and test runs. Code check-ins that cause a test to fail and code check-ins that resolve a failed test are linked from the test history.

Regression and aggregation tests are run nightly. KCC team members perform manual testing following a Test Plan for each internal deployment to KCC environments.

B. Component Testing

1. Testing software shall be used to assist in documenting and analyzing all components.

KCC uses non-model-based software, including NUnit, TeamCity Builder, and TeamCity runner, to test and document all components.

2. ***Unit tests shall be performed and documented for each updated component.***

   Unit tests are performed in DEV and documented for each component using NUnit, TeamCity Builder, and TeamCity Runner.

3. ***Regression tests shall be performed and documented on incremental builds.***

   Regression tests are performed and documented for each build released to QA using TeamCity Builder and TeamCity Runner.

4. ***Integration tests shall be performed and documented to ensure the correctness of all hurricane model components. Sufficient testing shall be performed to ensure that all components have been executed at least once.***

   Aggregation tests using TeamCity Builder and TeamCity Runner are performed and documented for each build in DEV and in QA to ensure all components are functioning correctly and have been exercised.

C. Data Testing

1. ***Testing software shall be used to assist in documenting and analyzing all databases and data files accessed by components.***

   KCC has implemented testing software and protocols to test and analyze data accessed from databases and data files by each component. Changes to SQL and non-SQL data sources are tracked through Source Control.

2. ***Integrity, consistency, and correctness checks shall be performed and documented on all databases and data files accessed by the components.***

   KCC has implemented an extensive set of built-in "always-on" tests to ensure the integrity and consistency of data being exchanged between the components and the databases. Documentation and tests will be available for review by the Professional Team.

Disclosures

1. ***State whether any two executions of the hurricane model with no changes in input data, parameters, code, and seeds of random number generators produce the same hurricane loss costs and hurricane probable maximum loss levels.***

   Any two executions with the same inputs will produce the same results, same loss costs, and same probable maximum loss levels. The KCC US Hurricane Reference Model does not use random number generators.

2. ***Provide an overview of the component testing procedures.***

   The KCC component test process is as follows:

   - Developer completes work on a task and submits the code for peer review.
   - If the code passes review, the code is checked-in to Source Control.
   - The TeamCity automated Build Server and Test Runner is notified of the change and pulls the latest code changes from Source Control.
   - TeamCity performs a full build of all RiskInsight® components for every code change. If the build passes, a collection of automated unit tests are performed. If any tests fail, the KCC software development team is notified, and a team member is assigned to investigate the issue.

- On a weekly basis, the TeamCity Build Server performs a full rebuild and runs an extended set of automated aggregation tests. These tests confirm that exposure queries, loss analysis results, and other reports return the exact results as expected.
- If the full rebuild succeeds, a "Build Artifact" is created. This is a collection of zip files that has passed all automated build steps and tests and is ready for deployment to KCC internal environments.
- The latest successful build is deployed to internal KCC environments as needed for manual testing by KCC team members.
- Once all product specifications are satisfied and all tests pass for the current product backlog, a Semantic Version is assigned to a build and end-user documentation is prepared.

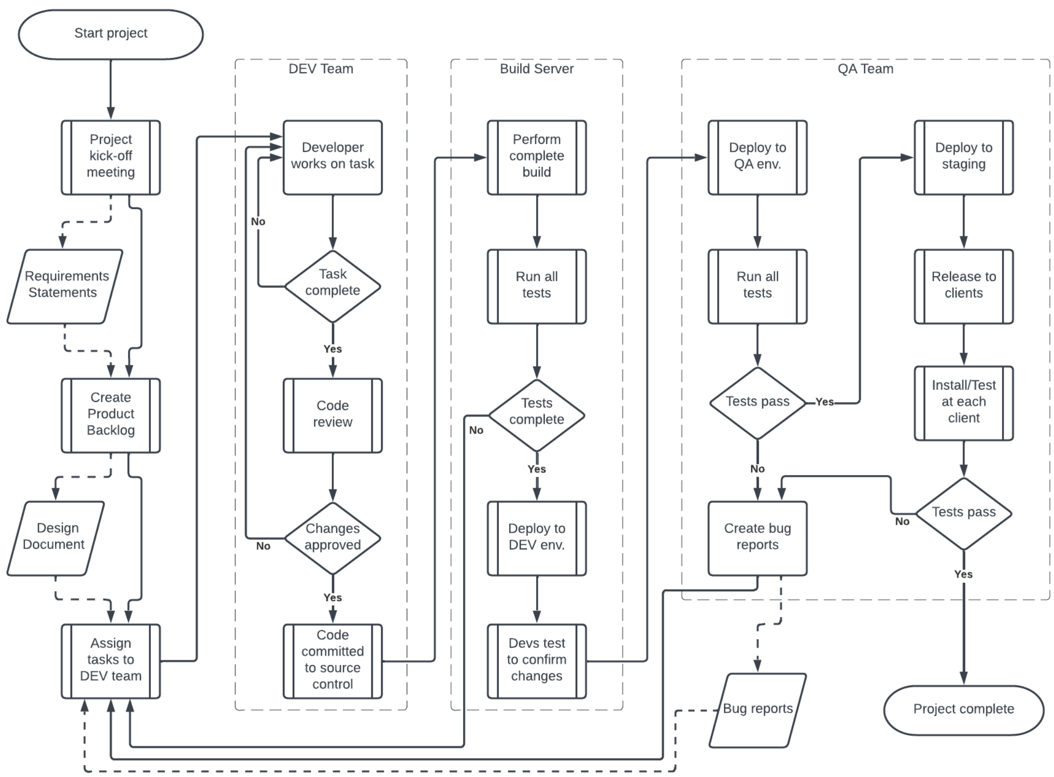


Figure 45 - Procedure for testing software components prior to release

3. ***Provide a description of verification approaches used for externally acquired data, software, and models.***

KCC performs extensive verification on all externally acquired data, as is shown below.

Source Title	Description	Verification Methods
HURDAT2	A database of Atlantic hurricanes with 6-hourly information on hurricane characteristics for storms from 1851 to 2021. HURDAT2 is produced by the National Hurricane Center with the recommended reference of Landsea and Franklin (2013).	Verified against the version currently available from the National Hurricane Center after download.

Source Title	Description	Verification Methods
Extended Best Tracks	A database of Atlantic hurricanes based on HURDAT2 but including additional hurricane data at each 6-hourly time step sourced from the National Hurricane Center. The version of the Extended Best Tracks Dataset covers the time period 1988 to 2021 and was originally published by Demuth et al. (2006).	Verified against the version available online after download. Additionally, the latitude and longitude of non-landfall track points were compared against the data in HURDAT2 for consistency as a method of validation.
United States Geological Survey (USGS) National Land Cover Database (NLCD)	Satellite-derived land cover classification for the entire United States at a 30-meter spatial resolution using Landsat's Thematic Mapper sensor.	Spot checks in different land cover types performed and validated against actual satellite imagery.
Natural Earth Land Polygons	10-meter resolution land polygons for the world delineating coastline, land, ocean, inland waterbodies, and similar. Used by KCC in raster, rather than native vector, format.	Visual verification of test event; footprint should mirror land surface.
Claritas Postal Centroids	ZIP Code centroids for the United States weighted by population.	Claritas centroids are compared to United States Census Bureau block group population data by creating another set of population weighted centroids with ZCTA boundaries. The two sets of population weighted centroids should be similar, but not identical owing to the fact that ZCTAs are not as frequently updated as official USPS ZIP codes. If the centroids are valid, a cross-check with the USPS Address Information System products and the Florida Department of Revenue Tax Parcel Database is performed to confirm all valid Postal Codes are included.
Claritas Postal Boundaries	US ZIP Code vector boundaries.	Claritas boundaries are compared against Census Bureau ZIP Code Tabulation Areas (ZCTAs), which are generalized areal representations of USPS carrier route boundaries, for general agreement.
HURSAT	The dataset covers the time period 1979 to 2017. The data were retrieved from the supplemental materials of the Kossin et al. (2020) paper published in Proceedings of the National Academy of Sciences.	Verified against the version currently available from the Proceedings of the National Academy of Sciences.

Source Title	Description	Verification Methods
NOAA Extended Reconstructed SST V4	The NOAA SST reconstruction dataset contains monthly, gridded sea surface temperature data covering the globe with 2 degree by 2 degree resolution. The dataset is based on the International Comprehensive Ocean-Atmosphere Data which was constructed with observations from many different platforms.	Verified against the version available for download from the NOAA Physical Sciences Laboratory and checked visually.
Florida Department of Revenue’s Tax Database Parcel Data	Florida Department of Revenue’s Tax database Parcel Data contains the 2022 vintage parcel boundaries with each parcel's associated tax information from the Florida Department of Revenue's tax database. Attributes include occupancy, site street addresses, GIS boundaries, land use codes, valuation, building details, legal description, and more.	Spot checks performed and validated using aggregate totals. Risks are validated against US Census data.
US Census Block Groups Centroids	US Census Block Centroids for the 2020 Census.	Visually verified using GIS tools to confirm centroids align with population centers.
US Census ZCTA Boundaries	US Census Bureau ZIP Code Tabulation Area (ZCTA) boundaries.	Visually verified using GIS tools to confirm boundaries align with state boundaries and population centers

Table 19 - External data sources and verification methods employed by KCC professionals

CI-6 Human-Computer Interaction

A. Interfaces shall be implemented as consistent with accepted principles and practices of Human-Computer Interaction (HCI), Interaction Design, and User Experience (UX) engineering.

The RiskInsight User Interface adheres to accepted principles for user interface design to implement an intuitive and informative user experience utilizing Microsoft Windows Forms, React JS and Leaflet JS.

B. Interface options used in the hurricane model shall be unique, explicit, and distinctly emphasized.

User workflows for interacting with the hurricane model within RiskInsight follow an intuitive process that makes it clear that all options are within the context of using the hurricane model.

C. For a Florida rate filing, interface options shall be limited to those options found acceptable by the Commission.

RiskInsight provides a pre-defined, read-only loss analysis options template which automatically selects only the options found acceptable by the Commission for rate filing in the state of Florida.

Disclosures

1. Identify Procedures used to design, implement, and evaluate interface options.

The RiskInsight user interface design process follows a three phase workflow.

Design:

For each feature within RiskInsight, a conceptual design is developed and reviewed by KCC team members. The conceptual design is then prototyped using mock ups.

Implementation:

Once the mock ups are approved, the software development team constructs the user interface using appropriate user interface libraries.

Testing:

The completed interface is deployed internally for testing. Any issues or feature requests are added to the project backlog. Once the details are clarified, the initial designs are updated and the developers update the implementation.

CI-7 Hurricane Model Maintenance and Revision

A. A clearly written policy shall be implemented for review, maintenance, and revision of the hurricane model and network organization, including verification and validation of revised components, databases, and data files.

KCC maintains written policies that outline the protocol for changing the hurricane model in any way (be it for review, maintenance, or revision). This includes specific documentation for each model component, in which details such as purpose, objective, and impact are provided.

The scientist(s) and/or engineer(s) proposing a change first document the change itself and the methodology proposed to implement it. They also document specifically how that model change will improve the accuracy of the annual average loss costs and probable maximum losses generated by the model. They then present their proposed change, methodology, and expected impacts to the KCC model development team for peer review. If the model development team determines the proposed change will not address any model deficiency or enhance model accuracy, the proposed change is rejected.

When a proposed change is accepted, the model developers responsible for implementing the change will document the inherent assumptions and expected results. The methodology and assumptions are again discussed with the model development team. Alternative assumptions and methodologies are evaluated before the final specifications are developed.

When the change to the model is ready for testing, engineers and scientists on the model development team not directly involved in the model update perform tests to verify that the expected changes appear in the updated database(s) and/or files prior to implementation. These tests can vary in terms of scope, as changes can vary from minor updates to new model components. Once all tests are passed, the updated database and files are made available to the software development team for implementation into the model.

B. A revision to any portion of the hurricane model that results in a change in any Florida residential hurricane loss cost or hurricane probable maximum loss level shall result in a new hurricane model version identification.

A revision to any portion of the KCC US Hurricane Reference Model, including software, hazard, or vulnerability, that results in a change in any Florida residential hurricane loss cost or hurricane probable maximum loss will result in a new hurricane model version identification.

C. Tracking software shall be used to identify and describe all errors, as well as modifications to code, data, and documentation.

KCC has implemented Microsoft Team Foundation Server to report errors and track software updates. Software modifications to address errors are seamlessly linked from the developer’s peer-reviewed source control check-in via Visual Studio to the error reported in Team Foundation Server and the associated product feature backlog item or test.

Test plans, software design documentation, and user documentation are updated as appropriate when changes are made to the software.

D. A list of all hurricane model versions since the initial submission for this year shall be maintained. Each hurricane model description shall have a unique version identification and a list of additions, deletions, and changes that define that version.

KCC maintains a list of all changes after this initial submission, each with a unique identification number and list of additions, deletions, and changes that define that version.

Disclosures

1. *Identify procedures used to review and maintain code, data, and documentation.*

Both Microsoft Team Foundation Server and Git / GitHub are used for Source Control. The following process describes the workflow for both version control systems.

The software development process starts with an initial project meeting, which establishes the purpose of a development project. Notes from the kick-off meeting are formally defined in traditional, text-based requirements statements. A product backlog item / GitHub issue is created in Source Control, and the project is broken down to tasks that are assigned to members of the software development team.

The tasks created in Source Control are seamlessly integrated into the Visual Studio environment. As the developer makes progress on a work item, the developer is required to submit changes for code review to a peer member of the development team. Visual Studio provides a robust code review system. Under both Source Control systems, the reviewer has access to the software requirement, the work-item task, and a full-featured code comparison tool that permits commenting and highlighting any line item in the code presented for review. The entire software development team meets daily for a stand-up meeting to discuss the day's work items and alert team members of impending changes. The KCC code check-in policy requires that all code pass a code review without any item noted as "Needs Work" on Team Foundation Server, or "requested changes" on GitHub. All code reviews and comments provided by the reviewer and the developer are linked to the code check-in record, as well as the work item and the product back log item.

After code has been reviewed and checked-in on Team Foundation Server, the KCC TeamCity automated Build Server and Test Runner gets the latest code changes from all developers, then compiles and runs the code. A full suite of automated tests is executed to confirm that the latest changes have not broken any previously passing tests. A similar workflow is executed if code is checked-in on Github by implementing a Github Actions *yaml* file to compile and run the latest code when merged onto the main branch. In addition to the builds and tests for every code check-in, a weekly build is performed and an extended set of aggregation tests are performed. If all tests pass, the compiled applications are added to a zip archive that can then be deployed to internal KCC environments for further testing by KCC professionals.

KCC developers work with a written Test Plan to confirm all documented functionality is performing as expected. Test Plans, Software Design Documents, and Software Requirement Specifications are also managed through the Source Control system. All KCC developers have access to the latest documentation for all software components via the Source Control web portal. In addition to the web portal, developers have access to the documentation from within the Visual Studio Source Control Explorer.

2. *Describe the rules underlying the hurricane model and code revision identification systems.*

KCC Models and Software applications follow semantic versioning for released builds and build stamp versioning for incremental builds. For publicly released APIs within RiskInsight and for publicly released models, the version format is X.Y.Z (Major.Minor.Patch). Bug fixes not affecting any public API or the model increment the "Patch." Backwards compatible additions or changes increment the "Minor" version. Any new features or changes that are not backwards compatible increment the "Major" version. This system simplifies dependency requirements in all client released software.

Fully implementing an update at the Major, Minor or Patch level typically requires multiple sets of changes from multiple developers. Progress builds, generated automatically by the TeamCity build server, aggregate all changes checked in to source control and assigns a Progress-Build number appended to the end of the version stamp, i.e. X.Y.Z.B (Major.Minor.Patch.Progress-Build). Once a Major.Minor.Patch.Progress-Build has been fully implemented, tested and confirmed to provide the correct results, the publicly released Major.Minor.Patch version is finalized. Only one instance of a Major.Minor.Patch version will be released. Any outstanding features or improvements will be rolled in to the next version of the software to be released with one or more of the Major, Minor, or Patch numbers incremented and the Progress-Build number reset to 1.

Internal builds to be included in the next Progress-Build follow a build stamp versioning schema that follows a pattern YYMMDD:HHmm (221017:1500). The build stamp versioning system enables developers to focus on specific work items and decouples work items from the publicly released version, which is the collection of all work items completed by the development team.

CI-8 Hurricane Model Security

Security procedures shall be implemented and fully documented for (1) secure access to individual computers where the software components or data can be created or modified, (2) secure operation of the hurricane model by clients, if relevant, to ensure that the correct software operation cannot be compromised, (3) anti-virus software installation for all machines where all components and data are being accessed, and (4) secure access to documentation, software, and data in the event of a catastrophe.

KCC has fully documented security procedures for access to code, data, and documentation in accordance with standard industry practices. These documents will be available for review by the Professional Team.

Disclosure

1. Describe methods used to ensure the security and integrity of the code, data, and documentation. These methods include the security aspects of each platform and its associated hardware, software, and firmware.

Physical Security

- Building Security: the building employs 24-hour security personnel, and access to the building is restricted with an electronic badge system.
- Office Access: Only KCC employees with authorized electronic badges may enter the offices. All external-facing doors close and lock automatically. Business Access Logs are maintained by the badge system for 1 year.
- Data Room Access: Only Administrators have access to the locked data room located in the KCC offices, which is controlled by electronic badges.

Network Security

- Firewall: FortiGate firewalls are used to control all traffic in and out of the network. IDS and IPS software are used to detect and prevent network intrusions, and website blocking is used to filter user traffic to only approved external sites.
- User Accounts: Authorized KCC user accounts are required for network access. Former employees' user accounts are immediately disabled following their last day of employment, emails are archived, and multifactor authentication & VPN access are revoked
- Internal Access: Access to files and folders on all servers is regulated by Windows permissions. Permissions are set on a server-by-server, folder-by-folder, or file-by-file basis as appropriate. Access to SQL instances is set on a user-by-user basis. KCC follows least-privilege access rights.
- External Access: Access to the KCC network from outside the firewall is granted using a VPN gateway. VPN access is tied to a user's Windows account and is controlled by the IT department. Multifactor Authentication is required for all remote connections into the KCC Network via Duo
- Collaborative Application Access: Access to collaborative applications, such as Microsoft Teams and Microsoft Office, is secured with Microsoft multifactor authentication (MFA).

Server and Workstation Security

- Physical Access: All servers are located in the secured data room, which requires electronic badge access.
- Patches and Updates: Windows updates and patches are administered by the IT department and run regularly on a monthly basis. The distribution of updates is controlled by Group Policy at the domain level, as well as a software agent to manage deployment.
- Virus Protection: All servers and workstations are protected via CrowdStrike Falcon antivirus.
- Remote Access: By default, users are only allowed remote (RDP) access to their own workstation. Any access to other servers is granted on an as-needed basis and regulated by the IT department.
- Desktop Access: Every desktop, after 15 minutes of inactivity, is automatically locked and requires a valid password to unlock for use.

Data Security

- Data Transfer: All confidential data can be sent via SFTP with PGP encryption.
- File Storage: All confidential data must be stored in a physically secure location, the data room. Secure file and SQL servers are not used for external access, including the Internet and emails. Both remote access (RDP) and file access (Explorer, SMB) are restricted to only authorized users. Any server containing client and/or sensitive data must have antivirus software installed and is backed up nightly.
- Data Access: Just as with file storage, all types of data access must be regulated to authorized users. This includes access to Source Control for version control and SQL for database access.
- Code: Only developers have access to KCC code. Microsoft Team Foundation Server and Git / GitHub is used for version control, and only specified developers have access to the necessary Collections, Projects, and Solutions. Only Administrators have physical and remote (RDP) access to the TFS server.
- File Backups: All workstations and servers are backed up using Veeam, with full backups monthly and incremental backups nightly. Encrypted cloud backups are made monthly to an offsite disaster recovery service. Nightly backups to the cloud are made for the TFS installation.
- Data Deletion: All old hard drives are wiped clean or physically destroyed by an Administrator when they are no longer needed.

User Management

- NDA: All company personnel are required to sign a non-disclosure agreement as a condition of employment.
- Background Check: All company personnel are required to pass a background check upon employment.
- VPN Access Form: All company personnel are required to file a signed VPN Request Form with their manager’s counter-signature.
- User Accounts: All KCC employees require an authorized user account to login to any workstation or server. Passwords must adhere to strict, industry-standard requirements. User account privileges are managed by the IT department.
- External Site Access: Access to potentially dangerous sites is restricted via the firewall. Developers may request access to certain sites for testing purposes only.

- Lockout Policy: Any user account with 5 unsuccessful logins will automatically be locked out.
- Access to email is secured with Microsoft multifactor authentication.
- Security of code, data, and documentation for each client organization is governed by strict licensing, mutually acceptable requirements under which they cannot reverse engineer or modify any of the binaries provided to them under the terms and conditions of the license, and secure installations involving both parties' IT departments.

Appendix A: General Forms

Form G-1: General Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the General Hurricane Standards (G-1 – G-5);***
2. ***The disclosures and forms related to the General Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession;***
4. ***My review involved ensuring the consistency of the content in all sections of the submission; and***
5. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Glen Daraskevich	**M.S. Engineering and Information Systems**
Name	***Professional Credentials (Area of Expertise)***
[signature]	**November 4, 2022**
Signature (original submission)	***Date***
[signature]	**January 24, 2023**
Signature (response to deficiencies, if any)	***Date***
[signature]	**March 9, 2023**
Signature (revisions to submission, if any)	***Date***
[signature]	**June 27, 2023**
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-1, General Hurricane Standards Expert Certification, in a submission appendix.

Form G-2: Meteorological Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Meteorological Hurricane Standards (M-1 – M-6);***
2. ***The disclosures and forms related to the Meteorological Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Daniel Ward	**Ph.D., Atmospheric Science**
Name	***Professional Credentials (Area of Expertise)***
	November 4, 2022
Signature (original submission)	***Date***
	January 24, 2023
Signature (response to deficiencies, if any)	***Date***
	March 9, 2023
Signature (revisions to submission, if any)	***Date***
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-2, Meteorological Hurricane Standards Expert Certification, in a submission appendix.

Form G-3: Statistical Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Statistical Hurricane Standards (S-1 – S-6);***
2. ***The disclosures and forms related to the Statistical Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Adam Jaeger	**Ph.D., Statistics**
Name	***Professional Credentials (Area of Expertise)***
[signature]	**November 4, 2022**
Signature (original submission)	***Date***
[signature]	**January 24, 2023**
Signature (response to deficiencies, if any)	***Date***
[signature]	**March 9, 2023**
Signature (revisions to submission, if any)	***Date***
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-3, Statistical Hurricane Standards Expert Certification, in a submission appendix.

Form G-4: Vulnerability Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Vulnerability Hurricane Standards (V-1 – V-4);***
2. ***The disclosures and forms related to the Vulnerability Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Shaoning Li	**Ph.D. Structural/Wind Engineering**
Name	***Professional Credentials (Area of Expertise)***
Shaoning Li	**November 4, 2022**
Signature (original submission)	***Date***
Signature (response to deficiencies, if any)	***Date***
Shaoning Li	**March 9, 2023**
Signature (revisions to submission, if any)	***Date***
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-4, Vulnerability Hurricane Standards Expert Certification, in a submission appendix.

Form G-4: Vulnerability Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Vulnerability Hurricane Standards (V-1 – V-4);***
2. ***The disclosures and forms related to the Vulnerability Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Girma Tsegaye Bitsuamlak	**Ph.D., P.Eng. Building Engineering**
Name	***Professional Credentials (Area of Expertise)***
	State: Ontario, CA **Expiration Date: 8/31/2023**
	Professional License Type: Professional Engineer
Girma Bitsuamlak	**November 4, 2022**
Signature (original submission)	***Date***
Girma Bitsuamlak	**January 24, 2023**
Signature (response to deficiencies, if any)	***Date***
Girma Bitsuamlak	**March 9, 2023**
Signature (revisions to submission, if any)	***Date***
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-4, Vulnerability Hurricane Standards Expert Certification, in a submission appendix.

Form G-5: Actuarial Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Actuarial Hurricane Standards (A-1 – A-6);***
2. ***The disclosures and forms related to the Actuarial Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the Actuarial Standards of Practice and Code of Conduct; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Melinda Vasecka	**B.A. Mathematics, ACAS**
Name	***Professional Credentials (Area of Expertise)***
Melinda Vasecka	**November 4, 2022**
Signature (original submission)	***Date***
Signature (response to deficiencies, if any)	***Date***
Melinda Vasecka	**March 9, 2023**
Signature (revisions to submission, if any)	***Date***
Melinda Vasecka	**June 27, 2023**
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-5, Actuarial Hurricane Standards Expert Certification, in a submission appendix.

Form G-6: Computer/Information Hurricane Standards Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the 2021 Hurricane Standards adopted by the Florida Commission on Hurricane Loss Projection Methodology and hereby certify that:***

1. ***The hurricane model meets the Computer/Information Hurricane Standards (CI-1 – CI-7);***
2. ***The disclosures and forms related to the Computer/Information Hurricane Standards section are editorially and technically accurate, reliable, unbiased, and complete;***
3. ***My review was completed in accordance with the professional standards and code of ethical conduct for my profession; and***
4. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Vivek Basrur	**M.S. Management Sciences**
Name	***Professional Credentials (Area of Expertise)***
	November 4, 2022
Signature (original submission)	***Date***
Signature (response to deficiencies, if any)	***Date***
	March 9, 2023
Signature (revisions to submission, if any)	***Date***
	June 27, 2023
Signature (final submission)	***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)	***Date***

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-6, Computer/Information Hurricane Standards Expert Certification, in a submission appendix.

Form G-7: Editorial Review Expert Certification

I hereby certify that I have reviewed the current submission of KCC US Hurricane Reference Model ***Version*** 4.0 ***for compliance with the "Process for Determining the Acceptability of a Computer Simulation Hurricane Model" adopted by the Florida Commission on Hurricane Loss Projection Methodology in its Hurricane Standards Report of Activities as of November 1, 2021, and hereby certify that:***

1. ***The hurricane model submission is in compliance with the Notification Requirements and General Hurricane Standard G-5, Editorial Compliance;***
2. ***The disclosures and forms related to each hurricane standards section are editorially accurate and contain complete information and any changes that have been made to the submission during the review process have been reviewed for completeness, grammatical correctness, and typographical errors;***
3. ***There are no incomplete responses, charts or graphs, inaccurate citations, or extraneous text or references;***
4. ***The current version of the hurricane model submission has been reviewed for grammatical correctness, typographical errors, completeness, the exclusion of extraneous data/information and is otherwise acceptable for publication; and***
5. ***In expressing my opinion I have not been influenced by any other party in order to bias or prejudice my opinion.***

Glen Daraskevich — ***Name***

M.S. Engineering and Information Systems — ***Professional Credentials (Area of Expertise)***

Signature (original submission) — **November 4, 2022** — ***Date***

Signature (response to deficiencies, if any) — **January 24, 2023** — ***Date***

Signature (revisions to submission, if any) — **March 9, 2023** — ***Date***

Signature (final submission) — **June 27, 2023** — ***Date***

An updated signature and form are required following any modification of the hurricane model and any revision of the original submission. If a signatory differs from the original signatory, provide the printed name and professional credentials for any new signatories. Additional signature lines should be added as necessary with the following format:

Signature (revisions to submission)Date

Note: A facsimile or any properly reproduced signature will be acceptable to meet this requirement.

Include Form G-7, Editorial Review Expert Certification, in a submission appendix.

Appendix B: Meteorology Forms

Form M-1: Annual Occurrence Rates

A. ***One or more automated programs or scripts should be used to generate and arrange the data in Form M-1, Annual Occurrence Rates.***

The results in this form have been produced and arranged using an automated program that reads the model and historical event catalog information.

B. ***Provide a table of annual occurrence rates for hurricane landfall from the dataset defined by marine exposure that the hurricane model generates by hurricane category (defined by maximum windspeed at hurricane landfall in the Saffir-Simpson Hurricane Wind Scale) for the entire state of Florida and additional regions as defined in Figure 1. List the annual occurrence rate per hurricane category. Annual occurrence rates should be rounded to three decimal places.***

The historical frequencies below have been derived from the Base Hurricane Storm Set as defined in Hurricane Standard M-1, Base Hurricane Storm Set. If the modeling organization Base Hurricane Storm Set differs from that provided in Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses (as described in the response to Hurricane Standard M-1, Base Hurricane Storm Set, Disclosure 2), then the historical rates for the modeling organization Base Hurricane Storm Set should be added in the appropriate column as labeled in the table below.

As defined, a by-passing hurricane (ByP) is a hurricane which does not make landfall on Florida, but produces minimum damaging windspeeds or greater on Florida. For the by-passing hurricanes included in the table only, the intensity entered is the maximum windspeed at closest approach to Florida as a hurricane, not the windspeed over Florida.

Annual Occurrence Rates

	Entire State					Region A – NW Florida				
	Historical		Modified Base Storm Set		Modeled	Historical		Modified Base Storm Set		Modeled
Category	**Nbr**	**Rate**	**Nbr**	**Rate**	**Rate**	**Nbr**	**Rate**	**Nbr**	**Rate**	**Rate**
1	26	0.215	24	0.197	0.222	16	0.132	15	0.123	0.110
2	15	0.125	18	0.148	0.119	4	0.033	5	0.041	0.048
3	14	0.117	14	0.115	0.106	6	0.050	6	0.049	0.033
4	11	0.091	10	0.082	0.091	0	0.000	0	0.000	0.018
5	3	0.025	3	0.025	0.028	1	0.008	1	0.008	0.003

	Region B – SW Florida					Region C – SE Florida				
	Historical		Modified Base Storm Set		Modeled	Historical		Modified Base Storm Set		Modeled
Category	**Nbr**	**Rate**	**Nbr**	**Rate**	**Rate**	**Nbr**	**Rate**	**Nbr**	**Rate**	**Rate**
1	7	0.058	6	0.049	0.053	8	0.066	8	0.066	0.075
2	4	0.033	6	0.049	0.033	6	0.050	6	0.049	0.043
3	5	0.042	5	0.041	0.034	5	0.041	4	0.033	0.042
4	5	0.041	4	0.033	0.033	6	0.050	6	0.049	0.040
5	0	0.000	0	0.000	0.011	2	0.017	2	0.016	0.014

	Region D - NE Florida					Florida By-Passing Hurricanes				
	Historical		Modified Base Storm Set		Modeled	Historical		Modified Base Storm Set		Modeled
Category	Nbr	Rate	Nbr	Rate	Rate	Nbr	Rate	Nbr	Rate	Rate
1	1	0.008	1	0.008	0.011	4	0.033	12	0.098	0.109
2	2	0.017	2	0.016	0.005	3	0.025	6	0.049	0.061
3	0	0.000	0	0.000	0.004	6	0.050	10	0.082	0.050
4	0	0.000	0	0.000	0.003	0	0.000	2	0.016	0.041
5	0	0.000	0	0.000	0.001	0	0.000	1	0.008	0.009

	Region E - Georgia					Region F – Alabama/Mississippi				
	Historical		Modified Base Storm Set		Modeled	Historical		Modified Base Storm Set		Modeled
Category	Nbr	Rate	Nbr	Rate	Rate	Nbr	Rate	Nbr	Rate	Rate
1	0	0.000	0	0.000	0.008	7	0.058	7	0.057	0.052
2	2	0.017	2	0.016	0.004	3	0.025	3	0.025	0.026
3	0	0.000	0	0.000	0.003	4	0.033	4	0.033	0.019
4	0	0.000	0	0.000	0.002	0	0.000	0	0.000	0.013
5	0	0.000	0	0.000	0.000	1	0.008	1	0.008	0.003

Table 20 - Annual occurrence rates for Florida and surrounding regions

C. Describe hurricane model variations from the historical frequencies.

The model produces a decrease in rates with increasing intensity for all regions and by-passers, which is consistent with our understanding of tropical cyclone climatology. The historical record comprises a smaller sample size, meaning noise in the system can produce higher rates for stronger storms in some regions.

Additionally, the historical data represent the hurricane wind speeds as they are recorded in the Base Hurricane Storm Set and the modeled occurrence rates are based on model intensity distributions that have been adjusted to account for climate change that has occurred to date.

D. Provide vertical bar graphs depicting distributions of hurricane frequencies by category by region of Florida (Figure 1), for the neighboring states of Alabama/Mississippi and Georgia, and for by-passing hurricanes. For the neighboring states, statistics based on the closest coastal segment to the state boundaries used in the hurricane model are adequate.

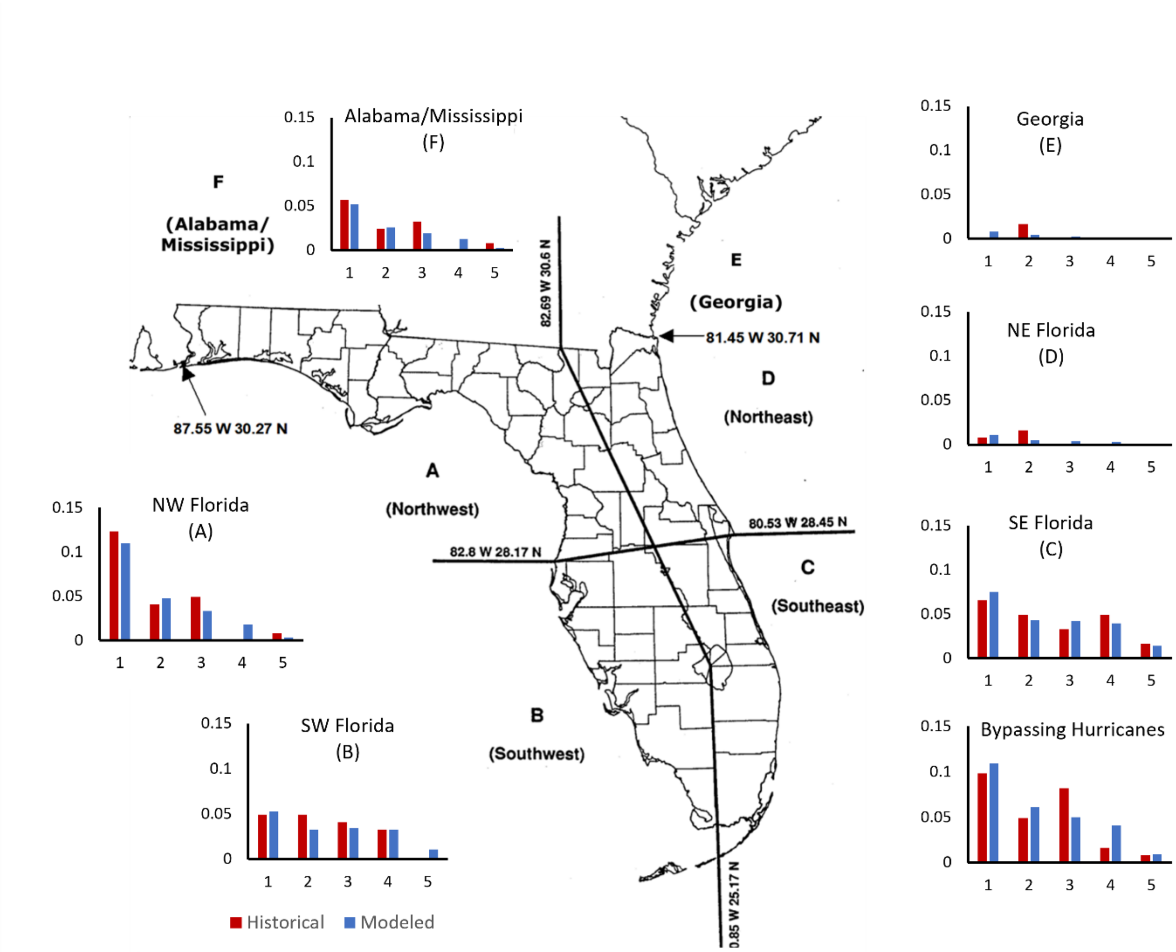


Figure 46 - Comparison of modeled to historical occurrence rates by intensity and region

E. If the data are partitioned or modified, provide the historical annual occurrence rates for the applicable partition (and its complement) or modification as well as the modeled annual occurrence rates in additional copies of Form M-1, Annual Occurrence Rates.

The historical data are not partitioned or modified for the purpose of developing the KCC US Hurricane Reference Model.

F. List all hurricanes added, removed, or modified from the currently accepted hurricane model version of the Base Hurricane Storm Set.

The following hurricanes have been added to the Base Hurricane Storm Set; Galveston (1900), NoName06 (1915), Hugo (1989), Floyd (1999), Gustav (2008), Irene (2011), Isaac (2012), Dorian (2019), Sally (2020), Zeta (2020).

The following hurricanes were modified in the Base Hurricane Storm Set following their reanalysis in the HURDAT2; Cleo (1964), Dora (1964), Isbell (1964), Betsy (1965), Alma (1966), Inez (1966), Gladys (1968).

G. ***Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form M-1, Annual Occurrence Rates, in a submission appendix.***

This form has been provided in Excel format, "KCC21_FormM1_221104.xls."

Form M-2: Maps of Maximum Winds

A. ***Provide color-coded contour plots on a map with ZIP Code boundaries of the maximum winds for the modeled version of the Base Hurricane Storm Set. Plot the position and value of the maximum windspeed on the contour map.***

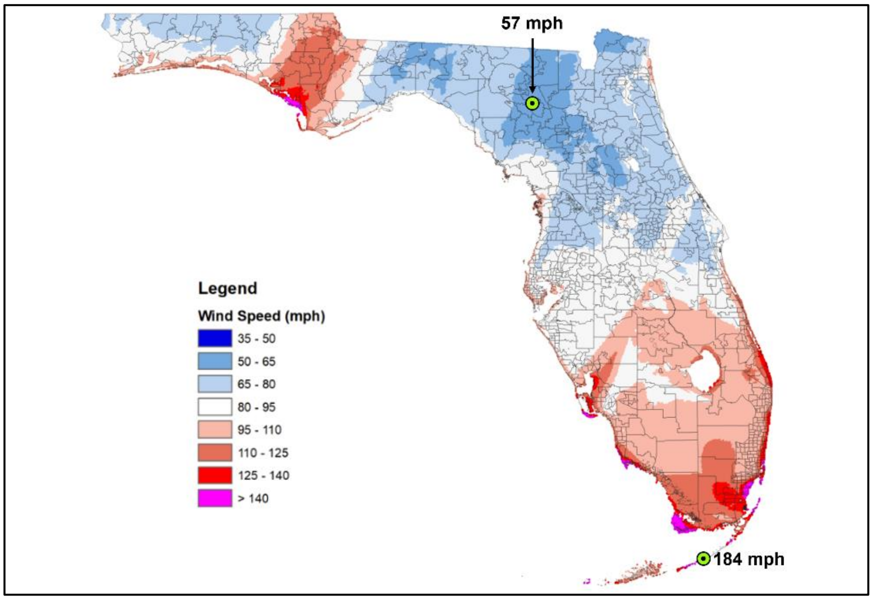


Figure 47 - Maximum wind speeds for historical events over actual terrain

B. ***Provide color-coded contour plots on maps with ZIP Code boundaries of the maximum winds for a 100-year and a 250-year return period from the stochastic storm set. Plot the position and value of the maximum windspeed on each contour map.***

Maximum winds in these maps are defined as the maximum one-minute sustained winds as modeled and recorded at each location.

The same color scheme and increments should be used for all maps.

Use the following eight isotach values and interval color-coding:

(1) Minimum damaging Blue

(2) 50 mph Medium Blue

(3) 65 mph Light Blue

(4) 80 mph White

(5) 95 mph Light Red

(6) 110 mph Medium Red

(7) 125 mph Red

(8) 140 mph Magenta

Contouring in addition to these isotach values may be included.

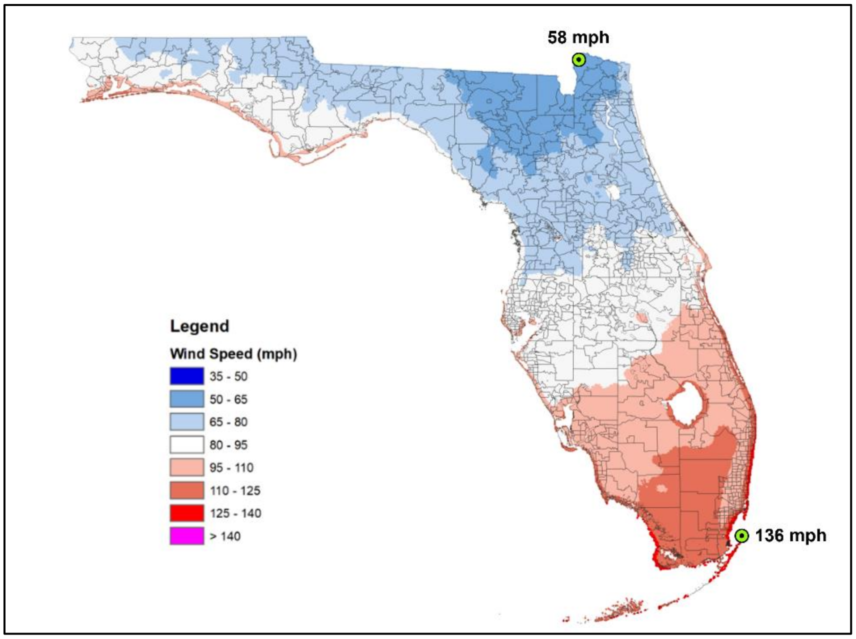


Figure 48 - 100-year return period wind speeds over actual terrain

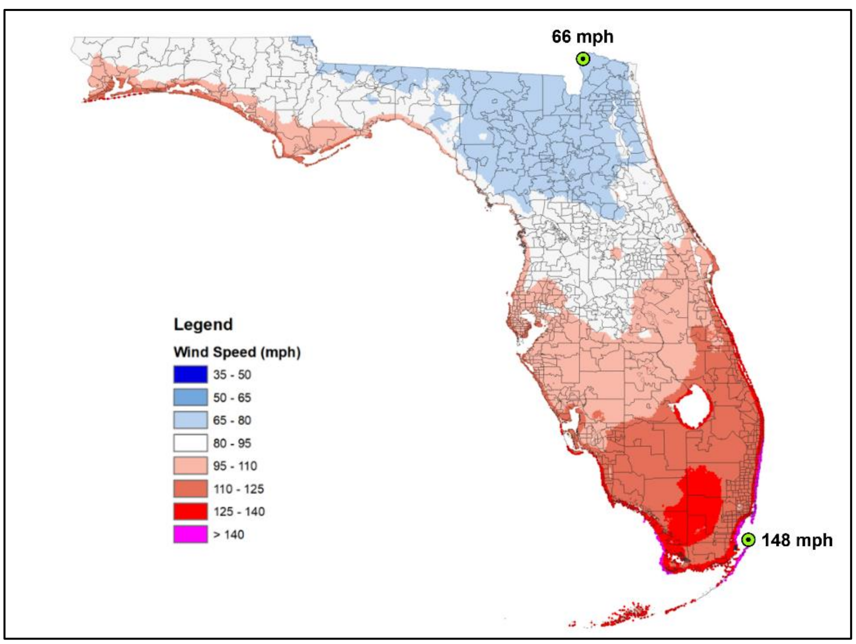


Figure 49 - 250-year return period wind speeds over actual terrain

C. Include Form M-2, Maps of Maximum Winds, in a submission appendix.

Form M-2 is included in this submission appendix.

Form M-3: Radius of Maximum Winds and Radii of Standard Wind Thresholds

A. One or more automated programs or scripts should be used to generate and arrange the data in Form M-3, Radius of Maximum Winds and Radii of Standard Wind Thresholds.

The results in this form have been produced and arranged using an automated program that reads the model event catalog information.

B. For the central pressure bins in the table below, provide the first quartile (1Q), second quartile (2Q), and third quartile (3Q) in the stochastic storm set of the following quantities: radii to maximum wind (Rmax), the Category 3 (110 mph) wind radii, the Category 1 (73 mph) wind radii, and the gale force (40 mph) wind radii. If a value is unavailable, then populate with "NA."

Central Pressure (mb) | Wind Speed (mph)	Rmax (mi)			Outer Radii (>110 mph) (mi)			Outer Radii (>73 mph) (mi)			Outer Radii (>40 mph) (mi)		
	1Q	2Q	3Q	1Q	2Q	3Q	1Q	2Q	3Q	1Q	2Q	3Q
990|79	17	34	48	NA	NA	NA	18	34	49	117	133	148
980|87	16	31	45	NA	NA	NA	24	39	53	126	141	155
970|97	14	28	41	NA	NA	NA	39	53	65	133	147	159
960|108	13	26	37	NA	NA	NA	51	63	75	136	149	160
950|117	12	23	33	12	24	34	49	61	71	148	159	170
940|129	11	21	30	13	23	32	57	67	76	152	163	172
930|143	10	19	27	18	28	36	63	73	80	154	164	172
920|155	15	17	18	28	30	32	73	75	77	160	162	164
910|166	10	12	13	28	29	30	71	73	74	155	157	157
900|178	7	8	9	28	28	29	70	70	72	149	150	151

Table 21 - Radius of maximum winds and radii of standard wind thresholds

C. Describe the procedure used to complete this form.

To complete this form, the model event catalog dataset, which includes the R_{max} and V_{max} at landfall for all model events, is input into a program that computes the R_{max} quartiles and frequencies within prescribed intensity bins and outputs the data in rows as arranged in Table 21. Windfield profiles are generated for each of the R_{max} quartile values in Table 21 using the KCC WindFieldBuilder software. The outer radii values are then extracted from the windfield profiles using a python script and output in columns that are included in Table 21. The central pressure (mb) to wind speed (mph) conversion in Table 21 was performed using Courtney and Knaff (2009).

D. Identify other variables that influence Rmax.

In the KCC US Hurricane Reference Model, R_{max} is influenced by the maximum wind speed (V_{max}) and the latitude of the storm center.

E. Specify any truncations applied to Rmax distributions in the hurricane model, and if and how these truncations vary with other variables.

A minimum R_{max} of 6 miles is imposed on the model.

F. Provide a box and whiskers plot of the data from the table with Central Pressure on the x-axis and Rmax on the y-axis.

The KCC US Hurricane Reference Model bases storm intensity on maximum wind speed and does not use central pressure as a variable. Therefore, we have produced the figures with wind speed on the x-axis.

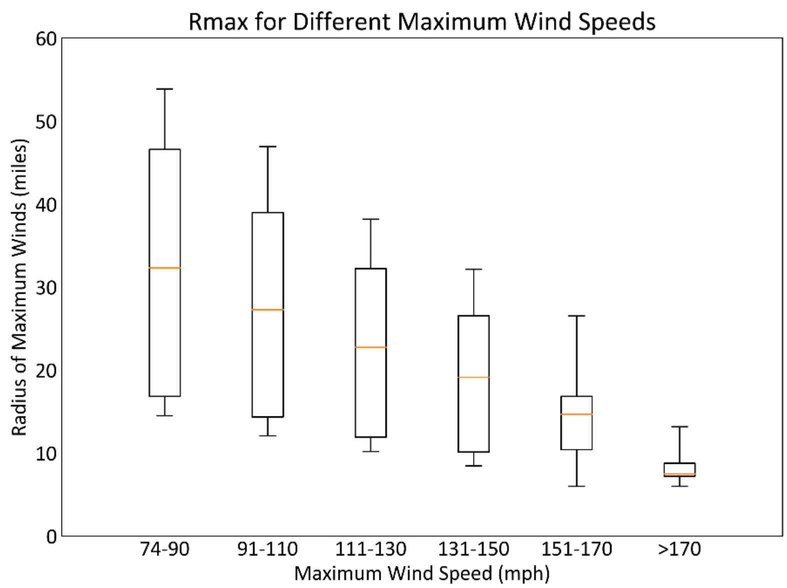


Figure 50 - Box plot of Rmax from the stochastic hurricane set versus ranges of maximum wind speed

G. Provide this form in Excel using the format given in the file named "2021FormM3.xlsx." The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form M-3, Radius of Maximum Winds and Radii of Standard Wind Thresholds, in a submission appendix.

The Excel file has been given with the name "KCC21_FormM3_221104.xlsx" using the provided format. This form is also included in this submission appendix.

Appendix C: Statistical Forms

Form S-1: Probability and Frequency of Florida Landfalling Hurricanes per Year

A. ***One or more automated programs or scripts shall be used to generate and arrange the data in Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year.***

The results in this form have been produced and arranged using an automated program.

B. ***Complete the table below for the modeled probabilities of the number of landfalling Florida hurricanes per year. Values derived from the Base Hurricane Storm Set (as given in Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses) have been provided. If the modeling organization has modified the Base Hurricane Storm Set, as identified in their response to Hurricane Standard M-1, Base Hurricane Storm Set, then the probabilities and frequencies of the modified set should also be provided in the appropriate columns. Probabilities should be rounded to three decimal places.***

Probability and Frequency of Florida Landfalling Hurricanes per Year

Number of Hurricanes Per Year	Historical Probability	Modified Base Storm Set Probability	Modeled Probability	Historical Frequency	Modified Base Storm Set Frequency
0	0.603	0.607	0.618	73	74
1	0.248	0.246	0.235	30	30
2	0.124	0.123	0.118	15	15
3	0.025	0.025	0.022	3	3
4	0.000	0.000	0.005	0	0
5	0.000	0.000	0.001	0	0
6	0.000	0.000	0.000	0	0
7	0.000	0.000	0.000	0	0
8	0.000	0.000	0.000	0	0
9	0.000	0.000	0.000	0	0
10 or more	0.000	0.000	0.000	0	0

Table 22 - Probability and frequency of modeled landfalling Florida hurricanes

C. ***Include Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year, in a submission appendix.***

This form is included in a submission appendix.

Form S-2: Examples of Hurricane Loss Exceedance Estimates

A. ***One or more automated programs or scripts shall be used to generate and arrange the data in Form S-2, Examples of Hurricane Loss Exceedance Estimates.***

The results in this form have been produced and arranged using an automated program.

B. ***Provide estimates of the annual aggregate combined personal and commercial insured hurricane losses for various probability levels using the notional risk dataset specified in Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code, and using the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data provided in the file named "hlpm2017c.zip." Provide the total average annual hurricane loss for the hurricane loss exceedance distribution. If the modeling methodology does not allow the hurricane model to produce a viable answer for certain return periods, state so and why.***

Part A

Return Period (Years)	Annual Probability of Exceedance	Estimated Hurricane Loss Notional Risk Dataset	Estimated Personal and Commercial Residential Hurricane Loss 2017 FHCF Dataset
Top Event	NA	105,071,767	244,468,017,519
10,000	0.01%	88,924,780	189,862,157,432
5,000	0.02%	82,313,659	175,780,182,756
2,000	0.05%	77,642,347	161,404,225,125
1,000	0.10%	69,368,153	144,556,941,076
500	0.20%	60,245,705	125,636,863,863
250	0.40%	50,161,735	106,265,682,259
100	1.00%	37,642,086	77,484,232,263
50	2.00%	28,327,403	57,989,647,108
20	5.00%	16,267,615	31,499,010,201
10	10.00%	7,857,431	14,946,703,854
5	20.00%	2,501,794	4,690,519,343

Table 23 - Annual probability of exceedance for the 2017 FHCF exposure data

Part B

	Estimated Hurricane Loss Notional Risk Dataset	Estimated Personal and Commercial Residential Hurricane Loss 2017 FHCF Dataset
Mean (Total Average Annual Hurricane Loss)	2,721,562	5,360,531,359
Median	16,689	31,886,634
Standard Deviation	7,364,324	15,041,001,907
Interquartile Range	1,472,668	2,747,462,629
Sample Size	100,000	100,000

Table 24 - Loss distribution for the 2017 FHCF exposure data

C. Include Form S-2, Examples of Hurricane Loss Exceedance Estimates, in a submission appendix.

This form is included in a submission appendix.

Form S-3: Distributions of Stochastic Hurricane Parameters

A. ***Provide the probability distribution functional form used for each stochastic hurricane parameter in the hurricane model. Provide a summary of the justification for each functional form selected for each general classification.***

Stochastic Hurricane Parameter (Function or Variable)	Functional Form of Distribution	Data Source	Year Range Used		Justification for Functional Form
			For Fitting	For Validation	
Maximum sustained wind speed	Generalized Pareto Distribution (μ, σ, ξ) where, μ, σ, and ξ are the location, scale, and shape parameters, respectively $f(x) = \frac{1}{\sigma}\left(1 + \xi\left(\frac{x-\mu}{\sigma}\right)\right)^{-\left(\frac{1}{\xi}+1\right)}$ $\mu \leq x \leq \mu - \sigma/\xi \; if \; \xi < 0$ $x \geq u \; otherwise$ $\mu, \xi, \in (-\infty, \infty)$ $\sigma \in (0, \infty)$	HURDAT2	1900-2021	1900-2021	The Generalized Pareto Distribution has been shown to accurately represent the distribution of extreme winds (e.g. Palutikof et al., 1999) and specifically for US hurricanes (Jagger and Elsner, 2006; Emanuel and Jagger, 2010). Goodness-of-fit tests support the use of this functional form.
Radius of maximum winds	Normal distribution (μ, σ^2) where μ is the mean, and σ is the standard deviation R_{max} = *f(Vmax, latitude)* + ε $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x+\mu}{\sigma}\right)^2}$ $\mu \in (-\infty, \infty)$ $\sigma > 0$ $x \in (-\infty, \infty)$	Demuth et al. (2006); Ho et al. (1987)	1900-2021	1900-2021	The model uses the relationship between R_{max}, maximum sustained wind speed, and latitude developed by Willoughby et al. (2006) with coefficients estimated using the historical data. The expected Rmax decreases with Vmax and increases with latitude. The residual values, ε, normalized to the expected Rmax, are modeled using a normal distribution supported by the results of goodness-of-fit tests.
Forward speed	Weibull distribution (α, β) where α and β are the scale and shape parameters, respectively $f(x) = \frac{\beta x^{\beta-1}}{\alpha^{\beta}} e^{-\left(\frac{x}{\alpha}\right)^{\beta}}$ α > 0 β > 0 x > 0	HURDAT2	1900-2021	1900-2021	The Weibull distribution is suitable for representing the hurricane forward speed data that are both non-negative and positively skewed. The results of goodness-of-fit tests

Stochastic Hurricane Parameter (Function or Variable)	Functional Form of Distribution	Data Source	Year Range Used		Justification for Functional Form
			For Fitting	For Validation	
					support the choice of the Weibull distribution for representing forward speed.
Annual Landfall Frequency	Empirical Cumulative Distribution Function $p(x) = Pr\{X \leq x\}$ where X is the number of events per year, $x \in \{0, 1, \ldots, 9\}$	HURDAT2	1900-2021	1900-2021	The number of landfall events per year is best represented by an empirical distribution that can accurately reflect both the portion of historical years with no landfalls and the portion with multiple landfalls. Goodness-of-fit tests support the use of the empirical distribution for this model parameter.
Event day of year	Empirical Cumulative Distribution Function $p(x) = Pr\{X \leq x\}$ where X is the number of events that occur on a Julian day, $x \in \{1, \ldots, 365\}$	HURDAT2	1900-2021	1900-2021	The day of the year for an event occurrence is represented by an empirical distribution function, developed based on smoothing of historical event occurrence dates. Goodness-of-fit tests support the use of the empirical distribution for this model parameter.

Table 25 - Assumptions, functional forms, and justifications for parameters used in the KCC US Hurricane Reference Model

B. Include Form S-3, Distributions of Stochastic Hurricane Parameters, in a submission appendix

This form is included in a submission appendix.

Form S-4: Validation Comparisons

A. Provide four validation comparisons of actual personal residential exposures and hurricane loss to modeled exposures and hurricane loss. Provide these comparisons by line of insurance, construction type, policy coverage, county or other level of similar detail in addition to total hurricane losses. Include hurricane loss as a percentage of total exposure. Total exposure represents the total amount of insured values (all coverages combined) in the area affected by the hurricane. This would include exposures for policies that did not have a hurricane loss. If this is not available, use exposures for only those policies that had a hurricane loss. Specify which was used. To the extent data are available, comparisons should include hurricane losses from Hurricane Irma (2017) and Hurricane Michael (2018).

Comparison #1
Hurricane = Charley
Exposure = Personal Residential

Coverage	Actual Loss/Exposure(%)	Modeled Loss/Exposure(%)
Building	0.89	0.87
Contents	0.16	0.12
Time	0.11	0.11
Total	**0.58**	**0.55**

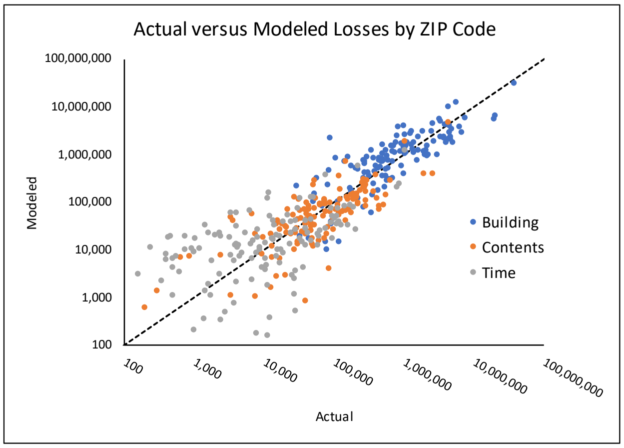


Figure 51 - Validation comparison for Hurricane Charley coverage types for multiple companies

Comparison #2
Hurricane = Jeanne and Frances
Exposure = Personal Residential

Construction	Actual Loss/Exposure (%)	Modeled Loss/Exposure (%)
Masonry	0.19	0.24
Wood	0.21	0.19
Total	**0.20**	**0.22**

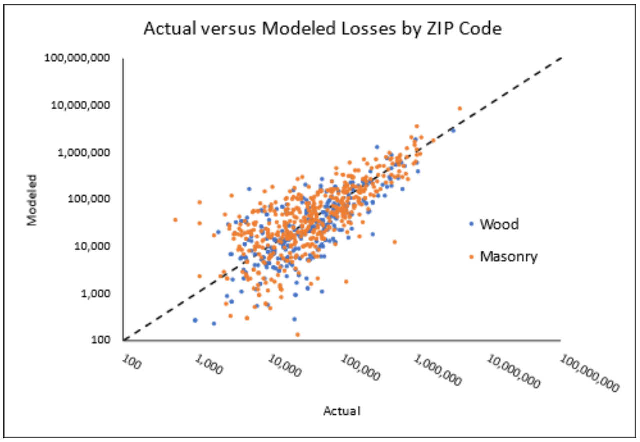


Figure 52 - Validation comparisons for Hurricanes Jeanne and Frances for residential construction types for multiple companies

Comparison #3
Hurricane = Charley
Exposure = Residential

Construction	Actual Loss/Exposure (%)	Modeled Loss/Exposure (%)
Masonry	0.58	0.58
Wood	0.30	0.33
Total	**0.57**	**0.56**

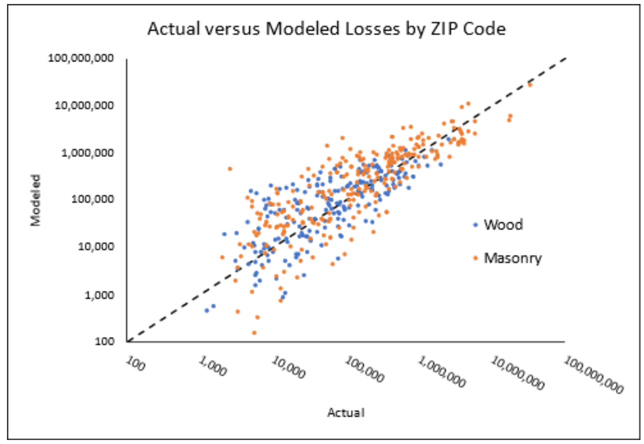


Figure 53 - Validation comparisons for Hurricane Charley residential construction types for multiple companies

Comparison #4
Hurricane = Irma
Exposure = Residential

Construction	Actual Loss/Exposure (%)	Modeled Loss/Exposure (%)
Mobile / Manufactured Home	0.97	1.00

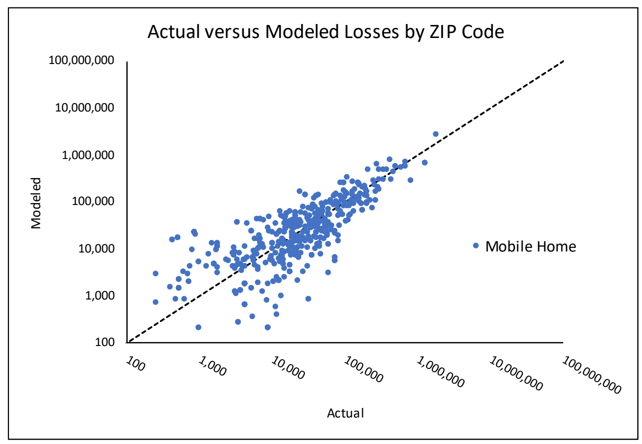


Figure 54 - Validation comparison for Hurricane Irma mobile homes

B. Provide a validation comparison of actual commercial residential exposures and hurricane loss to modeled exposures and hurricane loss. Use and provide a definition of the hurricane model relevant commercial residential classifications.

KCC classifies commercial residential properties using the following ATC Codes:

- ATC-2: Multi-Family Dwelling—Apartment Building
- ATC-42: Multi-Family Dwelling (Condominium Homeowners Association)

The comparison below is for insurer exposure data which is predominantly ATC-42.

Hurricane	Exposure	Actual Loss	Modeled Loss
Matthew	236,528,296,650	30,593,780	52,686,230

Hurricane	Exposure	Actual Loss	Modeled Loss
Irma	236,196,803,370	504,260,795	509,842,300
Total	**472,725,100,020**	**534,854,575**	**562,528,530**

Table 26 - Comparison of actual to modeled commercial residential losses (disguised by a scaling factor)

C. Provide scatter plots of modeled versus historical hurricane losses for each of the required validation comparisons. (Plot the historical hurricane losses on the x-axis and the modeled hurricane losses on the y-axis.)

Scatter plots for the required validation comparisons are included in the figures above and below.

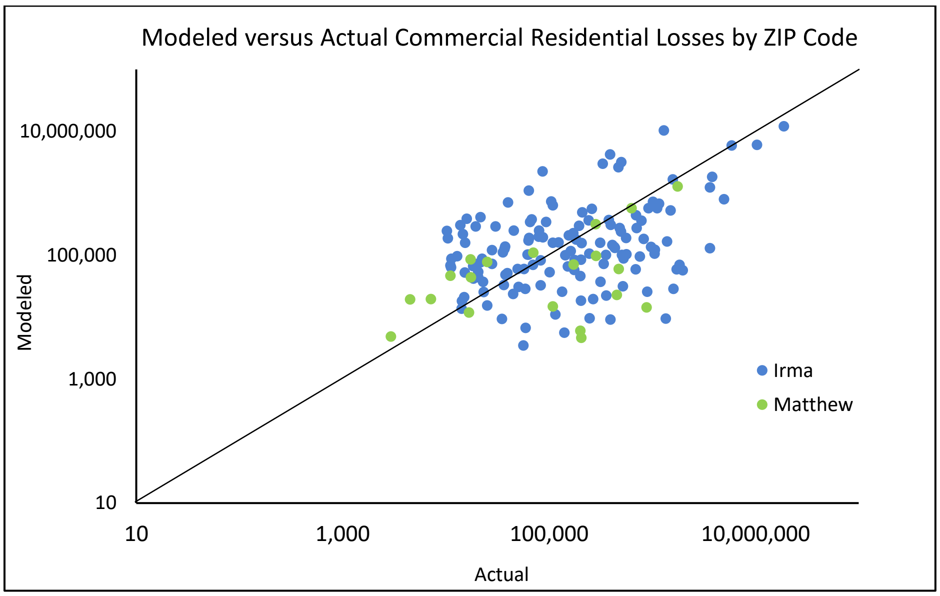


Figure 55 - Modeled versus actual commercial residential losses for Hurricanes Irma and Matthew

D. Include Form S-4, Validation Comparisons, in a submission appendix.

Rather than using a specific published hurricane windfield directly, the winds underlying the modeled hurricane loss cost calculations must be produced by the hurricane model being evaluated and should be the same hurricane parameters as used in completing Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses.

This form is included in a submission appendix.

Form S-5: Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled

A. Provide the average annual zero deductible statewide personal and commercial residential hurricane loss costs produced using the list of hurricanes in the Base Hurricane Storm Set as defined in Hurricane Standard M-1, Base Hurricane Storm Set, based on the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip."

Average Annual Zero Deductible Statewide Personal and Commercial Residential Hurricane Loss Costs

Time Period	Historical Hurricanes	Produced by Hurricane Model
Current Submission	$3.699 billion	$5.361 billion
Currently Accepted Hurricane Model* (2019 Hurricane Standards)	$3.463 billion	$4.553 billion
Percent Change Current Submission/ Currently Accepted Hurricane Model*	6.81%	17.73%
Second Previously Accepted Hurricane Model* (2017 Hurricane Standards)	$3.534 billion	$4.226 billion
Percent Change Current Submission/ Second Previously-Accepted Hurricane Model*	4.65%	26.85%

Table 27 - Average Annual Zero Deductible Statewide Personal and Commercial Residential Hurricane Loss Costs (2017 FHCF)

**NA if no previously-accepted hurricane model*

B. Provide a comparison with the statewide personal and commercial residential hurricane loss costs produced by the hurricane model on an average industry basis.

The average annual zero deductible historical statewide personal and commercial residential loss cost produced using the 2017 FHCF exposure data is $3.699 billion. The loss cost produced by the KCC US Hurricane Reference Model using the same exposure base is $5.361 billion.

C. Provide the 95% confidence interval on the differences between the means of the historical and modeled personal and commercial residential hurricane loss costs.

The 95% confidence interval for the mean hurricane loss cost is 2.965 billion to 8.311 billion, and the 95% confidence interval for the difference between the historical and modeled loss is -4.613 billion to 7.340 billion. The confidence intervals were calculated by generating 10,000 random draws of 122 years from the 100,000 year stochastic catalog.

The standard deviation of the hurricane loss cost from these 10,000 random samples is 1.371 billion, meaning that the modeled mean is 1.204 standard deviation from the historical mean.

D. ***If the data are partitioned or modified, provide the average annual zero deductible statewide personal and commercial residential hurricane loss costs for the applicable partition (and its complement) or modification, as well as the modeled average annual zero deductible statewide personal and commercial residential hurricane loss costs in additional copies of Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled.***

The data has not been partitioned or modified.

E. ***Include Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled, in a submission appendix.***

This form is provided in a submission appendix.

Form S-6: Hypothetical Events for Sensitivity and Uncertainty Analysis

Form S-6 was included in the previous submission for the 2017 Report of Activities and found acceptable. There have been no changes to the sensitivity or uncertainty analyses.

Appendix D: Vulnerability Forms

Form V-1: One Hypothetical Event

A. Windspeeds for 96 ZIP Codes and sample personal and commercial residential exposure data are provided in the file named "FormV1Input21.xlsx." The windspeeds and ZIP Codes represent a hypothetical hurricane track. Model the sample personal and commercial residential exposure data provided in the file against these windspeeds at the specified ZIP Codes, and provide the building and contents damage ratios and time element loss ratios summarized by windspeed (mph) and construction type.

The windspeeds provided are one-minute sustained 10-meter windspeeds. The sample personal and commercial residential exposure data provided consists of four structures (one of each construction type – wood frame, masonry, manufactured home, and concrete) individually placed at the population centroid of each of the ZIP Codes provided. Each ZIP Code is subjected to a specific windspeed.

For completing Part A, Estimated Damage for each individual windspeed range is the sum of ground up hurricane loss to all structures in the ZIP Codes subjected to that individual windspeed range, excluding demand surge and flood (including hurricane storm surge). Subject Exposure is all exposures in the ZIP Codes subjected to that individual windspeed range.

For completing Part B, Estimated Damage is the sum of the ground up hurricane loss to all structures of a specific type (wood frame, masonry, manufactured home, or concrete) in all of the windspeed ranges, excluding demand surge and flood (including hurricane storm surge). Subject Exposure is all exposures of that specific construction type in all of the ZIP Codes.

One reference structure for each of the construction types it to be placed at the population centroid of the ZIP Codes. Do not include appurtenant structure, contents, or time element coverages in the building damage ratios. Do not include building, appurtenant structure, or time element coverages in the contents damage ratios. Do not include building, appurtenant structure, or contents coverages in the time element loss ratios.

Reference Frame Structure	***Reference Masonry Structure***
One story ***Unbraced gable end roof*** ***ASTM D3161 Class D or ASTM D7158 Class D shingles*** ***½" plywood deck*** ***6d nails, deck to roof members*** ***Toe nail truss to wall anchor*** ***Wood framed exterior walls*** ***5/8" diameter anchors at 48" centers for wall-floor-foundation connections*** ***No shutters*** ***Standard glass windows*** ***No door covers*** ***No skylight covers*** ***Constructed in 1995***	***One story*** ***Unbraced gable end roof*** ***ASTM D3161 Class D or ASTM D7158 Class D shingles*** ***½" plywood deck*** ***6d nails, deck to roof members*** ***Weak truss to wall connection*** ***Masonry exterior walls*** ***No vertical wall reinforcing*** ***No shutters*** ***Standard glass windows*** ***No door covers*** ***No skylight covers*** ***Constructed in 1995***
Reference Manufactured Home Structure	***Reference Concrete Structure***

Tie downs *Single unit* *Manufactured in 1980*	*Twenty story* *Eight apartment units per story* *No shutters* *Standard glass windows* *Constructed in 1980*

B. ***Confirm that the structures used in completing the form are identical to those in the above table for the reference structures. If additional assumptions are necessary to complete this form (for example, regarding structural characteristics, duration, or surface roughness), provide the reasons why the assumptions were necessary as well as a detailed description of how they were included.***

The structures used to complete the form are identical to those specified above. No additional assumptions were necessary to complete this form.

C. ***Provide separate plots of the Estimated Damage/Subject Exposure (y-axis) versus Windspeed (x-axis) for the Building, Contents, and Time Element data in Part A.***

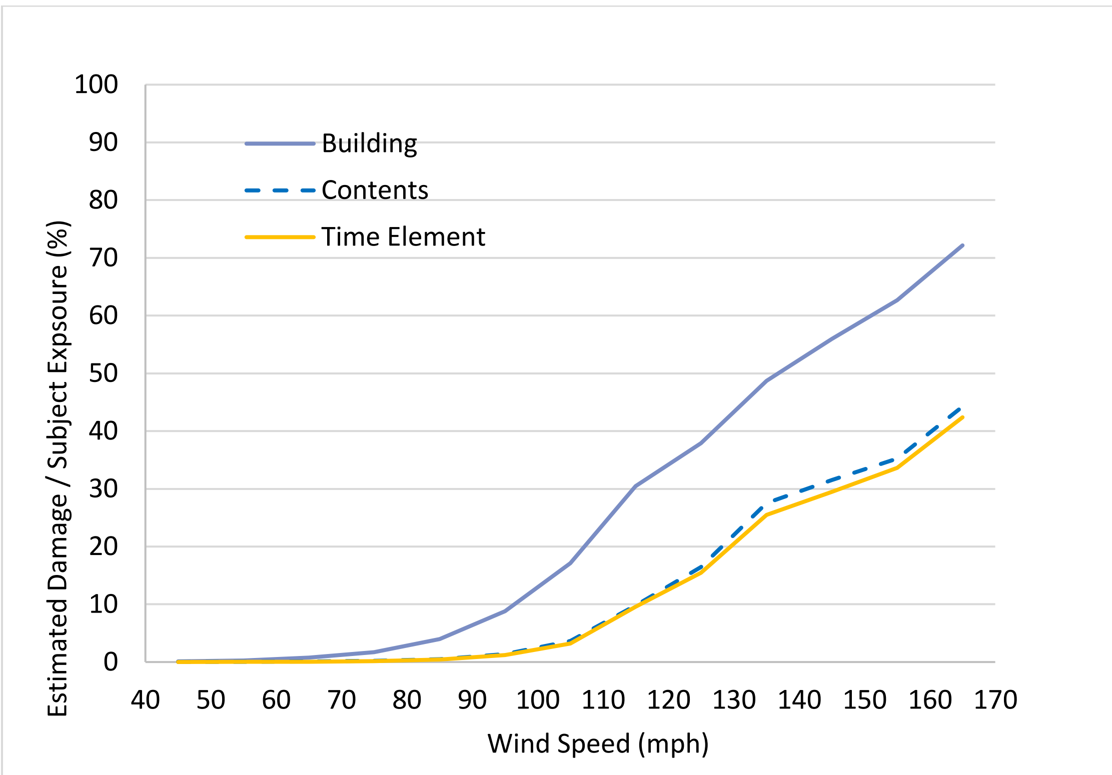


Figure 56 -Estimated Damage/Subject Exposure (y-axis) versus Wind Speed (x-axis) for the Building, Contents, and Time Element vulnerability functions

D. ***Include Form V-1, One Hypothetical Event, in a submission appendix.***

Form V-1: One Hypothetical Event has been included in a submission appendix.

Form V-1: One Hypothetical Event

Part A

Wind speed (mph, one-minute sustained 10-meter)	Estimated Building Damage/Subject Building Exposure (%)	Estimated Contents Damage/Subject Contents Exposure (%)	Estimated Time Element Loss/ Subject Time Element Exposure (%)
41 – 50	0.11	0.02	0.01
51 – 60	0.27	0.04	0.02
61 – 70	0.75	0.10	0.05
71 – 80	1.72	0.19	0.14
81 – 90	3.99	0.46	0.44
91 – 100	8.81	1.39	1.20
101 – 110	17.13	3.64	3.20
111 – 120	30.49	9.78	9.56
121 – 130	37.87	16.43	15.43
131 – 140	48.71	27.51	25.50
141 – 150	55.95	31.51	29.46
151 – 160	62.69	35.23	33.62
161 – 170	72.16	44.24	42.39

Table 28 - Estimated percent of damage for hypothetical event by wind speed band

Part B

Construction Type	Estimated Building Damage/Subject Building Exposure (%)	Estimated Contents Damage/Subject Contents Exposure (%)	Estimated Time Element Loss/ Subject Time Element Exposure (%)
Wood Frame	19.60	7.31	6.58
Masonry	19.06	6.72	5.99
Manufactured Home	35.95	28.25	27.97
Concrete	12.06	3.34	2.60

Table 29 - Estimated percent of damage for hypothetical event by construction type

Form V-2: Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage

A. Explain how the hurricane vulnerability functions for the two reference structures are developed. Demonstrate that the hurricane vulnerability function for each reference structure is related to one of the hurricane model's standard building structure vulnerability functions for frame and masonry constructions.

The building characteristics of the two reference structures are mapped to KCC primary and secondary building characteristics. Unique vulnerability functions related to the standard frame and masonry vulnerability functions are then selected, as described in Standard V-1, D. The selected vulnerability functions then are modified based on building secondary characteristics and mitigation measures, as described in Standard V-4.

B. Provide the change in the zero deductible personal residential reference building structure damage ratio (not hurricane loss cost) for each individual hurricane mitigation measure and secondary characteristic listed in Form V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage, as well as for the combination of the four hurricane mitigation measures and secondary characteristics provided for the Mitigated Frame Building and the Mitigated Masonry Building below.

This is included in the table on the following page.

C. If additional assumptions are necessary to complete this form (for example, regarding duration or surface roughness), provide the rationale for the assumptions as well as a detailed description of how they are included.

No additional assumptions were necessary to complete this form.

D. Provide an explanation for cells filled with "0" or blank cells.

"0" cells indicate that the hurricane mitigation measures and secondary characteristics have no impact or limited impact on the building vulnerability at specific wind speeds with respect to the reference buildings. Blank cells indicate that the hurricane mitigation measures and secondary characteristics in Form V-2 are in conflict with the reference buildings.

E. Provide this form in Excel format without truncation. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage, in a submission appendix.

The file has been provided and is named "KCC21_FormV2_221104" and has been provided as a submission appendix.

F. Place the reference building at the population centroid for ZIP Code 33921 in Lee County.

Reference Frame Building	*Reference Masonry Building*
One story *Unbraced gable end roof* *ASTM D3161 Class D or ASTM D7158 Class D shingles* *½" plywood deck* *6d nails deck to roof members* *Toe nail truss to wall anchor* *Wood framed exterior walls* *5/8" diameter anchors at 48" centers for wall-floor-foundation connections* *No shutters* *Standard glass windows* *No door covers* *No skylight covers* *Constructed in 1995*	*One story* *Unbraced gable end roof* *ASTM D3161 Class D or ASTM D7158 Class D shingles* *½" plywood deck* *6d nails deck to roof members* *Weak truss to wall connection* *Masonry exterior walls* *No vertical wall reinforcing* *No shutters* *Standard glass windows* *No door covers* *No skylight covers* *Constructed in 1995*
Mitigated Frame Building	*Mitigated Masonry Building*
ASTM D7158 Class H shingles *8d nails deck to roof members* *Truss straps at roof* *Structural wood panel shutters*	*ASTM D7158 Class H shingles* *8d nails deck to roof members* *Truss straps at roof* *Structural wood panel shutters*

INDIVIDUAL HURRICANE MITIGATION MEASURES AND SECONDARY CHARACTERISTICS			PERCENTAGE CHANGES IN DAMAGE ((REFERENCE DAMAGE RATIO - MITIGATED DAMAGE RATIO) / REFERENCE DAMAGE RATIO) * 100									
			FRAME BUILDING					MASONRY BUILDING				
			WIND SPEED (MPH)*					WIND SPEED (MPH)*				
			60	85	110	135	160	60	85	110	135	160
	REFERENCE BUILDING		-	-	-	-	-	-	-	-	-	-
ROOF CONFIGURATION	BRACED GABLE ENDS		12.1	10.5	6.6	2.7	0.5	12.1	10.5	6.6	2.7	0.5
	HIP ROOF		35.1	20.2	8.7	2.3	0.6	35.1	20.2	8.7	2.3	0.6
ROOF COVERING	METAL		21.2	8.1	0.9	0.0	0.0	21.5	8.0	0.9	0.0	0.0
	ASTM D7158 CLASS H SHINGLES		30.0	11.6	1.5	0.8	0.0	30.0	12.0	1.5	0.7	0.0
	MEMBRANE		21.0	11.0	1.5	0.8	0.0	21.3	11.4	1.5	0.7	0.0
	NAILING OF DECK	8d	13.7	25.5	22.8	9.8	3.2	13.7	25.7	22.8	11.0	4.4

INDIVIDUAL HURRICANE MITIGATION MEASURES AND SECONDARY CHARACTERISTICS			PERCENTAGE CHANGES IN DAMAGE ((REFERENCE DAMAGE RATIO - MITIGATED DAMAGE RATIO) / REFERENCE DAMAGE RATIO) * 100									
			FRAME BUILDING					MASONRY BUILDING				
			WIND SPEED (MPH)*					WIND SPEED (MPH)*				
			60	**85**	**110**	**135**	**160**	**60**	**85**	**110**	**135**	**160**
ROOF-WALL STRENGTH	CLIPS		3.7	13.3	11.2	10.5	4.6	3.7	13.7	11.2	11.0	6.2
ROOF-WALL STRENGTH	STRAPS		3.7	13.9	11.8	11.3	5.1	3.7	14.3	11.8	11.8	7.1
WALL-FLOOR STRENGTH	TIES OR CLIPS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WALL-FLOOR STRENGTH	STRAPS		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WALL-FOUNDATION STRENGTH	LARGER ANCHORS OR CLOSER SPACING		0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
WALL-FOUNDATION STRENGTH	STRAPS		0.0	0.0	0.0	0.0	0.5	-	-	-	-	-
WALL-FOUNDATION STRENGTH	VERTICAL REINFORCING		-	-	-	-	-	0.0	0.0	0.0	0.0	3.5
OPENING PROTECTION	WINDOW SHUTTERS	STRUCTURAL WOOD PANEL	0.4	5.1	15.7	14.1	4.6	0.4	5.1	15.7	13.8	4.4
OPENING PROTECTION	WINDOW SHUTTERS	METAL	0.4	5.1	15.7	14.1	4.6	0.4	5.1	15.7	13.8	4.4
OPENING PROTECTION	DOOR AND SKYLIGHT COVERS		1.8	1.7	2.9	3.1	1.3	1.8	1.7	2.9	3.0	1.3
WINDOW, DOOR, SKYLIGHT STRENGTH	WINDOWS	IMPACT RATED	3.8	17.9	19.8	4.9	0.5	3.8	17.7	19.8	4.7	0.4
WINDOW, DOOR, SKYLIGHT STRENGTH	ENTRY DOORS	MEETS WIND-BORNE DEBRIS REQUIREMENTS	0.0	0.7	2.5	2.0	0.6	0.0	0.7	2.5	1.9	1.1
WINDOW, DOOR, SKYLIGHT STRENGTH	GARAGE DOORS	MEETS WIND- BORNE DEBRIS REQUIREMENTS	0.0	1.2	5.8	1.6	0.0	0.0	1.2	5.8	1.6	0.0
WINDOW, DOOR, SKYLIGHT STRENGTH	SLIDING GLASS DOORS	MEETS WIND- BORNE DEBRIS REQUIREMENTS	0.0	0.0	0.4	0.8	0.2	0.0	0.0	0.4	0.7	0.2
WINDOW, DOOR, SKYLIGHT STRENGTH	SKYLIGHT	IMPACT RATED	3.7	3.0	2.6	1.6	1.8	3.7	2.9	2.6	1.6	1.8

HURRICANE MITIGATION MEASURES AND SECONDARY CHARACTERISTICS IN COMBINATION	PERCENTAGE CHANGES IN DAMAGE ((REFERENCE DAMAGE RATIO - MITIGATED DAMAGE RATIO) / REFERENCE DAMAGE RATIO) * 100									
	FRAME BUILDING					MASONRY BUILDING				
	WIND SPEED (MPH)*					WIND SPEED (MPH)*				
	60	**85**	**110**	**135**	**160**	**60**	**85**	**110**	**135**	**160**
MITIGATED BUILDING	47.9	56.0	51.8	35.9	12.9	47.9	57.1	51.8	37.3	15.8

Table 30 - Percent change in damage for mitigation measures and secondary characteristics

**Wind speeds are one-minute sustained 10-meter.*

Form V-3: Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item)

This item is considered a trade secret and will be presented to the Professional Team during the on-site visit and during the closed portion of the Commission meeting.

Form V-4: Differences in Hurricane Mitigation Measures and Secondary Characteristics

A. Provide the differences between the values reported in Form V-2, Hurricane Mitigation Measures and Secondary Characteristics, Range of Changes in Damage, relative to the equivalent data compiled from the currently accepted hurricane model.

This is provided on the following page.

B. Provide a list and describe any assumptions made to complete this form.

No assumptions were made to complete this form.

C. Provide a summary description of the differences.

There are no differences between the previously accepted hurricane model and the current Form V-2: Hurricane Mitigation Measures and Secondary Characteristics.

D. Provide this form in Excel format without truncation. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form V-4, Differences in Hurricane Mitigation Measures and Secondary Characteristics, in a submission appendix.

This file has been provided, named "KCC21_FormV4_221104.xls," and included in a submission appendix.

INDIVIDUAL HURRICANE MITIGATION MEASURES AND SECONDARY CHARACTERISTICS			DIFFERENCES FROM FORM V-2 RELATIVE TO CURRENTLY ACCEPTED HURRICANE MODEL									
			FRAME BUILDING					MASONRY BUILDING				
			WIND SPEED (MPH)*					WIND SPEED (MPH)*				
			60	85	110	135	160	60	85	110	135	160
	REFERENCE BUILDING		-	-	-	-	-	-	-	-	-	-
ROOF CONFIGURATION	BRACED GABLE ENDS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	HIP ROOF		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ROOF COVERING	METAL		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ASTM D7158 CLASS H SHINGLES		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MEMBRANE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	NAILING OF DECK	8d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ROOF-WALL STRENGTH	CLIPS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	STRAPS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WALL-FLOOR STRENGTH	TIES OR CLIPS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	STRAPS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WALL-FOUNDATION STRENGTH	LARGER ANCHORS OR CLOSER SPACING		0.00	0.00	0.00	0.00	0.00	-	-	-	-	-
	STRAPS		0.00	0.00	0.00	0.00	0.00	-	-	-	-	-
	VERTICAL REINFORCING		-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
OPENING PROTECTION	WINDOW SHUTTERS	STRUCTURAL WOOD PANEL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		METAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	DOOR AND SKYLIGHT COVERS			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WINDOW, DOOR, SKYLIGHT STRENGTH	WINDOWS	IMPACT RATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ENTRY DOORS	MEETS WIND- BORNE DEBRIS REQUIREMENTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	GARAGE DOORS	MEETS WIND-BORNE DEBRIS REQUIREMENTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SLIDING GLASS DOORS	MEETS WIND- BORNE DEBRIS REQUIREMENTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SKYLIGHT	IMPACT RATED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HURRICANE MITIGATION MEASURES AND SECONDARY CHARACTERISTICS IN COMBINATION	DIFFERENCES FROM FORM V-2 RELATIVE TO CURRENTLY ACCEPTED HURRICANE MODEL									
	FRAME BUILDING					MASONRY BUILDING				
	WIND SPEED (MPH)*					WIND SPEED (MPH)*				
	60	85	110	135	160	60	85	110	135	160
MITIGATED BUILDING	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.48	0.42	0.13

Table 31 - Percent change in damage for mitigation measures and secondary characteristics between current hurricane model and currently accepted hurricane model

**Wind speeds are one-minute sustained 10-meter.*

Form V-5: Differences in Hurricane Mitigation Measures and Secondary Characteristics, Mean Damage Ratios and Hurricane Loss Costs (Trade Secret Item)

This item is considered a trade secret and will be presented to the Professional Team during the on-site visit and during the closed portion of the Commission meeting.

Appendix E: Actuarial Forms

Form A-1: Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code

A. ***Provide three maps, color-coded by ZIP Code (with a minimum of seven value ranges), displaying zero deductible personal residential hurricane loss costs per $1,000 of exposure for frame owners, masonry owners, and manufactured homes.***

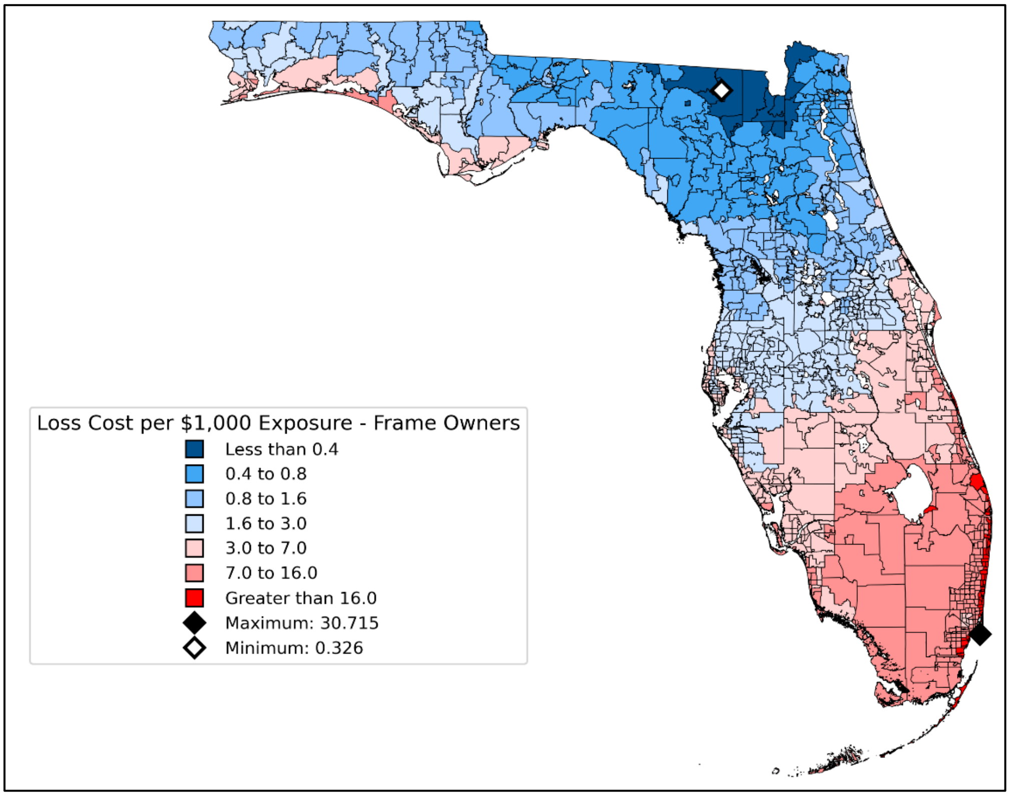


Figure 57 – Zero deductible loss cost per $1,000 exposure for frame owners

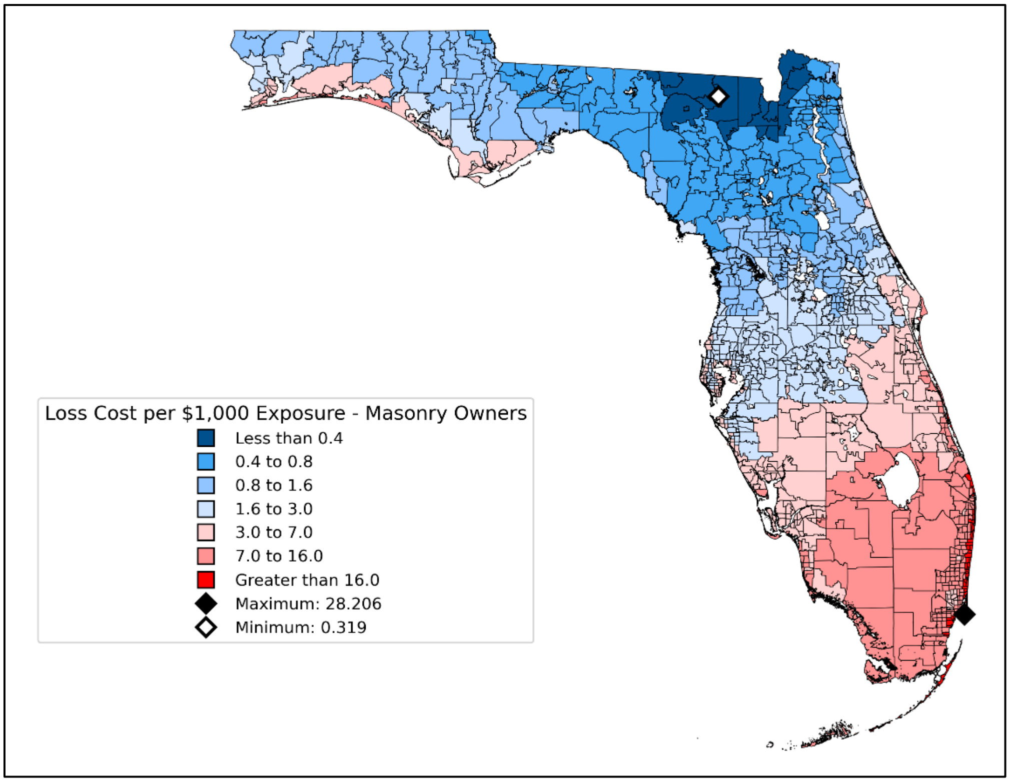


Figure 58 – Zero deductible loss cost per $1,000 exposure for masonry owners

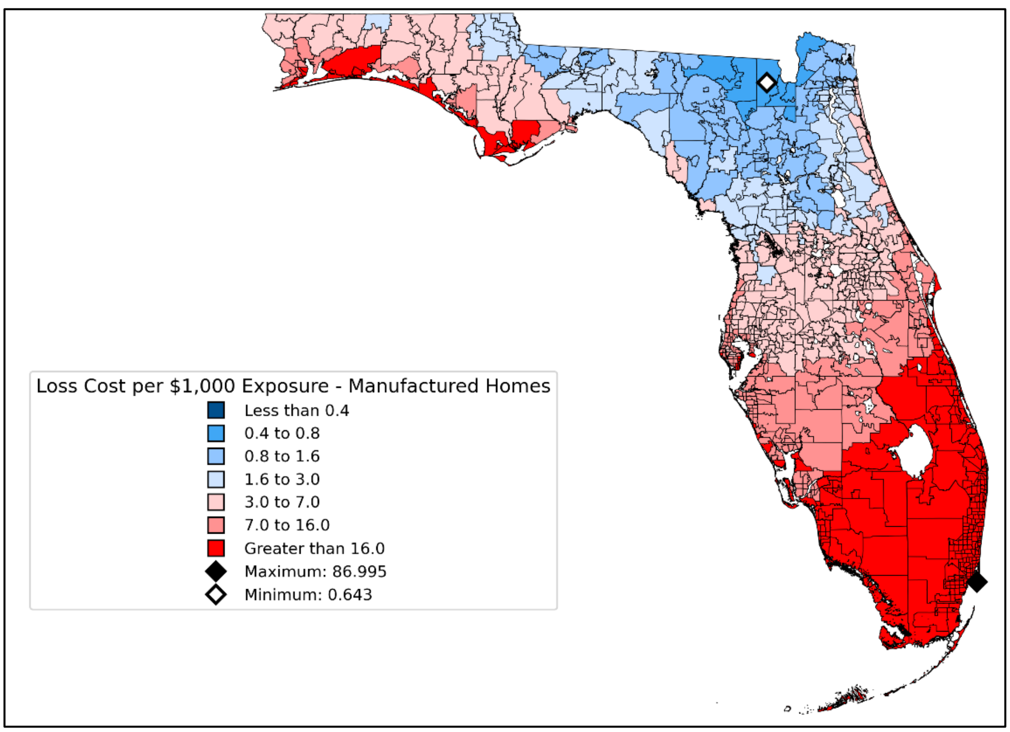


Figure 59 – Zero deductible loss cost per $1,000 exposure for manufactured homes

B. Create exposure sets for these exhibits by modeling the frame and masonry buildings and manufactured homes from Notional Set 3 described in the file "NotionalInput21.xlsx" geocoded to each ZIP Code

centroid in the state, as provided in the hurricane model. Provide the predominant County name and the Federal Information Processing Standards (FIPS) code (Figure 12) associated with each ZIP Code centroid. Refer to the Notional Hurricane Policy Specifications below for additional modeling information. Explain any assumptions, deviations, and differences from the prescribed exposure information.

The exposure sets for these exhibits were created by modeling the frame and masonry buildings and manufactured homes from Notional Set 3 described in the file "NotionalInput21.xlsx."

The state of Florida includes a few inhabited areas which would not display in maps if only ZIP Codes with population weighted centroids were modeled. For the purposes of visual consistency, 8 virtual ZIP Codes were created to provide coverage for the entire state of Florida. Geometric centroids were used for these virtual ZIP Codes, and each virtual ZIP Code has been provided in the file "KCC21_FormA1_Revised_221104."

C. Describe how Law and Ordinance is included in the hurricane loss cost data.

Law and ordinance coverage is not included in the Notional Set 3 input file and is not explicitly considered in the hurricane loss cost data. However, to the extent law and ordinance coverage associated with personal residential policies is present in the historical claims information, it is implicitly included in base vulnerability functions and accounted for in the hurricane loss cost data.

D. If additional assumptions are necessary to complete this form, provide the rationale for the assumptions as well as a detailed description of how they are included.

No additional assumptions were made to complete this form.

E. Provide, in the format given in the file named "2021FormA1.xlsx" in both Excel and PDF format, the underlying hurricane loss cost data, rounded to three decimal places, used for A. above. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name.

A completed Form A-1 has been provided in both Excel and PDF file formats and named "KCC21_FormA1_221104."

Form A-2: Base Hurricane Storm Set Statewide Hurricane Losses

A. ***Provide the total insured hurricane loss assuming zero deductible policies for individual historical hurricanes using the Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip." The list of hurricanes in this form should include all Florida and by-passing hurricanes in the modeling organization Base Hurricane Storm Set, as defined in Hurricane Standard M-1, Base Hurricane Storm Set.***

The table below contains the hurricanes from HURDAT2 based on the 121-year period 1900-2020. As defined in Hurricane Standard M-1, Base Hurricane Storm Set, the modeling organization's Base Hurricane Storm Set may exclude hurricanes that had zero modeled impact, or it may include additional hurricanes when there is clear justification for the additions. The modeling organization should populate the table with its own version of the Base Hurricane Storm Set, including any justified modifications. Each hurricane has been assigned an ID number. For hurricanes resulting in zero loss, the table entry should be left blank. Additional hurricanes included in the hurricane model Base Hurricane Storm Set should be added to the table in order of year and assigned an intermediate ID number within the bounding ID numbers.

As defined, a by-passing hurricane (ByP) is a hurricane which does not make landfall on Florida, but produces minimum damaging windspeeds or greater on Florida. For the by-passing hurricanes included in the table only, the hurricane intensity entered is the maximum windspeed at closest approach to Florida as a hurricane, not the windspeed over Florida.

B. ***If additional assumptions are necessary to complete this form, provide the rationale for the assumptions as well as a detailed description of how they are included.***

No additional assumptions were made to complete this form.

C. ***Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses, in a submission appendix.***

A completed Form A-2 has been provided in Excel format with the file name "KCC21_FormA2_Revised_230627" and within this submission appendix in the table below.

ID	Hurricane Landfall/ Closest Approach Date	Year	Name	Region as defined in *Figure 1*- Category	Personal and Commercial Residential Insured Hurricane Losses ($)
001	09/06/1900	1900	Galveston01-1900	ByP-1	54,173,424
005	08/15/1901	1901	NoName04-1901	F-1/ByP-1	303,432,916
010	09/11/1903	1903	NoName03-1903	C-1/A-1	2,931,815,835
015	10/17/1904	1904	NoName04-1904	C-1	1,082,640,843
020	06/17/1906	1906	NoName02-1906	B-1/C-1	1,269,458,732
025	09/27/1906	1906	NoName06-1906	F-2/ByP-2	247,540,164
030	10/18/1906	1906	NoName08-1906	B-3	11,014,478,683
031	10/01/1908	1908	NoName08-1908	ByP-2	41,959,008
035	10/11/1909	1909	NoName11-1909	B-3	995,898,486
040	10/18/1910	1910	NoName05-1910	B-2	6,083,561,851
045	08/11/1911	1911	NoName02-1911	A-1	329,806,419
050	09/14/1912	1912	NoName04-1912	F-1/ByP-1	755,011,310
055	08/01/1915	1915	NoName01-1915	D-1	606,845,486
060	09/04/1915	1915	NoName04-1915	A-1	278,942,519
061	09/30/1915	1915	NoName06-1915	ByP-1	4,118,955
065	07/05/1916	1916	NoName02-1916	F-3/ByP-3	448,128,642
070	10/18/1916	1916	NoName14-1916	A-2	1,202,818,156
075	09/29/1917	1917	NoName04-1917	A-3	2,128,346,741
080	09/10/1919	1919	NoName02-1919	B-4	626,282,385
085	10/25/1921	1921	TampaBay06-1921	B-3	11,717,925,205
090	09/15/1924	1924	NoName05-1924	A-1	137,039,435
095	10/21/1924	1924	NoName10-1924	B-1	1,016,169,246
100	07/28/1926	1926	NoName01-1926	D-2	2,403,425,735
105	09/18/1926	1926	GreatMiami07-1926	C-4/A-3	72,572,358,293
110	10/21/1926	1926	NoName10-1926	ByP-3	2,396,816,896
115	08/08/1928	1928	NoName01-1928	C-2	3,272,946,118

ID	Hurricane Landfall/ Closest Approach Date	Year	Name	Region as defined in *Figure 1*- Category	Personal and Commercial Residential Insured Hurricane Losses ($)
120	09/17/1928	1928	LakeOkeechobee04-1928	C-4	46,868,888,704
125	09/28/1929	1929	NoName02-1929	C-3/A-1	6,098,480,141
130	09/01/1932	1932	NoName03-1932	F-1/ByP-1	758,446,222
135	07/30/1933	1933	NoName05-1933	C-1	577,861,252
140	09/04/1933	1933	NoName11-1933	C-3	7,316,328,741
141	10/05/1933	1933	NoName17-1933	ByP-3	309,774,075
145	09/03/1935	1935	LaborDay03-1935	C-5/A-2	13,408,941,527
146	09/29/1935	1935	NoName05-1935	ByP-4	1,056,475,902
150	11/04/1935	1935	NoName07-1935	C-2	3,634,312,149
155	07/31/1936	1936	NoName05-1936	A-2	1,361,001,848
160	08/11/1939	1939	NoName02-1939	C-1/A-1	943,552,219
165	10/06/1941	1941	NoName05-1941	C-2/A-1	4,319,468,662
170	10/19/1944	1944	NoName13-1944	B-2	6,998,430,521
175	06/24/1945	1945	NoName01-1945	A-1	1,313,749,265
180	09/15/1945	1945	NoName09-1945	C-4	11,460,085,150
185	10/08/1946	1946	NoName06-1946	B-1	2,636,690,796
190	09/17/1947	1947	NoName04-1947	C-4	31,999,786,147
195	10/12/1947	1947	NoName09-1947	B-1/E-2	1,986,857,207
200	09/22/1948	1948	NoName08-1948	B-4	5,800,132,179
205	10/05/1948	1948	NoName09-1948	B-2	3,972,238,192
210	08/26/1949	1949	NoName02-1949	C-4	20,403,830,998
215	08/31/1950	1950	Baker-1950	F-1/ByP-1	72,930,027
220	09/05/1950	1950	Easy-1950	A-3	3,176,746,302
225	10/18/1950	1950	King-1950	C-4	17,134,896,543
226	05/21/1951	1951	Able-1951	ByP-1	192,145,451
227	10/25/1952	1952	Fox-1952	ByP-1	7,259,216

ID	Hurricane Landfall/ Closest Approach Date	Year	Name	Region as defined in *Figure 1*- Category	Personal and Commercial Residential Insured Hurricane Losses ($)
230	09/26/1953	1953	Florence-1953	A-1	363,354,743
235	10/09/1953	1953	Hazel-1953	B-1	1,645,177,867
240	09/25/1956	1956	Flossy-1956	A-1	197,713,083
245	09/10/1960	1960	Donna-1960	B-4	16,208,819,711
250	09/15/1960	1960	Ethel-1960	F-1/ByP-1	23,795,194
255	08/27/1964	1964	Cleo-1964	C-2	4,316,953,998
260	09/10/1964	1964	Dora-1964	D-2	2,518,676,957
265	10/14/1964	1964	Isbell-1964	B-2	4,692,512,858
270	09/08/1965	1965	Betsy-1965	C-3	928,027,402
275	06/09/1966	1966	Alma-1966	A-1	134,927,247
280	10/04/1966	1966	Inez-1966	B-2	737,205,426
285	10/19/1968	1968	Gladys-1968	A-2	1,244,498,299
290	08/18/1969	1969	Camille-1969	F-5/ByP-5	15,718,308
295	06/19/1972	1972	Agnes-1972	A-1	71,225,596
300	09/23/1975	1975	Eloise-1975	A-3	989,710,557
305	09/04/1979	1979	David-1979	C-2/E-2	1,714,824,488
310	09/13/1979	1979	Frederic-1979	F-3/ByP-3	257,222,910
315	09/02/1985	1985	Elena-1985	F-3/ByP-3	251,513,873
320	11/21/1985	1985	Kate-1985	A-2	287,799,853
325	10/12/1987	1987	Floyd-1987	C-1	166,873,576
326	09/22/1989	1989	Hugo-1989	ByP-4	64,079,048
330	08/24/1992	1992	Andrew-1992	C-5	28,494,819,804
335	08/03/1995	1995	Erin-1995	C-1/A-1	1,506,535,413
340	10/04/1995	1995	Opal-1995	A-3	2,004,612,423
345	07/19/1997	1997	Danny-1997	F-1/ByP-1	34,262,534
350	09/03/1998	1998	Earl-1998	A-1	223,151,570

ID	Hurricane Landfall/ Closest Approach Date	Year	Name	Region as defined in *Figure 1*- Category	Personal and Commercial Residential Insured Hurricane Losses ($)
355	09/25/1998	1998	Georges-1998	B-2/F-2	321,814,491
356	09/15/1999	1999	Floyd-1999	ByP-3	95,374,752
360	10/15/1999	1999	Irene-1999	B-1	769,482,297
365	08/13/2004	2004	Charley-2004	B-4	9,695,744,440
370	09/05/2004	2004	Frances-2004	C-2	3,744,475,972
375	09/16/2004	2004	Ivan-2004	F-3/ByP-3	1,176,746,740
380	09/26/2004	2004	Jeanne-2004	C-3	6,353,453,506
385	07/10/2005	2005	Dennis-2005	A-3	1,237,845,944
390	08/25/2005	2005	Katrina-2005	C-1	1,995,255,906
395	09/20/2005	2005	Rita-2005	ByP-2	170,818,347
400	10/24/2005	2005	Wilma-2005	B-3	20,843,997,176
401	09/01/2008	2008	Gustav-2008	ByP-3	5,621,392
402	08/25/2011	2011	Irene-2011	ByP-2	77,031,258
403	08/28/2012	2012	Isaac-2012	ByP-1	331,759,914
405	09/02/2016	2016	Hermine-2016	A-1	159,632,070
410	10/07/2016	2016	Matthew-2016	ByP-3	1,088,836,356
415	09/10/2017	2017	Irma-2017	B-3	11,383,713,655
420	10/08/2017	2017	Nate-2017	F-1/ByP-1	31,126,269
425	10/10/2018	2018	Michael-2018	A-5	4,012,324,615
430	09/04/2019	2019	Dorian-2019	ByP-2	104,119,548
435	09/16/2020	2020	Sally-2020	F-2/ByP-2	833,738,620
440	10/28/2020	2020	Zeta-2020	ByP-3	14,902,624
			Total		**451,273,079,546**

Table 32 - Modeled statewide losses for Base Hurricane Storm Set for the 2017 FHCF exposure data

Form A-3: Hurricane Losses

A. ***One or more automated programs or scripts should be used to generate and arrange the data in Form A-3, Hurricane Losses.***

The results in this form have been produced and arranged using an automated program that reads the losses generated by the KCC US Hurricane Reference Model.

B. ***Provide the percentage of residential zero deductible hurricane total loss, rounded to four decimal places, and the modeled loss from Hurricane Hermine (2016), Hurricane Matthew (2016), Hurricane Irma (2017), and Hurricane Michael (2018) for each affected ZIP Code.***

Use the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data provided in the file named "hlpm2017c.zip."

Rather than using directly a specified published windfield, the winds underlying the hurricane loss cost calculations must be produced by the hurricane model being evaluated and should be the same hurricane parameters as used in completing Form A-2, Base Hurricane Storm Set Statewide Hurricane Losses.

C. ***Provide maps color-coded by ZIP Code depicting the percentage of total residential hurricane loss from each hurricane: Hurricane Hermine (2016), Hurricane Matthew (2016), Hurricane Irma (2017), and Hurricane Michael (2018), using the following interval coding.***

Red	***≥ 5%***
Light Red	***≥ 2% to 5%***
Pink	***≥ 1% to 2%***
Light Pink	***≥ 0.5% to 1%***
Light Blue	***≥ 0.2% to 0.5%***
Medium Blue	***≥ 0.1% to 0.2%***
Blue	***≥ 0% to 0.1%***
White	***0%***

D. ***Plot the relevant storm track on each map.***

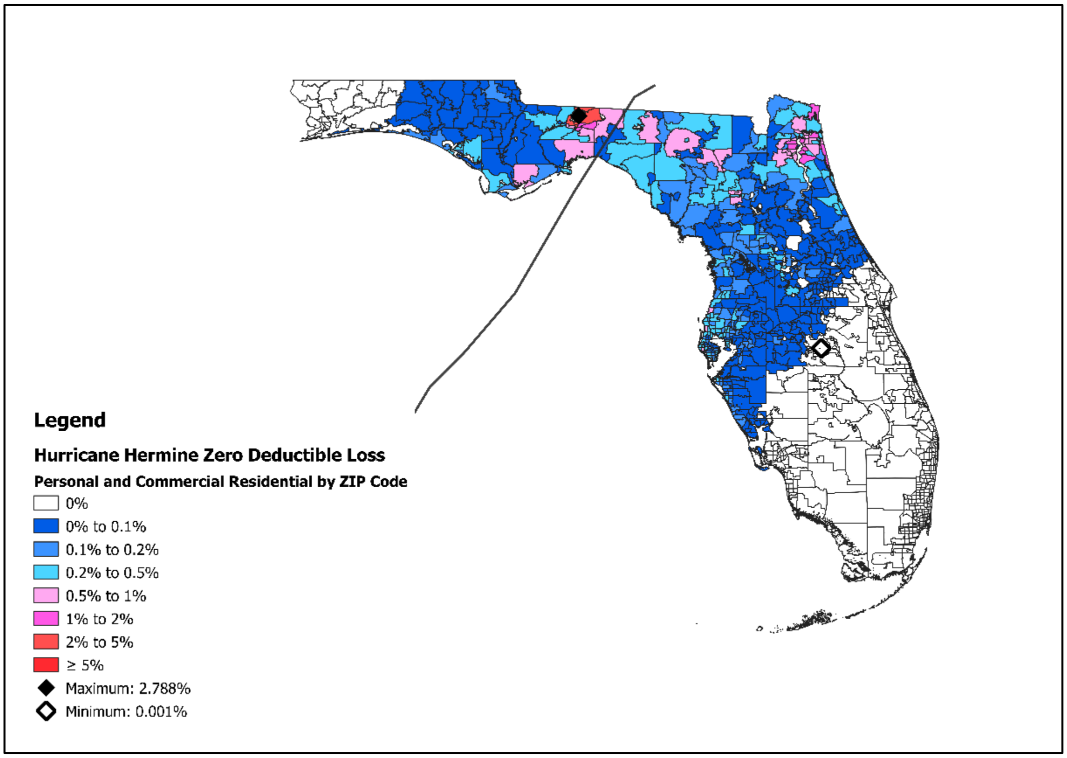


Figure 60 - Hurricane Hermine (2016) zero deductible loss

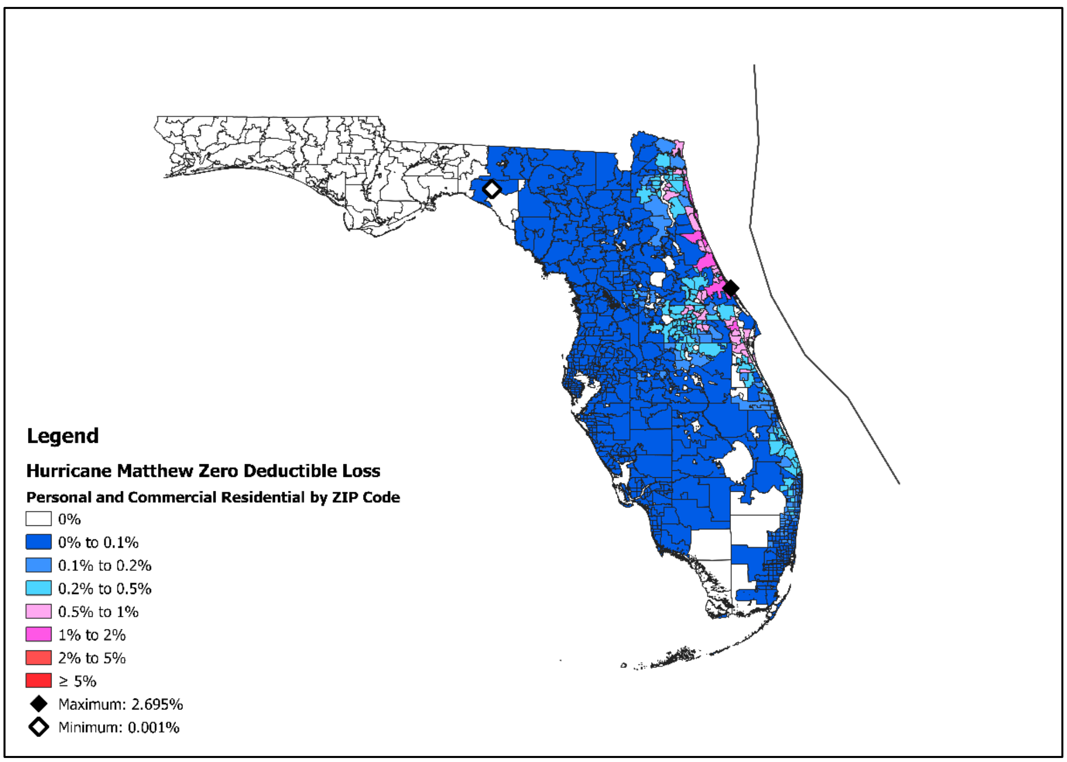


Figure 61 - Hurricane Matthew (2016) zero deductible loss

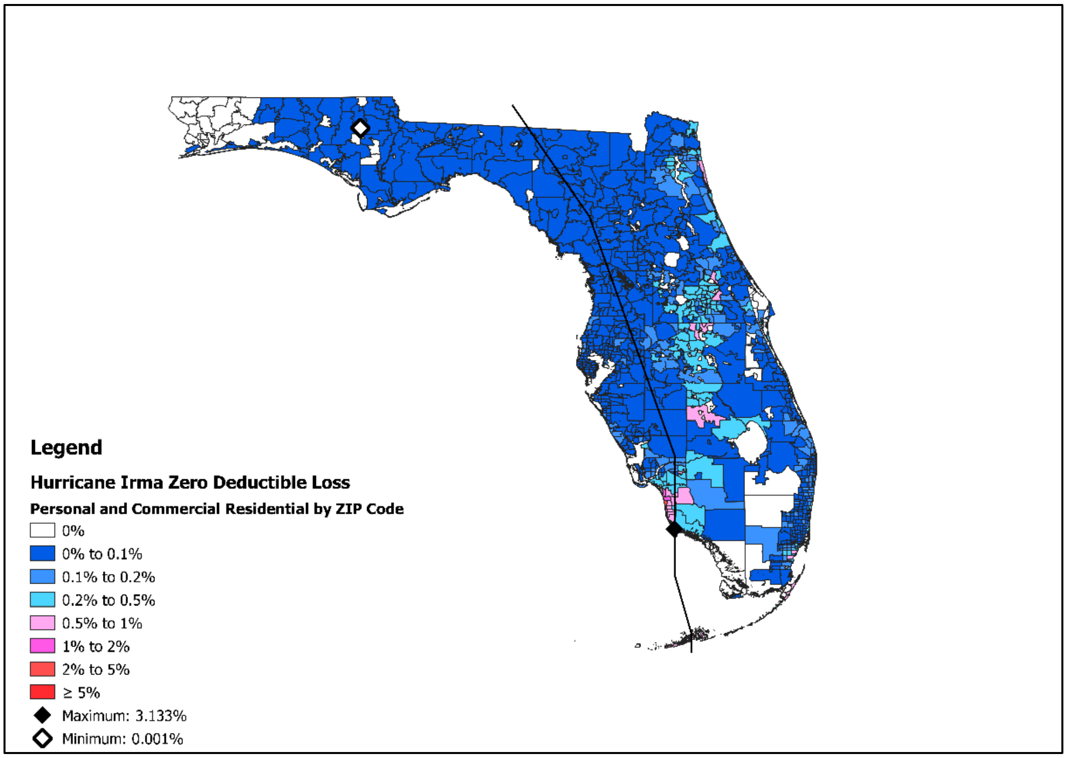


Figure 62 - Hurricane Irma (2017) Zero Deductible Loss

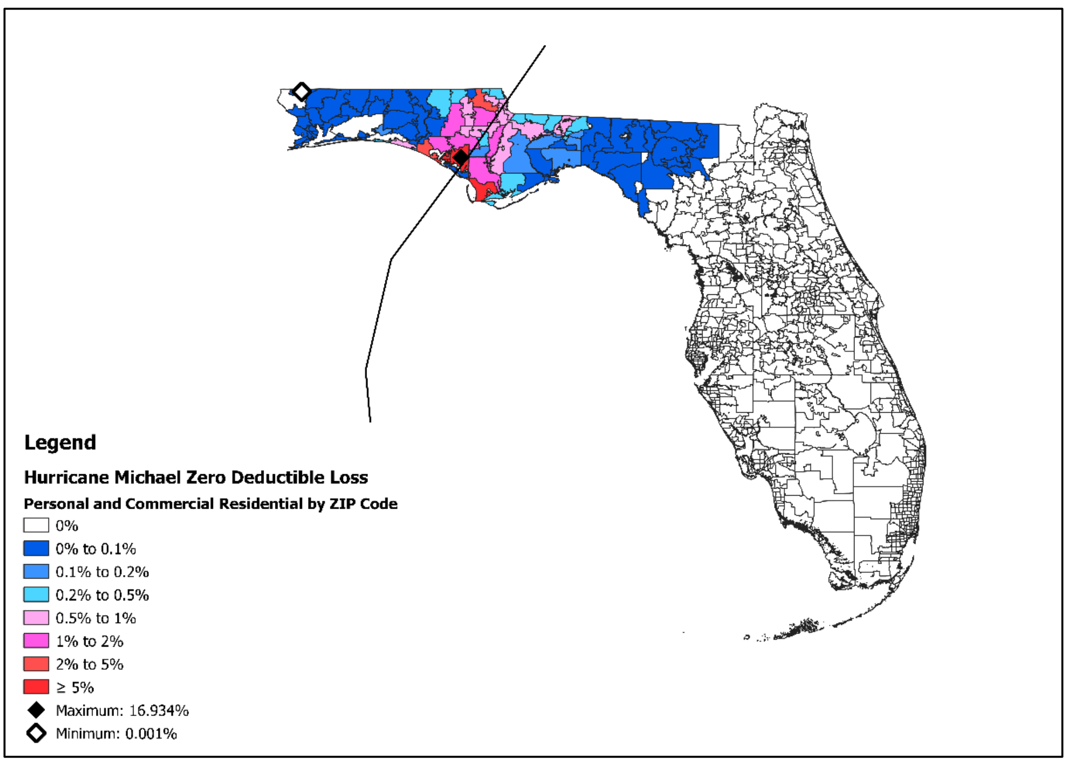


Figure 63 – Hurricane Michael (2018) Zero Deductible Loss

E. Provide this form in both Excel and PDF format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name.

A completed Form A-3 for the contribution and percentage of losses from Hurricane Hermine (2016), Hurricane Matthew (2016), Hurricane Irma (2017), and Hurricane Michael (2018) for each ZIP Code for 2017 FHCF personal and commercial residential policies has been provided in Excel and PDF format with the file name “KCC21_FormA3_ 221104”.

Form A-4: Hurricane Output Ranges

A. ***One or more automated programs or scripts should be used to generate the personal and commercial residential hurricane output ranges in the format shown in the file named "2021FormA4.xlsx."***

The results in this form have been produced and arranged using an automated program that reads the losses generated by the KCC US Hurricane Reference Model.

B. ***Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form A-4, Hurricane Output Ranges, in a submission appendix.***

A completed Form A-4 has been provided in Excel format with the file name " KCC21_FormA4_Revised_230309" and within this submission appendix.

C. ***Provide hurricane loss costs, rounded to three decimal places, by county (Figure 13). Within each county, hurricane loss costs should be shown separately per $1,000 of exposure for frame owners, masonry owners, frame renters, masonry renters, frame condo unit owners, masonry condo unit owners, manufactured homes, and commercial residential. For each of these categories using ZIP Code centroids, the hurricane output range should show the highest hurricane loss cost, the lowest hurricane loss cost, and the weighted average hurricane loss cost. The aggregate residential exposure data for this form shall is to be developed from the information in the file named "hlpm2017c.zip," except for insured values and deductibles information. Insured values are to be based on the hurricane output range specifications given below. Deductible amounts of 0% and as specified in the hurricane output range specifications given below are to be assumed to be uniformly applied to all risks. When calculating the weighted average hurricane loss costs, weight the hurricane loss costs by the total insured value calculated above. Include the statewide range of hurricane loss costs (i.e., low, high, and weighted average).***

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Alachua	LOW	0.224	0.370	0.798	0.048	0.057	0.035	0.035	0.189
	AVERAGE	0.439	0.527	0.979	0.070	0.072	0.065	0.065	0.450
	HIGH	0.775	0.898	1.850	0.109	0.098	0.076	0.079	0.662
Baker	LOW	0.245	0.283	0.513	0.049	0.041	NA	NA	0.319
	AVERAGE	0.261	0.294	0.575	0.052	0.048	NA	NA	0.319
	HIGH	0.347	0.297	0.614	0.055	0.050	NA	NA	0.319
Bay	LOW	1.191	1.280	3.308	0.211	0.169	0.144	0.170	0.743
	AVERAGE	3.058	2.875	8.056	0.468	0.448	1.030	0.677	3.712
	HIGH	7.492	6.031	18.511	0.986	0.743	1.222	1.008	5.661
Bradford	LOW	0.317	0.355	0.620	0.060	0.034	NA	NA	NA
	AVERAGE	0.379	0.424	0.737	0.067	0.062	NA	NA	NA
	HIGH	0.430	0.462	0.844	0.082	0.073	NA	NA	NA
Brevard	LOW	2.773	1.421	7.480	0.392	0.256	0.218	0.232	1.707
	AVERAGE	4.459	3.919	15.501	0.892	0.829	0.930	1.154	4.817

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	HIGH	11.851	9.802	29.683	2.892	2.196	2.580	2.204	8.391
Broward	LOW	5.041	4.489	17.081	0.473	0.735	0.614	0.574	3.299
	AVERAGE	10.986	8.952	29.953	1.685	1.822	1.714	1.878	8.718
	HIGH	25.585	22.565	53.501	5.619	5.115	6.022	5.027	17.818
Calhoun	LOW	1.047	1.087	2.385	0.089	0.192	NA	NA	NA
	AVERAGE	1.331	1.362	2.787	0.208	0.221	NA	NA	NA
	HIGH	1.527	1.593	3.248	0.246	0.223	NA	NA	NA
Charlotte	LOW	3.182	1.942	8.479	0.383	0.379	0.374	0.318	1.766
	AVERAGE	4.387	3.394	11.547	0.729	0.640	0.932	0.647	3.204
	HIGH	6.028	4.712	18.366	1.151	0.946	1.510	0.884	4.813
Citrus	LOW	0.769	0.488	1.722	0.106	0.102	0.148	0.053	0.403
	AVERAGE	1.175	0.895	2.569	0.180	0.162	0.209	0.184	1.145
	HIGH	1.648	1.477	3.864	0.295	0.262	0.286	0.264	1.714
Clay	LOW	0.352	0.357	0.809	0.056	0.057	0.038	0.033	0.349
	AVERAGE	0.486	0.579	1.013	0.096	0.091	0.067	0.062	0.490
	HIGH	0.659	0.745	1.859	0.116	0.110	0.114	0.103	0.597
Collier	LOW	2.720	2.509	12.192	0.539	0.444	0.440	0.453	2.645
	AVERAGE	6.716	5.200	18.060	1.058	1.092	1.560	1.258	5.027
	HIGH	15.315	11.111	37.516	2.936	2.606	3.505	2.794	10.552
Columbia	LOW	0.294	0.281	0.575	0.017	0.051	0.049	0.048	0.256
	AVERAGE	0.319	0.345	0.712	0.054	0.056	0.051	0.049	0.256
	HIGH	0.394	0.380	0.761	0.075	0.058	0.053	0.052	0.256
DeSoto	LOW	3.791	3.051	9.150	0.778	0.575	0.514	0.511	3.070
	AVERAGE	4.087	3.492	9.259	0.784	0.581	0.531	0.512	3.089
	HIGH	4.687	3.581	9.687	0.833	0.741	0.622	0.592	3.580
Dixie	LOW	0.447	0.397	0.958	0.067	0.091	0.030	0.028	0.592
	AVERAGE	0.698	0.494	1.204	0.092	0.095	0.107	0.099	0.676
	HIGH	1.643	1.520	4.735	0.098	0.095	0.129	0.119	0.768
Duval	LOW	0.259	0.305	0.664	0.045	0.052	0.027	0.023	0.231

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	AVERAGE	0.614	0.658	1.234	0.102	0.103	0.081	0.099	0.530
	HIGH	1.852	1.789	4.914	0.372	0.368	0.341	0.310	1.567
Escambia	LOW	1.283	1.390	3.381	0.192	0.214	0.150	0.123	0.852
	AVERAGE	3.839	4.045	8.540	0.700	0.695	1.039	0.681	4.895
	HIGH	6.913	6.333	19.398	1.642	1.105	1.244	1.041	5.945
Flagler	LOW	0.783	0.659	1.674	0.122	0.110	0.052	0.049	0.432
	AVERAGE	1.451	1.041	4.392	0.211	0.183	0.363	0.207	0.917
	HIGH	2.697	2.462	7.318	0.609	0.512	0.608	0.482	1.612
Franklin	LOW	3.173	3.988	11.151	0.735	0.796	0.348	0.365	3.978
	AVERAGE	4.422	4.718	13.423	0.874	0.841	0.509	0.741	3.978
	HIGH	4.993	5.226	16.736	0.988	0.928	1.203	1.184	3.978
Gadsden	LOW	0.227	0.495	1.056	0.090	0.084	NA	NA	0.437
	AVERAGE	0.591	0.641	1.282	0.105	0.104	NA	NA	0.606
	HIGH	0.825	0.869	1.675	0.139	0.108	NA	NA	0.737
Gilchrist	LOW	0.481	0.464	1.141	0.063	0.095	NA	NA	NA
	AVERAGE	0.499	0.531	1.243	0.096	0.095	NA	NA	NA
	HIGH	0.505	0.556	1.295	0.103	0.096	NA	NA	NA
Glades	LOW	6.483	3.090	12.845	1.528	1.253	NA	NA	6.511
	AVERAGE	7.912	5.865	17.765	1.528	1.253	NA	NA	6.511
	HIGH	7.945	5.927	17.999	1.528	1.253	NA	NA	6.511
Gulf	LOW	1.431	1.783	4.342	0.255	0.296	0.557	0.378	3.441
	AVERAGE	3.365	4.050	8.138	0.851	0.810	0.557	0.378	3.441
	HIGH	3.803	4.728	13.950	0.906	0.903	0.557	0.378	3.441
Hamilton	LOW	0.274	0.289	0.534	0.047	0.039	NA	NA	NA
	AVERAGE	0.319	0.342	0.613	0.057	0.056	NA	NA	NA
	HIGH	0.333	0.358	0.692	0.058	0.060	NA	NA	NA
Hardee	LOW	2.983	2.459	6.371	0.482	0.424	0.571	NA	2.476
	AVERAGE	3.155	2.727	6.817	0.529	0.468	0.571	NA	2.476
	HIGH	3.240	2.804	7.317	0.671	0.601	0.571	NA	2.476

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Hendry	LOW	6.802	3.969	14.634	1.173	0.894	1.258	1.114	4.907
	AVERAGE	7.482	6.251	17.171	1.434	1.106	1.502	1.136	5.899
	HIGH	8.748	7.246	18.961	1.598	1.365	1.525	1.143	7.637
Hernando	LOW	0.893	0.602	1.980	0.146	0.092	0.230	0.058	0.560
	AVERAGE	1.414	1.191	3.015	0.189	0.198	0.294	0.255	1.340
	HIGH	2.012	2.121	5.907	0.422	0.376	0.369	0.412	1.850
Highlands	LOW	2.379	1.498	6.632	0.462	0.415	0.484	0.406	2.576
	AVERAGE	3.678	3.273	8.454	0.576	0.526	0.583	0.531	3.346
	HIGH	5.062	4.669	12.068	1.001	0.889	0.700	0.662	4.643
Hillsborough	LOW	1.014	0.657	3.879	0.150	0.118	0.120	0.117	0.729
	AVERAGE	1.949	1.948	5.488	0.348	0.334	0.333	0.345	1.796
	HIGH	3.880	4.149	10.344	0.922	0.925	0.723	0.776	3.419
Holmes	LOW	1.051	1.196	2.627	0.198	0.201	NA	NA	1.392
	AVERAGE	1.257	1.333	2.857	0.225	0.217	NA	NA	1.392
	HIGH	1.390	1.485	3.291	0.273	0.244	NA	NA	1.392
Indian River	LOW	4.009	2.673	12.761	0.401	0.478	0.703	0.584	4.001
	AVERAGE	7.927	5.008	16.321	1.581	1.113	1.697	1.748	6.938
	HIGH	15.515	15.898	44.732	3.264	2.741	3.807	3.148	11.755
Jackson	LOW	0.688	0.739	1.354	0.126	0.109	NA	NA	0.438
	AVERAGE	0.921	0.981	1.973	0.157	0.151	NA	NA	0.973
	HIGH	1.136	1.182	2.459	0.195	0.198	NA	NA	1.085
Jefferson	LOW	0.558	0.379	1.252	0.101	0.090	NA	NA	NA
	AVERAGE	0.570	0.584	1.318	0.103	0.101	NA	NA	NA
	HIGH	0.786	0.776	1.721	0.130	0.105	NA	NA	NA
Lafayette	LOW	0.495	0.498	1.068	0.101	0.084	NA	NA	NA
	AVERAGE	0.496	0.499	1.068	0.101	0.084	NA	NA	NA
	HIGH	0.702	0.669	1.092	0.101	0.084	NA	NA	NA
Lake	LOW	0.908	0.782	1.782	0.109	0.100	0.074	0.074	0.803
	AVERAGE	1.296	1.104	3.597	0.173	0.165	0.227	0.190	1.333
	HIGH	2.997	2.811	7.530	0.464	0.341	0.319	0.299	1.988

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Lee	LOW	1.610	2.048	9.379	0.362	0.322	0.259	0.249	1.727
	AVERAGE	5.428	3.228	13.912	0.562	0.554	0.979	0.658	3.130
	HIGH	10.173	9.472	26.330	2.560	2.034	2.634	2.331	9.020
Leon	LOW	0.532	0.530	1.163	0.069	0.061	0.037	0.038	0.266
	AVERAGE	0.651	0.686	1.479	0.093	0.089	0.067	0.078	0.492
	HIGH	0.887	0.843	1.753	0.135	0.127	0.091	0.109	0.651
Levy	LOW	0.498	0.520	1.189	0.093	0.066	0.232	0.217	0.659
	AVERAGE	0.716	0.604	1.429	0.109	0.115	0.232	0.217	0.909
	HIGH	1.475	1.407	4.262	0.342	0.270	0.232	0.217	1.778
Liberty	LOW	1.062	1.119	2.501	0.171	0.222	NA	NA	NA
	AVERAGE	1.150	1.223	2.759	0.195	0.222	NA	NA	NA
	HIGH	1.192	1.251	2.886	0.200	0.222	NA	NA	NA
Madison	LOW	0.337	0.356	0.694	0.023	0.054	NA	NA	NA
	AVERAGE	0.499	0.501	1.049	0.084	0.082	NA	NA	NA
	HIGH	0.683	0.673	1.509	0.112	0.117	NA	NA	NA
Manatee	LOW	1.467	1.017	5.027	0.161	0.164	0.121	0.126	0.753
	AVERAGE	2.910	1.982	6.964	0.451	0.385	0.636	0.531	1.616
	HIGH	7.371	7.239	19.318	1.800	1.671	1.749	1.617	5.461
Marion	LOW	0.452	0.319	0.842	0.076	0.055	0.058	0.070	0.300
	AVERAGE	0.868	0.652	1.834	0.120	0.110	0.134	0.101	0.699
	HIGH	1.357	1.223	2.558	0.215	0.171	0.196	0.188	1.394
Martin	LOW	6.538	4.257	16.216	0.736	0.907	1.122	0.982	5.524
	AVERAGE	10.196	7.410	29.990	1.403	1.483	2.805	1.768	8.013
	HIGH	15.717	13.026	39.204	3.192	3.727	3.594	2.980	12.911
Miami-Dade	LOW	4.048	1.960	16.001	0.435	0.586	0.302	0.218	3.683
	AVERAGE	11.396	9.423	26.377	2.086	2.328	2.272	2.209	8.873
	HIGH	28.323	23.450	47.348	7.471	5.759	6.360	5.982	17.642
Monroe	LOW	11.525	10.679	34.541	2.570	2.403	2.858	2.704	9.658
	AVERAGE	13.647	15.229	45.850	3.454	3.314	3.587	3.868	12.719

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	HIGH	20.912	18.084	54.500	5.130	4.105	5.137	4.589	16.423
Nassau	LOW	0.248	0.273	0.564	0.040	0.045	0.115	0.123	0.507
	AVERAGE	0.506	0.490	0.975	0.091	0.084	0.115	0.123	0.507
	HIGH	0.676	0.736	3.379	0.127	0.114	0.115	0.123	0.507
Okaloosa	LOW	0.867	0.947	2.228	0.157	0.128	0.074	0.577	0.591
	AVERAGE	4.190	4.096	5.970	0.783	0.728	1.185	1.031	5.084
	HIGH	9.900	7.433	24.415	1.693	1.480	1.503	1.149	7.379
Okeechobee	LOW	5.701	4.386	14.478	1.052	0.820	0.352	1.050	4.204
	AVERAGE	8.993	7.466	24.264	1.840	1.368	1.443	1.977	8.276
	HIGH	11.347	9.198	26.491	2.196	1.981	1.611	1.986	8.316
Orange	LOW	0.535	0.723	2.717	0.118	0.115	0.054	0.092	0.565
	AVERAGE	1.302	1.435	4.061	0.190	0.189	0.179	0.183	1.288
	HIGH	2.735	2.280	6.649	0.437	0.421	0.328	0.271	2.502
Osceola	LOW	0.992	1.261	3.908	0.138	0.160	0.123	0.136	0.854
	AVERAGE	1.678	1.872	6.096	0.222	0.245	0.212	0.195	1.348
	HIGH	3.707	2.855	8.361	0.703	0.566	0.266	0.393	3.488
Palm Beach	LOW	3.449	2.818	17.969	0.736	0.636	0.405	0.422	2.143
	AVERAGE	11.793	8.826	30.711	1.898	1.906	2.424	2.005	8.061
	HIGH	24.586	22.436	53.122	5.020	4.422	5.485	4.680	17.142
Pasco	LOW	0.848	0.882	3.515	0.148	0.144	0.088	0.089	0.495
	AVERAGE	1.462	1.740	4.578	0.237	0.311	0.283	0.396	1.673
	HIGH	2.839	3.052	8.700	0.779	0.658	0.707	0.661	2.952
Pinellas	LOW	0.515	0.864	4.722	0.184	0.196	0.211	0.236	1.585
	AVERAGE	3.696	3.188	7.337	0.608	0.613	0.677	0.652	2.637
	HIGH	6.729	6.104	16.997	1.394	1.398	1.550	1.357	4.393
Polk	LOW	0.805	0.735	3.546	0.145	0.095	0.097	0.100	0.658
	AVERAGE	1.807	1.609	4.627	0.244	0.261	0.226	0.236	1.474
	HIGH	3.675	3.284	7.895	0.550	0.505	0.572	0.526	3.034
Putnam	LOW	0.432	0.429	0.848	0.082	0.058	0.051	0.039	0.773

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	AVERAGE	0.731	0.751	1.601	0.127	0.122	0.098	0.078	0.784
	HIGH	1.275	1.273	2.757	0.176	0.173	0.179	0.169	1.144
St. Johns	LOW	0.334	0.334	1.354	0.060	0.054	0.040	0.040	0.266
	AVERAGE	0.844	1.081	2.648	0.224	0.203	0.274	0.297	1.235
	HIGH	2.091	1.949	6.311	0.458	0.364	0.442	0.428	1.878
St. Lucie	LOW	4.519	2.263	15.560	0.597	0.342	0.390	0.333	2.107
	AVERAGE	8.008	4.500	23.394	1.087	0.917	1.944	1.842	6.904
	HIGH	16.642	13.482	43.517	3.285	2.865	3.573	2.866	11.486
Santa Rosa	LOW	1.216	1.329	3.529	0.227	0.219	0.325	0.416	0.589
	AVERAGE	3.666	3.414	9.501	0.805	0.714	1.574	1.106	3.983
	HIGH	9.439	9.146	30.256	2.213	1.771	2.215	1.673	9.356
Sarasota	LOW	1.337	1.219	4.831	0.259	0.232	0.194	0.163	1.132
	AVERAGE	3.706	2.821	10.331	0.595	0.562	0.888	0.744	2.277
	HIGH	6.925	5.780	17.903	1.631	1.398	1.682	1.477	5.060
Seminole	LOW	0.679	0.833	3.352	0.170	0.102	0.123	0.127	0.790
	AVERAGE	1.646	1.615	4.343	0.231	0.222	0.209	0.209	1.406
	HIGH	2.357	1.940	5.402	0.369	0.376	0.375	0.272	1.925
Sumter	LOW	0.421	0.387	2.272	0.074	0.063	0.075	0.071	0.516
	AVERAGE	0.606	0.560	3.170	0.103	0.092	0.156	0.097	0.646
	HIGH	1.613	1.403	3.528	0.283	0.262	0.218	0.207	1.682
Suwannee	LOW	0.326	0.319	0.689	0.047	0.019	NA	NA	0.290
	AVERAGE	0.366	0.374	0.776	0.061	0.063	NA	NA	0.367
	HIGH	0.464	0.442	0.991	0.080	0.091	NA	NA	0.554
Taylor	LOW	0.613	0.627	1.192	0.070	0.090	0.041	0.068	0.488
	AVERAGE	0.653	0.656	1.579	0.101	0.101	0.074	0.068	0.488
	HIGH	0.917	0.933	2.701	0.120	0.190	0.075	0.068	0.488
Union	LOW	0.337	0.375	0.603	0.059	0.064	NA	NA	NA
	AVERAGE	0.338	0.376	0.734	0.060	0.066	NA	NA	NA
	HIGH	0.548	0.430	0.915	0.067	0.068	NA	NA	NA

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Volusia	LOW	0.474	0.517	1.834	0.095	0.083	0.064	0.071	0.668
	AVERAGE	1.980	1.647	4.755	0.301	0.297	0.494	0.539	1.850
	HIGH	4.649	4.199	12.513	0.813	0.762	0.984	0.749	3.716
Wakulla	LOW	0.529	0.613	1.635	0.094	0.093	0.078	0.499	0.366
	AVERAGE	0.794	0.920	2.014	0.143	0.198	0.262	0.499	1.006
	HIGH	2.490	2.925	7.894	0.451	0.442	0.446	0.499	2.402
Walton	LOW	0.868	1.242	2.391	0.177	0.187	0.226	0.592	1.304
	AVERAGE	3.528	2.921	7.195	0.669	0.583	1.263	0.877	4.509
	HIGH	5.885	5.083	22.734	1.335	1.010	1.476	0.948	7.694
Washington	LOW	1.110	1.238	2.588	0.208	0.196	0.097	NA	0.859
	AVERAGE	1.124	1.255	2.676	0.218	0.201	0.097	NA	0.859
	HIGH	1.469	1.761	4.183	0.299	0.273	0.097	NA	0.859
Statewide	LOW	0.224	0.273	0.513	0.017	0.019	0.027	0.023	0.189
	AVERAGE	2.630	4.142	7.114	0.434	0.855	0.645	1.220	4.338
	HIGH	28.323	23.450	54.500	7.471	5.759	6.360	5.982	17.818

Table 33 - Output Ranges: Hurricane loss costs per $1,000 with 0% deductible (2017 FCHF exposure data)

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Alachua	LOW	0.140	0.234	0.575	0.025	0.029	0.013	0.013	0.095
	AVERAGE	0.291	0.350	0.729	0.038	0.039	0.028	0.027	0.247
	HIGH	0.550	0.642	1.480	0.063	0.054	0.033	0.034	0.374
Baker	LOW	0.144	0.167	0.336	0.024	0.020	NA	NA	0.151
	AVERAGE	0.155	0.176	0.385	0.025	0.023	NA	NA	0.151
	HIGH	0.208	0.179	0.419	0.027	0.024	NA	NA	0.151
Bay	LOW	0.893	0.961	2.776	0.137	0.102	0.073	0.085	0.427
	AVERAGE	2.561	2.371	7.253	0.347	0.327	0.761	0.469	2.834
	HIGH	6.615	5.240	17.255	0.780	0.578	0.920	0.724	4.491
Bradford	LOW	0.193	0.217	0.422	0.030	0.016	NA	NA	NA
	AVERAGE	0.236	0.265	0.514	0.034	0.031	NA	NA	NA

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	HIGH	0.270	0.294	0.601	0.042	0.037	NA	NA	NA
Brevard	LOW	2.284	1.086	6.665	0.292	0.176	0.123	0.129	1.188
	AVERAGE	3.813	3.331	14.350	0.708	0.655	0.690	0.884	3.783
	HIGH	10.750	8.799	28.067	2.510	1.870	2.136	1.789	6.909
Broward	LOW	4.282	3.765	15.717	0.335	0.538	0.377	0.346	2.380
	AVERAGE	9.853	7.910	28.308	1.391	1.509	1.291	1.441	7.135
	HIGH	23.918	20.979	51.541	5.033	4.531	5.259	4.322	15.527
Calhoun	LOW	0.761	0.787	1.932	0.048	0.116	NA	NA	NA
	AVERAGE	1.000	1.016	2.297	0.131	0.137	NA	NA	NA
	HIGH	1.163	1.212	2.716	0.158	0.139	NA	NA	NA
Charlotte	LOW	2.673	1.585	7.685	0.279	0.276	0.232	0.199	1.270
	AVERAGE	3.794	2.885	10.620	0.575	0.494	0.708	0.465	2.463
	HIGH	5.387	4.161	17.243	0.969	0.784	1.236	0.694	3.893
Citrus	LOW	0.565	0.348	1.398	0.068	0.061	0.079	0.023	0.224
	AVERAGE	0.910	0.674	2.171	0.121	0.106	0.124	0.105	0.775
	HIGH	1.309	1.158	3.414	0.208	0.181	0.177	0.158	1.199
Clay	LOW	0.235	0.233	0.597	0.031	0.030	0.016	0.013	0.193
	AVERAGE	0.337	0.400	0.764	0.057	0.053	0.031	0.028	0.281
	HIGH	0.466	0.526	1.515	0.070	0.066	0.059	0.050	0.352
Collier	LOW	2.242	2.042	11.147	0.398	0.317	0.276	0.281	1.940
	AVERAGE	5.932	4.531	16.815	0.857	0.888	1.243	0.974	4.014
	HIGH	14.065	10.115	35.799	2.553	2.256	2.970	2.337	8.895
Columbia	LOW	0.178	0.167	0.387	0.007	0.026	0.018	0.018	0.115
	AVERAGE	0.197	0.213	0.506	0.027	0.028	0.019	0.018	0.115
	HIGH	0.245	0.233	0.546	0.040	0.029	0.020	0.020	0.115
DeSoto	LOW	3.207	2.509	8.213	0.591	0.422	0.340	0.337	2.297
	AVERAGE	3.437	2.902	8.327	0.598	0.428	0.351	0.338	2.310
	HIGH	3.962	2.970	8.780	0.641	0.554	0.413	0.378	2.645
Dixie	LOW	0.304	0.265	0.733	0.038	0.055	0.011	0.011	0.360

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	AVERAGE	0.515	0.338	0.954	0.054	0.055	0.062	0.056	0.434
	HIGH	1.325	1.212	4.158	0.058	0.057	0.079	0.071	0.515
Duval	LOW	0.162	0.202	0.475	0.024	0.027	0.011	0.009	0.115
	AVERAGE	0.452	0.477	0.987	0.066	0.065	0.045	0.059	0.329
	HIGH	1.531	1.464	4.363	0.289	0.281	0.245	0.217	1.134
Escambia	LOW	0.957	1.036	2.822	0.119	0.132	0.073	0.058	0.519
	AVERAGE	3.269	3.432	7.707	0.542	0.531	0.757	0.467	3.843
	HIGH	6.086	5.538	18.149	1.361	0.881	0.932	0.746	4.755
Flagler	LOW	0.569	0.469	1.345	0.076	0.066	0.022	0.020	0.240
	AVERAGE	1.170	0.813	3.880	0.151	0.127	0.250	0.134	0.622
	HIGH	2.272	2.052	6.609	0.482	0.396	0.446	0.342	1.160
Franklin	LOW	2.692	3.407	10.246	0.578	0.621	0.225	0.229	3.060
	AVERAGE	3.829	4.074	12.419	0.696	0.659	0.352	0.527	3.060
	HIGH	4.356	4.549	15.596	0.789	0.739	0.902	0.874	3.060
Gadsden	LOW	0.134	0.330	0.759	0.047	0.043	NA	NA	0.232
	AVERAGE	0.395	0.427	0.961	0.057	0.055	NA	NA	0.324
	HIGH	0.569	0.597	1.288	0.077	0.059	NA	NA	0.407
Gilchrist	LOW	0.330	0.315	0.887	0.036	0.056	NA	NA	NA
	AVERAGE	0.345	0.366	0.975	0.057	0.056	NA	NA	NA
	HIGH	0.351	0.386	1.019	0.062	0.056	NA	NA	NA
Glades	LOW	5.542	2.499	11.626	1.216	0.970	NA	NA	5.070
	AVERAGE	6.880	4.995	16.347	1.216	0.970	NA	NA	5.070
	HIGH	6.912	5.050	16.572	1.216	0.970	NA	NA	5.070
Gulf	LOW	1.106	1.390	3.748	0.170	0.196	0.384	0.243	2.627
	AVERAGE	2.858	3.454	7.360	0.675	0.632	0.384	0.243	2.627
	HIGH	3.255	4.072	12.889	0.722	0.711	0.384	0.243	2.627
Hamilton	LOW	0.162	0.171	0.356	0.024	0.018	NA	NA	NA
	AVERAGE	0.197	0.210	0.425	0.029	0.028	NA	NA	NA
	HIGH	0.206	0.221	0.492	0.029	0.030	NA	NA	NA

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Hardee	LOW	2.398	1.984	5.530	0.338	0.287	0.345	NA	1.695
	AVERAGE	2.554	2.171	5.947	0.376	0.322	0.345	NA	1.695
	HIGH	2.626	2.236	6.488	0.501	0.438	0.345	NA	1.695
Hendry	LOW	5.924	3.319	13.489	0.932	0.688	0.918	0.781	3.748
	AVERAGE	6.530	5.378	15.847	1.143	0.858	1.079	0.784	4.611
	HIGH	7.659	6.261	17.518	1.272	1.066	1.094	0.793	6.121
Hernando	LOW	0.682	0.441	1.648	0.095	0.055	0.140	0.027	0.341
	AVERAGE	1.137	0.939	2.593	0.130	0.137	0.196	0.162	0.923
	HIGH	1.693	1.771	5.336	0.330	0.288	0.264	0.293	1.365
Highlands	LOW	1.834	1.092	5.715	0.314	0.275	0.264	0.213	1.741
	AVERAGE	2.995	2.630	7.419	0.404	0.361	0.345	0.304	2.373
	HIGH	4.229	3.859	10.863	0.757	0.659	0.441	0.407	3.462
Hillsborough	LOW	0.787	0.499	3.367	0.100	0.073	0.066	0.064	0.460
	AVERAGE	1.606	1.588	4.854	0.259	0.245	0.224	0.229	1.308
	HIGH	3.411	3.620	9.583	0.764	0.770	0.551	0.588	2.715
Holmes	LOW	0.752	0.861	2.148	0.123	0.123	NA	NA	0.878
	AVERAGE	0.937	0.991	2.362	0.144	0.135	NA	NA	0.878
	HIGH	1.057	1.127	2.767	0.180	0.156	NA	NA	0.878
Indian River	LOW	3.379	2.180	11.651	0.281	0.344	0.461	0.380	3.011
	AVERAGE	7.014	4.336	15.087	1.311	0.900	1.331	1.370	5.608
	HIGH	14.229	14.516	42.919	2.857	2.369	3.227	2.620	9.898
Jackson	LOW	0.455	0.489	1.001	0.069	0.059	NA	NA	0.216
	AVERAGE	0.648	0.688	1.549	0.091	0.086	NA	NA	0.580
	HIGH	0.823	0.853	1.995	0.117	0.120	NA	NA	0.658
Jefferson	LOW	0.392	0.251	0.989	0.060	0.054	NA	NA	NA
	AVERAGE	0.402	0.409	1.047	0.062	0.059	NA	NA	NA
	HIGH	0.576	0.562	1.398	0.081	0.061	NA	NA	NA
Lafayette	LOW	0.341	0.340	0.828	0.060	0.048	NA	NA	NA
	AVERAGE	0.341	0.341	0.828	0.060	0.048	NA	NA	NA
	HIGH	0.498	0.467	0.849	0.060	0.048	NA	NA	NA

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Lake	LOW	0.632	0.533	1.373	0.059	0.056	0.030	0.029	0.471
	AVERAGE	0.960	0.797	2.989	0.101	0.095	0.109	0.088	0.842
	HIGH	2.403	2.231	6.591	0.318	0.222	0.165	0.151	1.329
Lee	LOW	1.288	1.672	8.503	0.258	0.224	0.153	0.139	1.212
	AVERAGE	4.752	2.711	12.840	0.426	0.415	0.732	0.462	2.364
	HIGH	9.261	8.570	25.007	2.229	1.741	2.209	1.916	7.573
Leon	LOW	0.366	0.359	0.888	0.038	0.033	0.014	0.014	0.131
	AVERAGE	0.455	0.478	1.169	0.053	0.049	0.029	0.034	0.274
	HIGH	0.641	0.602	1.400	0.080	0.074	0.041	0.049	0.373
Levy	LOW	0.346	0.358	0.930	0.056	0.037	0.145	0.132	0.392
	AVERAGE	0.527	0.428	1.142	0.067	0.070	0.145	0.132	0.574
	HIGH	1.172	1.104	3.709	0.249	0.190	0.145	0.132	1.242
Liberty	LOW	0.778	0.818	2.044	0.104	0.138	NA	NA	NA
	AVERAGE	0.852	0.904	2.275	0.121	0.138	NA	NA	NA
	HIGH	0.883	0.927	2.388	0.125	0.138	NA	NA	NA
Madison	LOW	0.215	0.226	0.501	0.011	0.027	NA	NA	NA
	AVERAGE	0.343	0.340	0.811	0.048	0.046	NA	NA	NA
	HIGH	0.493	0.480	1.216	0.068	0.070	NA	NA	NA
Manatee	LOW	1.181	0.791	4.470	0.107	0.109	0.066	0.070	0.495
	AVERAGE	2.484	1.642	6.287	0.349	0.289	0.482	0.387	1.177
	HIGH	6.690	6.531	18.284	1.565	1.439	1.470	1.338	4.533
Marion	LOW	0.289	0.200	0.599	0.039	0.028	0.025	0.029	0.146
	AVERAGE	0.630	0.460	1.466	0.072	0.064	0.067	0.049	0.422
	HIGH	1.020	0.906	2.104	0.136	0.101	0.100	0.090	0.903
Martin	LOW	5.633	3.584	14.911	0.558	0.683	0.778	0.663	4.257
	AVERAGE	9.090	6.494	28.281	1.143	1.201	2.272	1.345	6.469
	HIGH	14.331	11.702	37.266	2.756	3.225	2.975	2.420	10.852
Miami-Dade	LOW	3.400	1.529	14.688	0.301	0.421	0.163	0.106	2.803
	AVERAGE	10.283	8.399	24.870	1.773	1.978	1.819	1.765	7.347

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	HIGH	26.635	21.914	45.479	6.772	5.137	5.618	5.238	15.376
Monroe	LOW	10.567	9.745	33.082	2.233	2.067	2.365	2.275	8.041
	AVERAGE	12.578	14.011	44.070	3.044	2.889	3.078	3.257	10.917
	HIGH	19.427	16.684	52.445	4.543	3.591	4.411	3.887	14.187
Nassau	LOW	0.155	0.171	0.403	0.019	0.023	0.071	0.074	0.324
	AVERAGE	0.375	0.354	0.766	0.060	0.054	0.071	0.074	0.324
	HIGH	0.517	0.559	2.963	0.088	0.077	0.071	0.074	0.324
Okaloosa	LOW	0.622	0.680	1.796	0.096	0.075	0.032	0.381	0.326
	AVERAGE	3.616	3.519	5.308	0.619	0.569	0.887	0.749	4.016
	HIGH	8.871	6.574	22.963	1.408	1.213	1.151	0.842	6.052
Okeechobee	LOW	4.853	3.666	13.209	0.805	0.609	0.194	0.696	3.087
	AVERAGE	7.939	6.509	22.697	1.506	1.087	1.074	1.491	6.680
	HIGH	10.147	8.121	24.857	1.823	1.621	1.209	1.499	6.715
Orange	LOW	0.342	0.492	2.177	0.066	0.063	0.021	0.037	0.306
	AVERAGE	0.963	1.061	3.404	0.114	0.112	0.085	0.086	0.814
	HIGH	2.224	1.782	5.759	0.296	0.288	0.185	0.146	1.745
Osceola	LOW	0.699	0.909	3.224	0.076	0.089	0.058	0.058	0.490
	AVERAGE	1.284	1.433	5.261	0.136	0.150	0.101	0.092	0.863
	HIGH	3.045	2.289	7.397	0.513	0.397	0.135	0.224	2.516
Palm Beach	LOW	2.841	2.274	16.537	0.549	0.460	0.245	0.250	1.495
	AVERAGE	10.579	7.801	28.982	1.578	1.581	1.915	1.541	6.539
	HIGH	22.892	20.776	50.983	4.437	3.860	4.690	3.926	14.716
Pasco	LOW	0.656	0.675	3.015	0.101	0.094	0.046	0.044	0.312
	AVERAGE	1.186	1.430	4.022	0.172	0.233	0.188	0.284	1.217
	HIGH	2.464	2.633	8.029	0.648	0.538	0.557	0.514	2.306
Pinellas	LOW	0.387	0.709	4.202	0.127	0.135	0.131	0.146	1.139
	AVERAGE	3.250	2.766	6.728	0.493	0.496	0.526	0.500	2.054
	HIGH	6.089	5.486	16.076	1.219	1.213	1.326	1.145	3.640
Polk	LOW	0.573	0.513	2.935	0.079	0.051	0.045	0.041	0.369

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
	AVERAGE	1.379	1.205	3.882	0.151	0.161	0.113	0.115	0.953
	HIGH	2.958	2.608	6.916	0.375	0.338	0.332	0.295	2.099
Putnam	LOW	0.279	0.275	0.612	0.044	0.030	0.021	0.016	0.460
	AVERAGE	0.514	0.525	1.256	0.075	0.071	0.046	0.034	0.467
	HIGH	0.947	0.943	2.267	0.109	0.106	0.091	0.083	0.716
St. Johns	LOW	0.230	0.236	1.081	0.035	0.032	0.018	0.018	0.153
	AVERAGE	0.663	0.856	2.267	0.167	0.147	0.193	0.206	0.881
	HIGH	1.729	1.584	5.658	0.359	0.278	0.321	0.305	1.378
St. Lucie	LOW	3.826	1.804	14.303	0.435	0.230	0.228	0.187	1.441
	AVERAGE	7.031	3.825	21.891	0.864	0.718	1.534	1.458	5.591
	HIGH	15.291	12.270	41.538	2.865	2.472	3.021	2.372	9.674
Santa Rosa	LOW	0.905	0.990	2.956	0.143	0.134	0.182	0.242	0.321
	AVERAGE	3.136	2.891	8.636	0.637	0.556	1.231	0.822	3.121
	HIGH	8.499	8.192	28.783	1.880	1.476	1.772	1.257	7.789
Sarasota	LOW	1.055	0.949	4.273	0.178	0.158	0.109	0.091	0.767
	AVERAGE	3.205	2.403	9.503	0.474	0.444	0.694	0.568	1.716
	HIGH	6.264	5.182	16.897	1.408	1.191	1.405	1.209	4.160
Seminole	LOW	0.476	0.584	2.750	0.103	0.054	0.059	0.059	0.474
	AVERAGE	1.260	1.222	3.685	0.146	0.138	0.105	0.102	0.906
	HIGH	1.888	1.524	4.701	0.249	0.256	0.221	0.145	1.281
Sumter	LOW	0.281	0.254	1.845	0.041	0.034	0.033	0.031	0.284
	AVERAGE	0.422	0.389	2.662	0.060	0.053	0.080	0.045	0.379
	HIGH	1.257	1.076	2.998	0.195	0.168	0.116	0.106	1.135
Suwannee	LOW	0.211	0.205	0.493	0.024	0.009	NA	NA	0.143
	AVERAGE	0.237	0.240	0.570	0.033	0.033	NA	NA	0.187
	HIGH	0.314	0.295	0.755	0.046	0.052	NA	NA	0.313
Taylor	LOW	0.433	0.439	0.936	0.043	0.052	0.016	0.035	0.298
	AVERAGE	0.470	0.464	1.282	0.060	0.059	0.039	0.035	0.298
	HIGH	0.671	0.708	2.299	0.074	0.128	0.040	0.035	0.298

County	Hurricane Loss Costs	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Union	LOW	0.208	0.232	0.407	0.030	0.031	NA	NA	NA
	AVERAGE	0.209	0.233	0.514	0.030	0.033	NA	NA	NA
	HIGH	0.358	0.272	0.665	0.034	0.034	NA	NA	NA
Volusia	LOW	0.322	0.362	1.453	0.057	0.047	0.030	0.032	0.382
	AVERAGE	1.595	1.305	4.154	0.218	0.211	0.348	0.385	1.320
	HIGH	4.027	3.600	11.490	0.658	0.608	0.755	0.555	2.864
Wakulla	LOW	0.370	0.432	1.314	0.055	0.054	0.037	0.336	0.194
	AVERAGE	0.598	0.695	1.663	0.093	0.135	0.170	0.336	0.697
	HIGH	2.085	2.451	7.156	0.341	0.328	0.303	0.336	1.802
Walton	LOW	0.627	0.905	1.938	0.110	0.113	0.132	0.410	0.864
	AVERAGE	3.006	2.438	6.481	0.523	0.445	0.951	0.624	3.541
	HIGH	5.146	4.393	21.302	1.089	0.801	1.122	0.678	6.254
Washington	LOW	0.818	0.913	2.119	0.130	0.121	0.043	NA	0.509
	AVERAGE	0.829	0.927	2.199	0.137	0.124	0.043	NA	0.509
	HIGH	1.108	1.352	3.570	0.199	0.176	0.043	NA	0.509
Statewide	LOW	0.134	0.167	0.336	0.007	0.009	0.011	0.009	0.095
	AVERAGE	2.227	3.568	6.416	0.332	0.689	0.478	0.931	3.440
	HIGH	26.635	21.914	52.445	6.772	5.137	5.618	5.238	15.527

Table 34 - Output Ranges: Hurricane loss costs per $1,000 with specified deductibles (2017 FCHF exposure data)

D. If a modeling organization has hurricane loss costs for a ZIP Code for which there is no exposure, give the hurricane loss costs zero weight (i.e., assume the exposure in that ZIP Code is zero). Provide a list in the submission document of those ZIP Codes where this occurs.

Loss costs were not produced for a ZIP Code for which there is no exposure.

E. If a modeling organization does not have hurricane loss costs for a ZIP Code for which there is some exposure, do not assume such hurricane loss costs are zero, but use only the exposures for which there are hurricane loss costs in calculating the weighted average hurricane loss costs. Provide a list in the submission document of the ZIP Codes where this occurs.

There are no ZIP Codes for which the 2017 FHCF file had exposure data and the KCC US Hurricane Reference Model did not produce loss costs.

F. NA should be used in cells to signify no exposure.

NA has been used in cells to signify no exposure.

G. ***Indicate if per diem is used in producing hurricane loss costs for Coverage D (Time Element) in the personal residential hurricane output ranges. If a per diem rate is used, a rate of $300.00 per day per policy is to be used.***

A per diem was not used in producing hurricane loss costs for Coverage D.

H. ***Describe how Law and Ordinance is included in the hurricane output ranges.***

Law and ordinance coverage is not included in the "hlpm2017c.zip" input file and is not explicitly considered in the hurricane output ranges. However, to the extent law and ordinance coverage associated with personal residential policies is present in the historical claims information, it is implicitly included in base vulnerability functions and accounted for in the hurricane output range.

I. ***If additional assumptions are necessary to complete this form, provide the rationale for the assumptions as well as a detailed description of how they are included***.

No additional assumptions were made to complete this form.

Form A-5: Percentage Change in Hurricane Output Ranges

A. ***One or more automated programs or scripts should be used to generate and arrange the data in Form A-5, Percentage Change in Hurricane Output Ranges.***

The results in this form have been produced and arranged using an automated program that reads the losses generated by the KCC US Hurricane Reference Model.

B. ***Provide summaries of the percentage change in average hurricane loss cost output range data compiled in Form A-4, Hurricane Output Ranges, relative to the equivalent data compiled from the currently accepted hurricane model in the format shown in the file named "2021FormA5.xlsx."***

For the change in hurricane output range exhibit, provide the summary by:

- ***Statewide (overall percentage change),***
- ***By region, as defined in Figure 14 – North, Central and South, and***
- ***By county, as defined in Figure 15 – Coastal and Inland.***

Region	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Coastal	26.33	18.42	4.39	30.65	23.98	31.36	24.27	18.78
Inland	20.67	20.27	1.25	21.41	21.82	20.74	22.50	21.42
North	34.19	30.63	10.05	39.33	36.58	44.57	42.09	34.81
Central	22.28	22.50	2.31	30.21	30.05	29.28	31.78	24.72
South	21.78	16.91	4.42	24.41	21.90	27.19	22.64	17.58
Statewide	25.59	18.57	3.63	29.29	23.86	30.51	24.25	18.84

Table 35 - Percent change in $0 deductible hurricane output ranges

Region	Frame Owners	Masonry Owners	Manufactured Homes	Frame Renters	Masonry Renters	Frame Condo Unit	Masonry Condo Unit	Commercial Residential
Coastal	28.82	20.27	5.51	35.37	27.14	38.66	30.00	21.97
Inland	24.17	23.68	2.35	26.58	27.10	26.59	29.76	27.09
North	37.64	34.35	11.25	46.13	43.35	53.70	50.59	40.74
Central	25.33	25.84	3.54	37.25	36.63	38.37	40.34	30.41
South	23.73	18.50	5.44	27.53	24.63	33.55	28.01	20.47
Statewide	28.29	20.50	4.79	34.35	27.14	38.03	30.00	22.06

Table 36 - Percent change in specified deductible hurricane output ranges

C. ***Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include all tables in Form A-5, Percentage Change in Hurricane Output Ranges, in a submission appendix.***

A completed Form A-5 has been provided in Excel format with the file name "KCC21_FormA5_ 221104" and within this submission appendix.

D. ***Provide color-coded maps by county reflecting the percentage changes in the average hurricane loss costs with specified deductibles for frame owners, masonry owners, frame renters, masonry renters, frame condo unit owners, masonry condo unit owners, manufactured homes, and commercial residential from the hurricane output ranges from the currently accepted hurricane model.***

Counties with a negative percentage change (reduction in hurricane loss costs) should be indicated with shades of blue, counties with a positive percentage change (increase in hurricane loss costs) should be indicated with shades of red, and counties with no percentage change should be white. The larger the percentage change in the county, the more intense the color-shade.

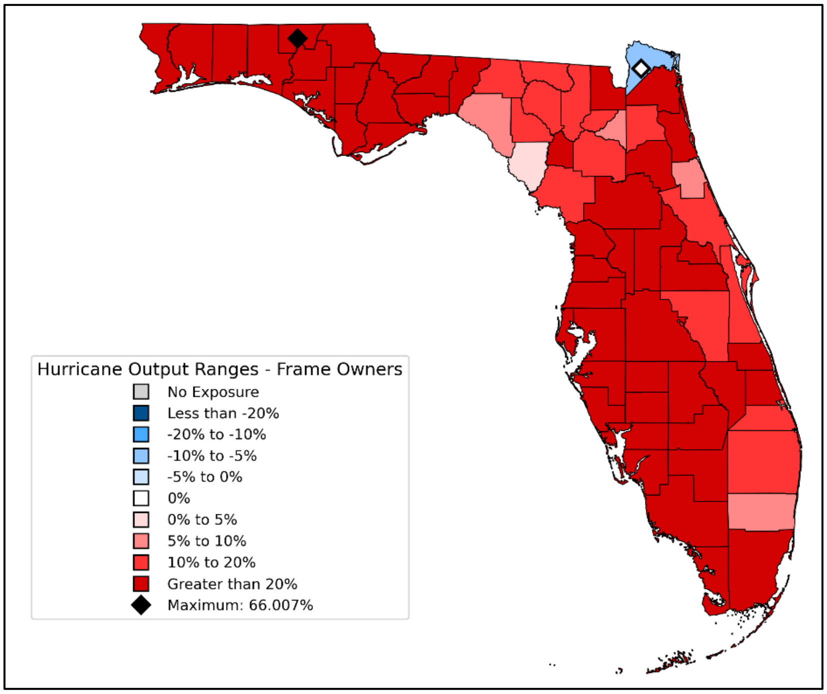


Figure 64 - Percentage change in hurricane output ranges for frame owners

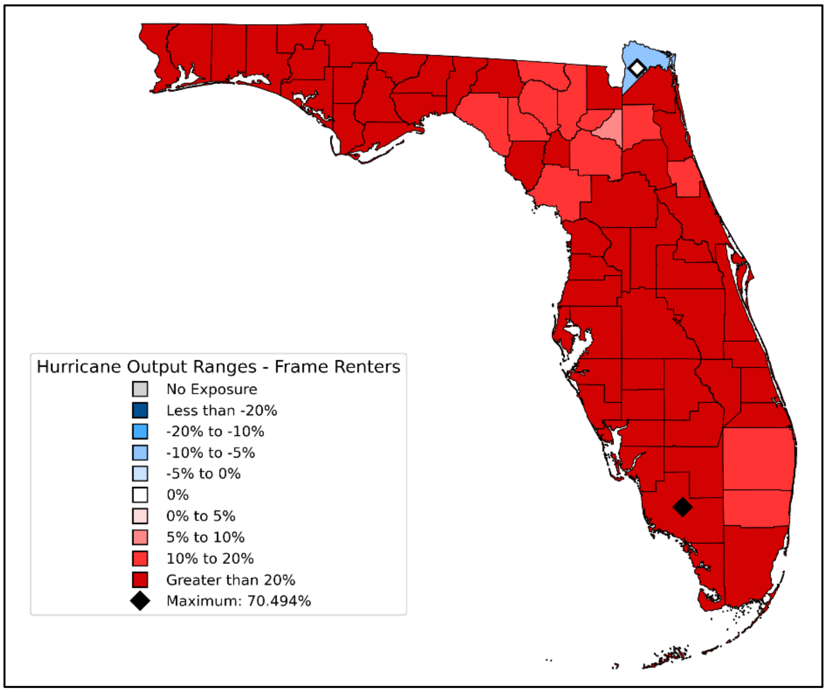


Figure 65 - Percentage change in hurricane output ranges for frame renters

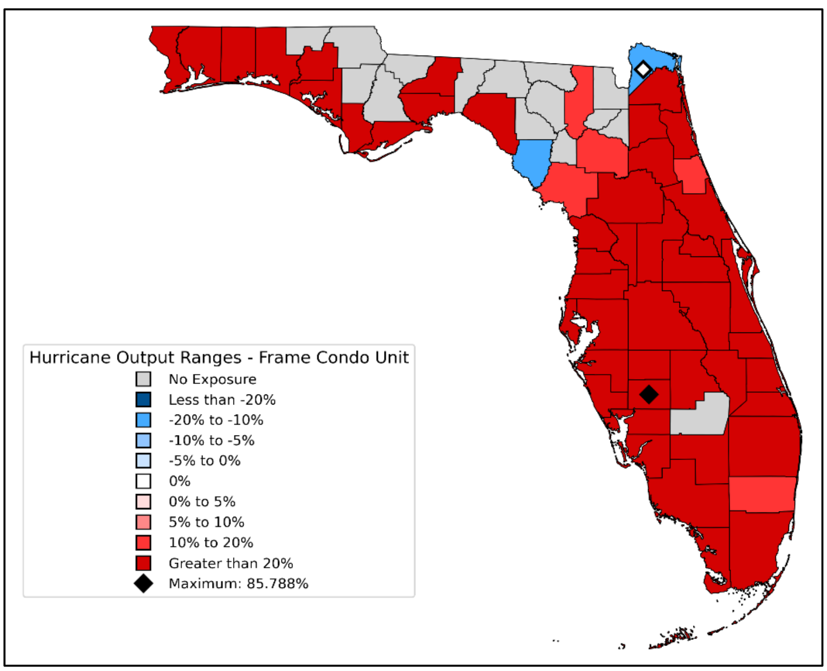


Figure 66 - Percentage change in hurricane output ranges for frame condo unit owners

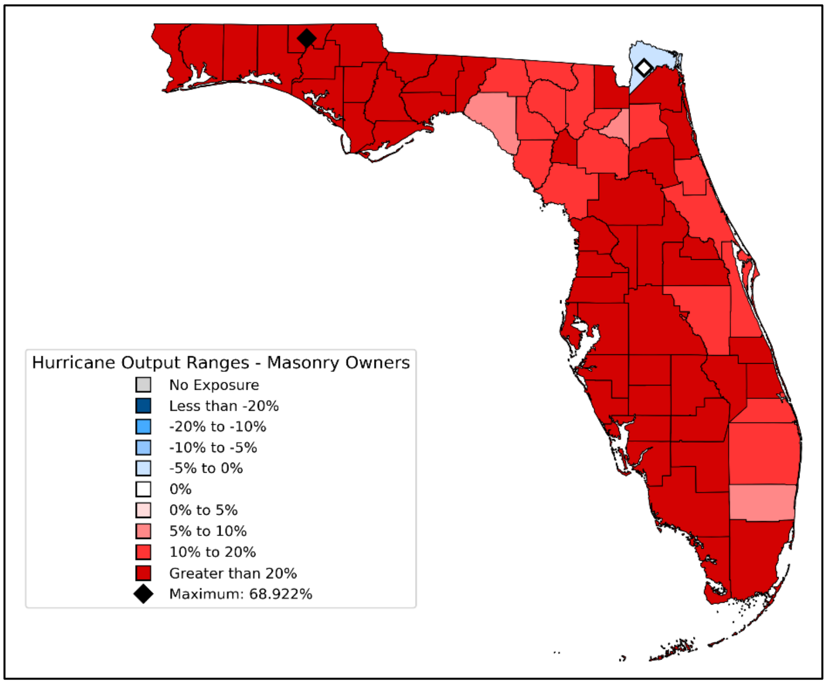


Figure 67 - Percentage change in hurricane output ranges for masonry owners

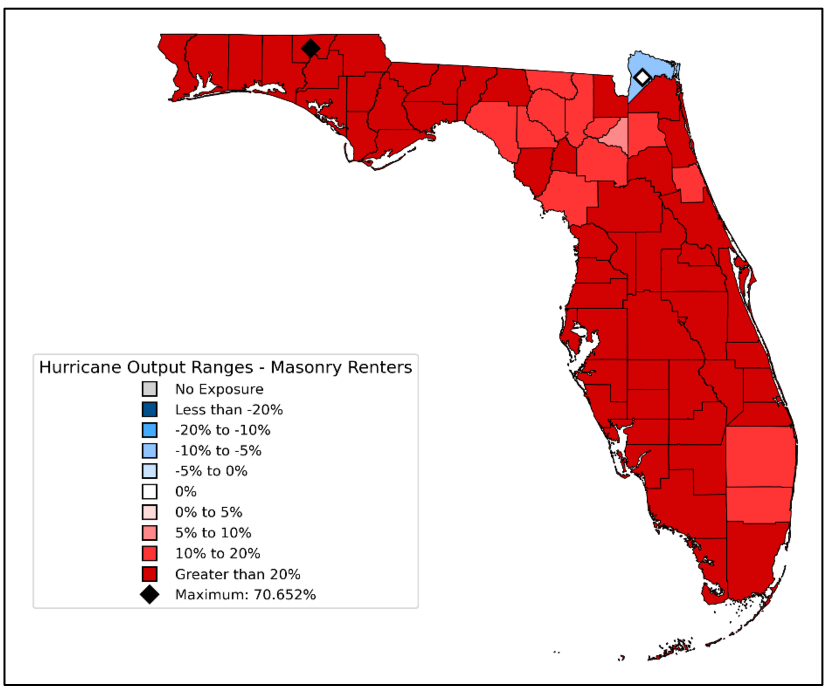


Figure 68 - Percentage change in hurricane output ranges for masonry renters

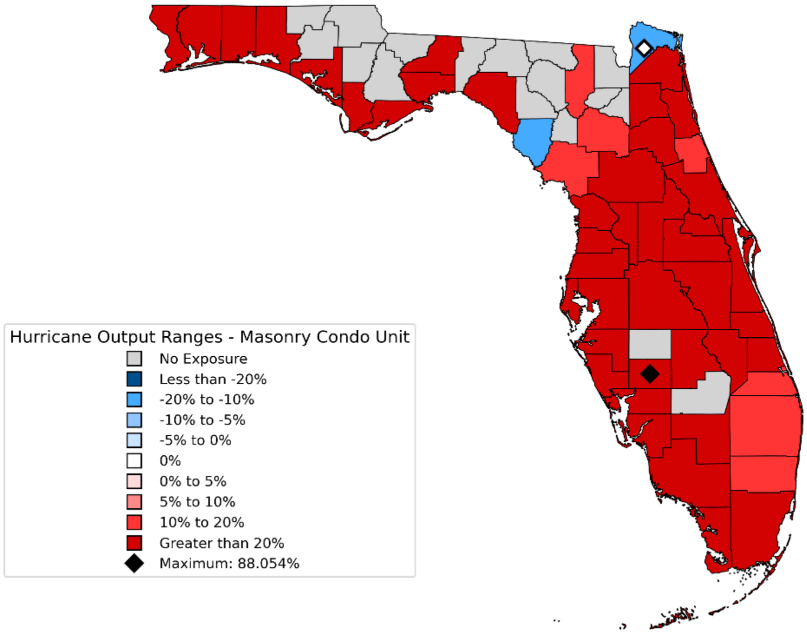


Figure 69 - Percentage change in hurricane output ranges for masonry condo unit owners

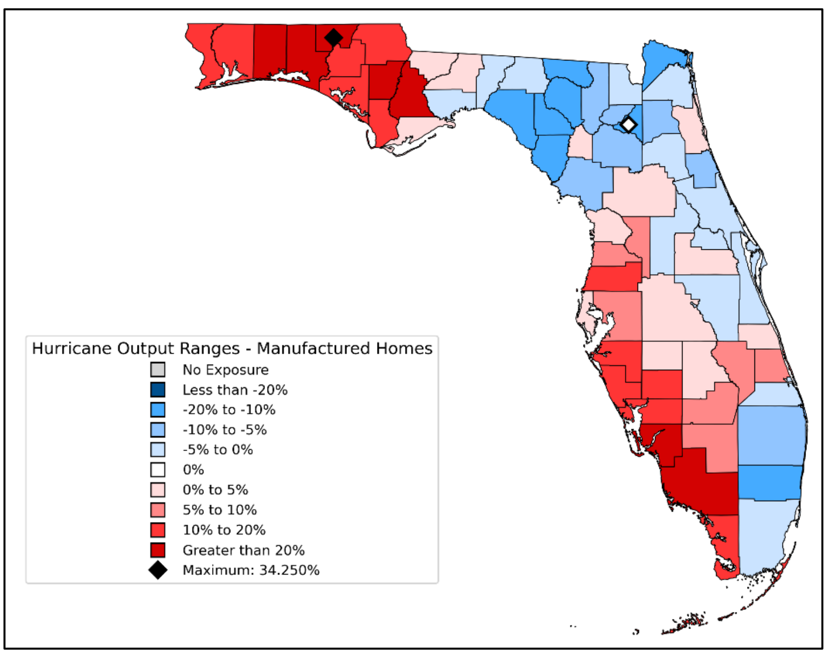


Figure 70 - Percentage change in hurricane output ranges for manufactured homes

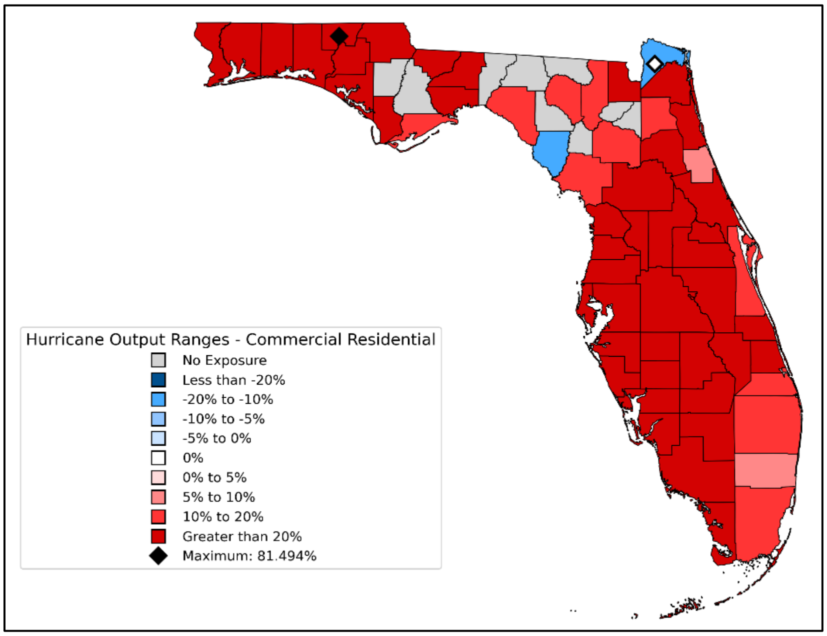


Figure 71 - Percentage change in hurricane output ranges for commercial residential

Form A-6: Logical Relationship to Hurricane Risk (Trade Secret Item)

Form A-6 is a trade secret and will be reviewed with the Professional Team during their onsite visit and presented during the closed portion of the Commission meeting.

Form A-7: Percentage Change in Logical Relationship to Hurricane Risk

A. ***One or more automated programs or scripts should be used to generate the exhibits in Form A- 7, Percentage Change in Logical Relationship to Hurricane Risk.***

The results in this form have been produced and arranged using an automated program that reads the losses generated by the KCC US Hurricane Reference Model.

B. ***Provide summaries of the percentage change in logical relationship to hurricane risk exhibits from the currently accepted hurricane model in the format shown in the file named "2021FormA7.xlsx."***

C. ***Create exposure sets for each exhibit by modeling all of the coverages from the appropriate Notional Set listed below at each of the locations in Location Grid B as described in the file "NotionalInput21.xlsx." Refer to the Notional Hurricane Policy Specifications provided in Form A-6, Logical Relationship to Hurricane Risk (Trade Secret Item), for additional modeling information.***

Exhibit	Notional Set
Deductible Sensitivity	Set 1
Policy Form Sensitivity	Set 2
Construction Sensitivity	Set 3
Coverage Sensitivity	Set 4
Year Built Sensitivity	Set 5
Building Strength Sensitivity	Set 6
Number of Stories Sensitivity	Set 7

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost					
		$0	$500	1%	2%	5%	10%
Frame Owners	Coastal	22.0%	22.6%	23.1%	24.0%	26.8%	31.2%
	Inland	23.4%	24.7%	25.7%	26.9%	31.6%	38.3%
	North	38.1%	39.4%	40.6%	42.0%	47.0%	53.3%
	Central	24.3%	25.4%	26.3%	27.5%	31.8%	38.1%
	South	19.7%	20.2%	20.7%	21.4%	24.0%	28.1%
	Statewide	22.1%	22.8%	23.4%	24.2%	27.1%	31.5%
Masonry Owners	Coastal	22.0%	22.6%	23.2%	24.0%	26.9%	31.3%
	Inland	23.2%	24.5%	25.6%	26.8%	31.5%	38.4%
	North	37.8%	39.2%	40.5%	41.8%	47.1%	53.6%
	Central	24.0%	25.2%	26.1%	27.4%	31.8%	38.1%
	South	19.7%	20.3%	20.7%	21.5%	24.1%	28.2%
	Statewide	22.1%	22.8%	23.4%	24.2%	27.2%	31.7%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost					
		$0	$500	1%	2%	5%	10%
Manufactured Homes	Coastal	0.7%	1.1%	1.1%	1.5%	2.8%	5.2%
	Inland	0.4%	1.0%	1.0%	1.4%	2.9%	5.5%
	North	13.3%	14.0%	14.0%	14.4%	16.0%	18.0%
	Central	2.1%	2.8%	2.8%	3.3%	5.2%	8.3%
	South	-1.1%	-0.7%	-0.7%	-0.4%	0.9%	3.3%
	Statewide	0.7%	1.1%	1.1%	1.5%	2.8%	5.2%
Frame Renters	Coastal	7.6%	8.2%	8.2%	8.4%	9.5%	10.5%
	Inland	8.4%	10.1%	10.1%	10.5%	13.5%	13.6%
	North	21.9%	23.9%	23.9%	24.5%	27.6%	28.7%
	Central	10.4%	12.0%	12.0%	12.5%	15.0%	16.0%
	South	5.5%	5.9%	5.9%	6.1%	7.0%	8.1%
	Statewide	7.6%	8.3%	8.3%	8.5%	9.6%	10.6%
Masonry Renters	Coastal	7.5%	8.1%	8.1%	8.3%	9.4%	10.3%
	Inland	7.9%	9.7%	9.7%	10.1%	13.2%	13.2%
	North	21.4%	23.5%	23.5%	24.1%	27.5%	28.5%
	Central	10.0%	11.7%	11.7%	12.2%	14.8%	15.7%
	South	5.5%	5.9%	5.9%	6.1%	7.0%	7.9%
	Statewide	7.5%	8.2%	8.2%	8.4%	9.6%	10.4%
Frame Condo Unit	Coastal	7.5%	8.8%	8.8%	9.8%	11.4%	13.1%
	Inland	8.5%	10.7%	10.7%	12.1%	15.0%	17.2%
	North	22.3%	24.8%	24.8%	26.2%	28.5%	30.5%
	Central	10.3%	12.7%	12.7%	14.2%	16.8%	19.1%
	South	5.5%	6.7%	6.7%	7.6%	9.1%	10.8%
	Statewide	7.6%	8.9%	8.9%	9.9%	11.5%	13.2%
Masonry Condo Unit	Coastal	7.5%	8.8%	8.8%	9.7%	11.4%	13.0%
	Inland	8.1%	10.3%	10.3%	11.6%	14.5%	16.7%
	North	21.9%	24.5%	24.5%	25.9%	28.3%	30.3%
	Central	9.9%	12.3%	12.3%	13.9%	16.5%	18.7%
	South	5.5%	6.6%	6.6%	7.6%	9.1%	10.7%
	Statewide	7.5%	8.9%	8.9%	9.8%	11.5%	13.1%

Table 37 - Percentage change in logical relationships to risk by construction/policy for residential – deductibles

Construction / Policy	Region	Percent Change in Loss Cost					
		$0	2%	3%	5%	10%	
Commercial Residential	Coastal	6.5%	7.5%	8.0%	9.2%	11.6%	
	Inland	6.6%	8.6%	9.5%	12.6%	16.9%	
	North	19.1%	21.9%	23.0%	26.4%	30.6%	
	Central	7.9%	10.2%	11.1%	13.9%	18.2%	
	South	4.7%	5.4%	5.8%	6.8%	9.0%	
	Statewide	6.5%	7.6%	8.1%	9.4%	11.9%	

Table 38 - Percentage change in logical relationships to risk by construction/policy for commercial residential – deductibles

Policy Form	Region	Percentage Change in Hurricane Loss Cost		
		Masonry	Frame	Manufactured Homes
Owners	Coastal	22.0%	22.0%	0.7%
	Inland	23.2%	23.4%	0.4%
	North	37.8%	38.1%	13.3%
	Central	24.0%	24.3%	2.1%
	South	19.7%	19.7%	-1.1%
	Statewide	22.1%	22.1%	0.7%
Renters	Coastal	7.5%	7.6%	
	Inland	7.9%	8.4%	
	North	21.4%	21.9%	
	Central	10.0%	10.4%	
	South	5.5%	5.5%	
	Statewide	7.5%	7.6%	
Condo Unit	Coastal	7.5%	7.5%	
	Inland	8.1%	8.5%	
	North	21.9%	22.3%	
	Central	9.9%	10.3%	
	South	5.5%	5.5%	
	Statewide	7.5%	7.6%	

Table 39 - Percentage change in logical relationships to risk by for residential - policy form

Policy Form	Region	Percentage Change in Hurricane Loss Cost		
		Concrete		
Commercial Residential	Coastal	6.5%		
	Inland	6.6%		
	North	19.1%		
	Central	7.9%		
	South	4.7%		
	Statewide	6.5%		

Table 40 - Percentage change in logical relationships to risk for commercial residential - policy form

Region	Percentage Change in Hurricane Loss Cost		
	Frame Owners	Masonry Owners	Manufactured Homes
Coastal	22.0%	22.0%	0.7%
Inland	23.4%	23.2%	0.4%
North	38.1%	37.8%	13.3%
Central	24.3%	24.0%	2.1%
South	19.7%	19.7%	-1.1%
Statewide	22.1%	22.1%	0.7%

Table 41 - Percentage change in logical relationships to risk– construction

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost			
		Coverage A	Coverage B	Coverage C	Coverage D
Frame Owners	Coastal	21.8%	21.8%	23.3%	23.8%
	Inland	23.3%	23.3%	24.0%	27.5%
	North	37.8%	37.8%	40.0%	43.3%
	Central	24.0%	24.0%	26.6%	29.2%
	South	19.5%	19.5%	20.9%	21.1%
	Statewide	21.9%	21.9%	23.3%	24.0%
Masonry Owners	Coastal	21.8%	21.8%	23.3%	23.8%
	Inland	23.1%	23.1%	23.5%	27.6%
	North	37.5%	37.5%	39.4%	43.1%
	Central	23.8%	23.8%	26.1%	29.1%
	South	19.6%	19.6%	21.0%	21.2%
	Statewide	21.9%	21.9%	23.3%	24.0%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost			
		Coverage A	Coverage B	Coverage C	Coverage D
Manufactured Homes	Coastal	0.5%	0.5%	1.5%	0.9%
	Inland	0.0%	0.0%	3.8%	3.3%
	North	12.8%	12.8%	15.9%	15.6%
	Central	1.5%	1.5%	5.7%	5.2%
	South	-1.2%	-1.2%	-0.7%	-1.2%
	Statewide	0.5%	0.5%	1.6%	1.0%
Frame Renters	Coastal	NA	NA	7.4%	7.9%
	Inland	NA	NA	7.8%	10.1%
	North	NA	NA	21.2%	24.0%
	Central	NA	NA	9.9%	11.9%
	South	NA	NA	5.4%	5.6%
	Statewide	NA	NA	7.5%	8.0%
Masonry Renters	Coastal	NA	NA	7.3%	7.8%
	Inland	NA	NA	7.3%	9.9%
	North	NA	NA	20.7%	23.7%
	Central	NA	NA	9.4%	11.7%
	South	NA	NA	5.4%	5.6%
	Statewide	NA	NA	7.3%	8.0%
Frame Condo Unit	Coastal	6.7%	NA	7.7%	8.2%
	Inland	7.9%	NA	8.1%	11.5%
	North	20.8%	NA	22.2%	25.4%
	Central	8.7%	NA	10.4%	13.0%
	South	4.8%	NA	5.8%	5.9%
	Statewide	6.8%	NA	7.8%	8.4%
Masonry Condo Unit	Coastal	6.7%	NA	7.7%	8.2%
	Inland	7.7%	NA	7.6%	11.2%
	North	20.6%	NA	21.7%	25.2%
	Central	8.5%	NA	9.9%	12.7%
	South	4.8%	NA	5.8%	5.9%
	Statewide	6.8%	NA	7.7%	8.3%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost			
		Coverage A	Coverage B	Coverage C	Coverage D
Commercial Residential	Coastal	6.5%	NA	7.1%	7.6%
	Inland	6.5%	NA	6.2%	9.9%
	North	19.0%	NA	19.1%	23.5%
	Central	7.8%	NA	8.4%	11.8%
	South	4.6%	NA	5.4%	5.2%
	Statewide	6.5%	NA	7.0%	7.7%

Table 42 - Percentage change in logical relationship to risk – coverage

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost				
		Year Built 1980	Year Built 1989	Year Built 1998	Year Built 2004	Year Built 2019
Frame Owners	Coastal	22.0%	22.0%	22.5%	22.9%	4.3%
	Inland	23.4%	23.4%	23.7%	24.0%	1.3%
	North	38.1%	38.1%	38.5%	38.6%	15.6%
	Central	24.3%	24.3%	24.6%	25.2%	4.5%
	South	19.7%	19.7%	20.2%	20.6%	2.7%
	Statewide	22.1%	22.1%	22.6%	23.0%	4.1%
Masonry Owners	Coastal	22.0%	22.0%	22.4%	22.9%	4.4%
	Inland	23.2%	23.2%	23.6%	23.8%	1.2%
	North	37.8%	37.8%	38.1%	38.3%	15.5%
	Central	24.0%	24.0%	24.4%	25.0%	4.4%
	South	19.7%	19.7%	20.2%	20.6%	2.8%
	Statewide	22.1%	22.1%	22.6%	22.9%	4.1%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost				
		Year Built 1972	Year Built 1989	Year Built 1992	Year Built 2004	Year Built 2019
Manufactured Homes	Coastal	0.7%	-5.6%	0.7%	3.6%	0.6%
	Inland	0.4%	-6.2%	0.4%	3.6%	-1.2%
	North	13.3%	6.0%	13.3%	16.6%	12.4%
	Central	2.1%	-4.3%	2.1%	5.1%	1.4%
	South	-1.1%	-7.3%	-1.1%	1.7%	-1.1%
	Statewide	0.7%	-5.7%	0.7%	3.6%	0.4%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost				
		Year Built 1980	Year Built 1989	Year Built 1998	Year Built 2004	Year Built 2019
Frame Renters	Coastal	7.6%	7.6%	7.8%	7.8%	-10.0%
	Inland	8.4%	8.4%	7.8%	7.3%	-11.6%
	North	21.9%	21.9%	21.4%	21.1%	0.1%
	Central	10.4%	10.4%	9.8%	9.4%	-9.4%
	South	5.5%	5.5%	5.9%	6.0%	-11.4%
	Statewide	7.6%	7.6%	7.8%	7.8%	-10.1%
Masonry Renters	Coastal	7.5%	7.5%	7.7%	7.8%	-10.2%
	Inland	7.9%	7.9%	7.4%	7.0%	-12.1%
	North	21.4%	21.4%	20.9%	20.7%	-0.5%
	Central	10.0%	10.0%	9.3%	8.9%	-10.0%
	South	5.5%	5.5%	5.8%	6.0%	-11.4%
	Statewide	7.5%	7.5%	7.7%	7.7%	-10.4%
Frame Condo Unit	Coastal	7.5%	7.5%	7.8%	8.0%	-7.8%
	Inland	8.5%	8.5%	8.2%	8.2%	-11.3%
	North	22.3%	22.3%	22.2%	22.2%	2.5%
	Central	10.3%	10.3%	10.0%	10.0%	-7.7%
	South	5.5%	5.5%	5.9%	6.1%	-9.1%
	Statewide	7.6%	7.6%	7.8%	8.1%	-8.0%
Masonry Condo Unit	Coastal	7.5%	7.5%	7.8%	7.9%	-8.1%
	Inland	8.1%	8.1%	7.9%	7.9%	-11.2%
	North	21.9%	21.9%	21.9%	21.9%	2.1%
	Central	9.9%	9.9%	9.7%	9.7%	-8.0%
	South	5.5%	5.5%	5.9%	6.1%	-9.4%
	Statewide	7.5%	7.5%	7.8%	7.9%	-8.4%
Commercial Residential	Coastal	6.5%	6.5%	6.8%	7.1%	-5.5%
	Inland	6.6%	6.6%	6.8%	7.1%	-8.3%
	North	19.1%	19.1%	19.5%	19.8%	4.5%
	Central	7.9%	7.9%	8.2%	8.6%	-5.4%
	South	4.7%	4.7%	4.9%	5.1%	-7.0%
	Statewide	6.5%	6.5%	6.8%	7.1%	-5.8%

Table 43 - Percentage change in logical relationships to risk – year built

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost		
		Weak	Medium	Strong
Frame Owners	Coastal	21.7%	22.5%	23.2%
	Inland	23.7%	23.7%	25.3%
	North	38.2%	38.5%	40.7%
	Central	24.1%	24.6%	26.6%
	South	19.3%	20.2%	20.8%
	Statewide	21.9%	22.6%	23.4%
Masonry Owners	Coastal	21.7%	22.4%	23.2%
	Inland	23.4%	23.6%	25.1%
	North	38.0%	38.1%	40.5%
	Central	23.9%	24.4%	26.4%
	South	19.4%	20.2%	20.8%
	Statewide	21.9%	22.6%	23.3%
Manufactured Homes	Coastal	-5.6%	0.7%	3.9%
	Inland	-6.1%	0.4%	4.2%
	North	6.0%	13.3%	17.4%
	Central	-4.3%	2.1%	5.9%
	South	-7.3%	-1.1%	1.9%
	Statewide	-5.7%	0.7%	3.9%
Frame Renters	Coastal	7.4%	7.8%	8.3%
	Inland	8.7%	7.8%	8.9%
	North	22.0%	21.4%	23.5%
	Central	10.4%	9.8%	11.1%
	South	5.3%	5.9%	6.3%
	Statewide	7.5%	7.8%	8.3%
Masonry Renters	Coastal	7.3%	7.7%	8.2%
	Inland	8.3%	7.4%	8.5%
	North	21.6%	20.9%	23.2%
	Central	10.0%	9.3%	10.7%
	South	5.2%	5.8%	6.3%
	Statewide	7.4%	7.7%	8.3%

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost		
		Weak	Medium	Strong
Frame Condo Unit	Coastal	7.4%	7.8%	8.3%
	Inland	8.7%	8.2%	9.3%
	North	22.3%	22.2%	23.8%
	Central	10.2%	10.0%	11.2%
	South	5.3%	5.9%	6.4%
	Statewide	7.5%	7.8%	8.4%
Masonry Condo Unit	Coastal	7.3%	7.8%	8.3%
	Inland	8.4%	7.9%	9.0%
	North	22.0%	21.9%	23.6%
	Central	9.9%	9.7%	10.9%
	South	5.3%	5.9%	6.3%
	Statewide	7.4%	7.8%	8.3%
Commercial Residential	Coastal	6.5%	6.8%	6.9%
	Inland	6.8%	6.8%	6.3%
	North	19.3%	19.5%	19.3%
	Central	8.2%	8.2%	8.0%
	South	4.6%	4.9%	5.0%
	Statewide	6.6%	6.8%	6.8%

Table 44 - Percentage change in logical relationships to risk – building strength

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost		
		1 Story	2 Story	
Frame Owners	Coastal	22.0%	21.8%	
	Inland	23.4%	23.3%	
	North	38.1%	37.8%	
	Central	24.3%	24.0%	
	South	19.7%	19.6%	
	Statewide	22.1%	22.0%	
Masonry Owners	Coastal	22.0%	21.8%	
	Inland	23.2%	23.1%	
	North	37.8%	37.5%	
	Central	24.0%	23.8%	
	South	19.7%	19.6%	

Construction / Policy	Region	Percentage Change in Hurricane Loss Cost		
		1 Story	2 Story	
	Statewide	22.1%	21.9%	
Frame Renters	Coastal	7.6%	7.6%	
	Inland	8.4%	8.4%	
	North	21.9%	21.9%	
	Central	10.4%	10.4%	
	South	5.5%	5.5%	
	Statewide	7.6%	7.6%	
Masonry Renters	Coastal	7.5%	7.5%	
	Inland	7.9%	8.0%	
	North	21.4%	21.4%	
	Central	10.0%	10.0%	
	South	5.5%	5.4%	
	Statewide	7.5%	7.5%	
Construction / Policy	**Region**	**Percentage Change in Hurricane Loss Cost**		
		5 Story	**10 Story**	**20 Story**
Commercial Residential	Coastal	6.4%	6.5%	6.5%
	Inland	6.4%	6.5%	6.6%
	North	18.8%	18.9%	19.1%
	Central	7.6%	7.8%	7.9%
	South	4.6%	4.6%	4.7%
	Statewide	6.4%	6.5%	6.5%

Table 45 - Percentage change in logical relationship to risk - number of stories

D. Hurricane models are to treat points in Location Grid B as coordinates that would result from a geocoding process. Hurricane models should treat points by simulating hurricane loss at exact location or by using the nearest modeled parcel/street/cell in the hurricane model. Provide the results statewide (overall percentage change) and by the regions defined in Form A-5, Percentage Change in Hurricane Output Ranges.

Hurricane models do treat the points in "Location Grid B" as coordinates that would result from a geocoding process. Additional information on the State, County, and ZIP Code which define the correct sub-region vulnerability functions have been added.

E. Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include all exhibits in Form A-7, Percentage Change in Logical Relationships to Hurricane Risk, in a submission appendix.

A completed Form A-7 has been provided in Excel format with the file name "KCC21_FormA7_221104" and within this submission appendix.

Form A-8: Hurricane Probable Maximum Loss for Florida

A. One or more automated programs or scripts should be used to generate and arrange the data in Form A-8, Hurricane Probable Maximum Loss for Florida.

The results in this form have been produced and arranged using an automated program that reads the losses generated by the KCC US Hurricane Reference Model.

B. Provide a detailed explanation of how the Expected Annual Hurricane Losses and Return Periods are calculated.

To calculate the expected hurricane losses in Form A-8, KCC first computes the total hurricane loss and number of hurricanes that fall within each given range. The average hurricane loss column is then calculated by dividing the total hurricane loss by the number of hurricanes for each range. The expected annual hurricane loss for each range is computed by dividing the total hurricane loss of that range by the number of years in the event catalog (100,000 years).

The return period is computed as the reciprocal of the exceedance probability of the Average Hurricane Loss in each range with the exceedance probability calculated by the methodology described in Disclosure A-4.1.

C. Complete Part A showing the personal and commercial residential hurricane probable maximum loss for Florida. For the Expected Annual Hurricane Losses column, provide personal and commercial residential, zero deductible statewide hurricane loss costs based on the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "hlpm2017c.zip."

In the column, Return Period (Years), provide the return period associated with the average hurricane loss within the ranges indicated on a cumulative basis.

For example, if the average hurricane loss is $4,705 million for the range $4,501-$5,000 million, provide the return period associated with a hurricane loss that is $4,705 million or greater.

For each hurricane loss range in millions ($1,001-$1,500, $1,501-$2,000, $2,001-$2,500) the average hurricane loss within that range should be identified and then the return period associated with that hurricane loss calculated. The return period is then the reciprocal of the probability of the hurricane loss equaling or exceeding this average hurricane loss size.

The probability of equaling or exceeding the average of each range should be smaller as the ranges increase (and the average hurricane losses within the ranges increase). Therefore, the return period associated with each range and average hurricane loss within that range should be larger as the ranges increase. Return periods should be based on cumulative probabilities.

A return period for an average hurricane loss of $4,705 million within the $4,501-$5,000 million range should be lower than the return period for an average hurricane loss of $5,455 million associated with a $5,001-$6,000 million range.

Part A – Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida

HURRICANE LOSS RANGE (MILLIONS)			TOTAL HURRICANE LOSS	AVERAGE HURRICANE LOSS (MILLIONS)	NUMBER OF HURRICANES	EXPECTED ANNUAL HURRICANE LOSSES*	RETURN PERIOD (YEARS)
$>0	to	$500	5,104,255	127	40,279	51	2.2
$501	to	$1,000	7,193,065	733	9,808	72	2.7
$1,001	to	$1,500	8,068,088	1,237	6,524	81	3.1
$1,501	to	$2,000	7,924,728	1,736	4,566	79	3.4
$2,001	to	$2,500	7,390,337	2,239	3,300	74	3.7
$2,501	to	$3,000	7,211,775	2,744	2,628	72	4.0
$3,001	to	$3,500	6,748,011	3,249	2,077	67	4.3
$3,501	to	$4,000	6,984,165	3,743	1,866	70	4.5
$4,001	to	$4,500	6,708,509	4,246	1,580	67	4.8
$4,501	to	$5,000	6,451,490	4,747	1,359	65	5.0
$5,001	to	$6,000	11,843,921	5,478	2,162	118	5.4
$6,001	to	$7,000	11,257,222	6,492	1,734	113	5.9
$7,001	to	$8,000	10,817,562	7,476	1,447	108	6.4
$8,001	to	$9,000	9,796,045	8,467	1,157	98	6.8
$9,001	to	$10,000	9,685,230	9,495	1020	97	7.3
$10,001	to	$11,000	8,551,558	10,480	816	86	7.8
$11,001	to	$12,000	8,735,282	11,509	759	87	8.3
$12,001	to	$13,000	9,265,321	12,504	741	93	8.7
$13,001	to	$14,000	8,578,450	13,488	636	86	9.3
$14,001	to	$15,000	7,996,346	14,486	552	80	9.8
$15,001	to	$16,000	7,562,321	15,497	488	76	10.3
$16,001	to	$17,000	7,466,599	16,519	452	75	10.8
$17,001	to	$18,000	8,099,995	17,495	463	81	11.3
$18,001	to	$19,000	7,159,521	18,500	387	72	11.8
$19,001	to	$20,000	7,041,880	19,507	361	70	12.4
$20,001	to	$21,000	7,378,639	20,496	360	74	12.9

HURRICANE LOSS RANGE (MILLIONS)			TOTAL HURRICANE LOSS	AVERAGE HURRICANE LOSS (MILLIONS)	NUMBER OF HURRICANES	EXPECTED ANNUAL HURRICANE LOSSES*	RETURN PERIOD (YEARS)
$21,001	to	$22,000	6,618,331	21,488	308	66	13.4
$22,001	to	$23,000	6,737,898	22,535	299	67	14.1
$23,001	to	$24,000	6,541,374	23,530	278	65	14.7
$24,001	to	$25,000	7,283,900	24,525	297	73	15.3
$25,001	to	$26,000	6,092,120	25,490	239	61	15.9
$26,001	to	$27,000	6,224,148	26,486	235	62	16.5
$27,001	to	$28,000	5,803,321	27,504	211	58	17.2
$28,001	to	$29,000	6,784,401	28,506	238	68	17.8
$29,001	to	$30,000	6,191,614	29,484	210	62	18.5
$30,001	to	$35,000	29,645,938	32,471	913	296	20.7
$35,001	to	$40,000	27,017,632	37,369	723	270	24.9
$40,001	to	$45,000	22,814,436	42,485	537	228	29.7
$45,001	to	$50,000	22,823,912	47,451	481	228	35.4
$50,001	to	$55,000	18,673,539	52,454	356	187	42.2
$55,001	to	$60,000	16,600,101	57,440	289	166	49.0
$60,001	to	$65,000	16,992,280	62,472	272	170	58.5
$65,001	to	$70,000	14,989,149	67,216	223	150	69.6
$70,001	to	$75,000	11,810,377	72,456	163	118	83.1
$75,001	to	$80,000	13,293,638	77,289	172	133	99.2
$80,001	to	$90,000	16,111,870	84,799	190	161	127.9
$90,001	to	$100,000	14,798,741	94,864	156	148	176.2
$100,001	to	$Maximum	41,184,103	124,800	330	412	495.1
Total			**536,053,136**	**5,664**	**94,642**	**5,361**	

Table 46 - Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida

*Personal and commercial residential zero deductible statewide hurricane loss using the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data found in the file named "*hlpm2017c.zip*".

Part B – Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida – Annual Aggregate

Return Period (Years)	Expected Hurricane Loss Level	10% Loss Level	90% Loss Level
Top Event	244,468,017,519	241,048,388,344	247,887,679,431
1,000	144,556,941,076	142,048,852,620	147,064,876,277
500	125,636,863,863	123,432,075,895	127,841,456,243
250	106,265,682,259	103,960,632,222	108,570,608,233
100	77,484,232,263	75,783,643,262	79,185,953,097
50	57,989,647,108	56,379,847,769	59,599,596,727
20	31,499,010,201	30,781,308,737	32,216,082,978
10	14,946,703,854	14,404,661,526	15,488,993,303
5	4,690,519,343	4,438,075,497	4,942,987,163

Table 47 - Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida – Annual Aggregate

Part C – Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida – Annual Occurrence

Return Period (Years)	Expected Hurricane Loss Level	10% Loss Level	90% Loss Level
Top Event	244,468,017,519	241,048,388,344	247,887,679,431
1,000	130,101,925,104	127,970,563,533	132,233,679,553
500	113,915,074,156	111,945,919,300	115,884,340,828
250	95,457,308,189	93,344,111,104	97,570,537,621
100	70,228,454,857	68,728,632,787	71,728,259,525
50	51,582,261,250	50,314,860,949	52,849,569,999
20	28,137,887,021	27,251,847,207	29,023,911,107
10	13,009,237,154	12,534,302,045	13,484,182,014
5	4,032,372,756	3,823,305,690	4,241,353,409

Table 48 - Personal and Commercial Residential Hurricane Probable Maximum Loss for Florida – Annual Occurrence

D. ***Provide a graphical comparison of the current hurricane model Residential Return Periods hurricane loss curve to the currently accepted hurricane model Residential Return Periods hurricane loss curve. Residential Return Period (Years) should be shown on the y-axis on a log- 10 scale with Hurricane Losses***

in Billions shown on the x-axis. The legend should indicate the corresponding hurricane model with a solid line representing the current year and a dotted line representing the currently accepted hurricane model.

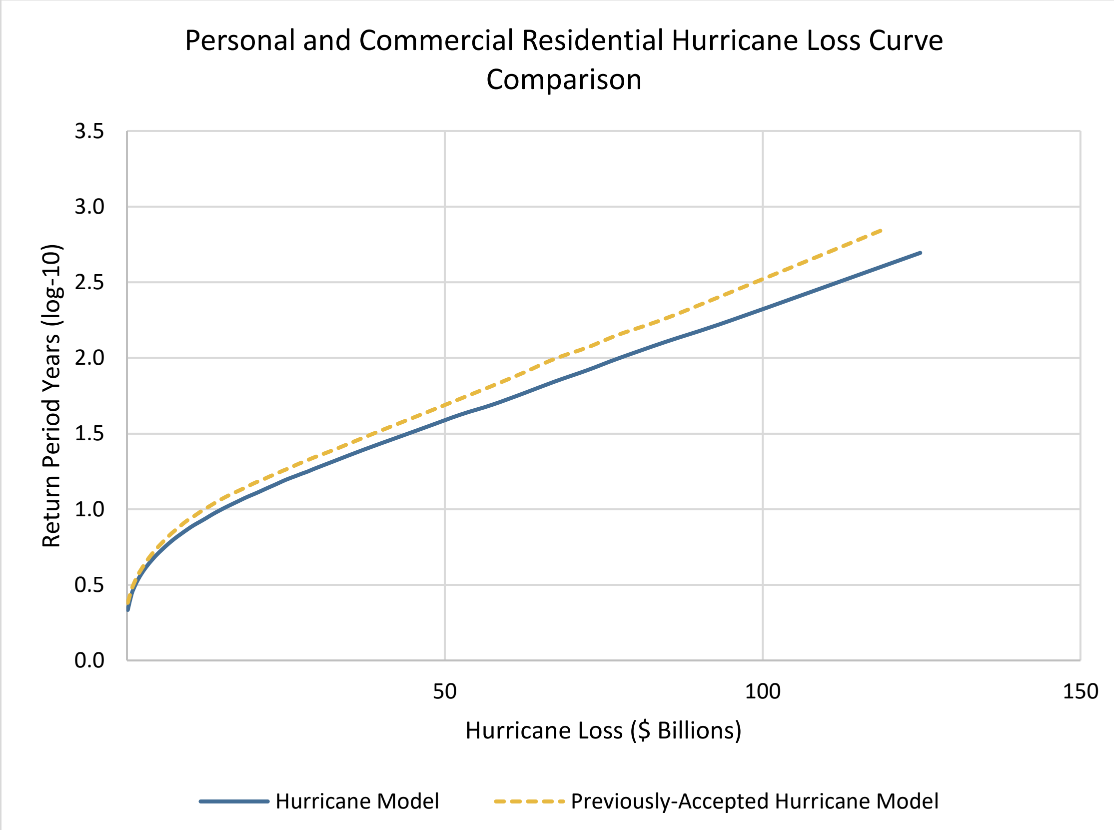


Figure 72 - Personal and commercial residential hurricane loss curve comparison

E. Provide the expected hurricane loss and 10% (lower bound) and 90% (upper bound) hurricane loss levels for each of the Personal and Commercial Residential Return Periods given in Part B, Annual Aggregate, and Part C, Annual Occurrence. Describe how the uncertainty in hurricane vulnerability functions has been propagated to the uncertainty in portfolio loss and how it relates to the 10% and 90% hurricane loss levels.

As explained in the response to Disclosure G-1.2, the hurricane vulnerability functions include empirical distributions that consider the full range of damage levels (the secondary uncertainty) that can occur around the MDR. This secondary uncertainty is always considered in loss calculations.

To calculate the uncertainty intervals for an event, the expected value and variance in loss experienced at each location (as defined by the location's secondary uncertainty distribution) within the event footprint is aggregated to determine the event's expected loss and variance. The 10% (lower bound) and 90% (upper bound) hurricane loss levels are estimated from each event's expected loss and variance using properties of sums of random variables and Chebyshev's theorem.

F. If additional assumptions are necessary to complete this form, provide the rationale for the assumptions as well as a detailed description of how they are included.

No additional assumptions were made to complete this form.

G. Provide this form in Excel format. The file name should include the abbreviated name of the modeling organization, the hurricane standards year, and the form name. Also include Form A-8, Hurricane Probable Maximum Loss for Florida, in a submission appendix.

A completed Form A-8 has been provided in Excel format with the file name "KCC21_FormA8_ 221104" and within this submission appendix.

Appendix F: Model Evaluation

External Review of the KCC US Hurricane Reference Model Version 4.0 Vulnerability Module

Western Engineering

Civil & Environmental Engineering

November 4, 2022

Glen Daraskevich, SVP
Karen Clark & Company
116 Huntington Avenue
Boston, MA 02116

Cover letter

Upon Karen Clark & Company's (KCC) request for an independent peer review, I reviewed KCC's US Hurricane Reference Model -Version 4.0 Vulnerability Module and KCC's Vulnerability Hurricane Standards submission to the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM). The review was based on materials provided by KCC and a presentation and Q&A session with KCC's vulnerability experts. In support of my opinion that KCC's Vulnerability Module complies with the 2021 FCHLPM Vulnerability Hurricane Standards, I am attaching my review report and a copy of my curriculum vitae for inclusion with your submission to the FCHLPM.

Sincerely,

Girma Bitsuamlak, PhD PEng F CSCE
Professor, Civil and Environmental Engineering
Director WindEEE Research Faciltites (The Dome + BLWTL + 3LP)
Site leader at SHARCNET
ACEB Room#4478 - London, ON, Canada
gbitsuam@uwo.ca; +1519 6612111 x 88028
Western University
www.windeee.ca www.bitsuamlak.com

Western University Department of Civil and environmental Engineering, Spencer Engineering Building, Rm. 3005
London, ON, Canada N6A 5B9 t. 519.661.2139 f. 519.661.3779 www.eng.uwo.ca/civil/

KCC Letter of Review

General:

The 2021 KCC Vulnerability Hurricane Standards submission to FCHLPM has been reviewed. The following sections give the reviewer's opinions.

The scope of the review:

My review has been limited to (1) the 2021 Vulnerability Hurricane Standards requirements of FCHLPM, (2) the disclosures and forms completed by KCC in compliance with the 2021 Vulnerability Hurricane Standards (V-1 - V-4) including forms V-1 through V-5 of FCHLPM, (2) five supporting documents used as primary sources by KCC for its hurricane vulnerability functions development and submitted to me, (3) an online presentation by KCC vulnerability experts and (4) relevant wind load and vulnerability models available to me. I haven't looked into detailed calculations implemented in KCC's model. My review is the vulnerability module outlined in the 2021 Vulnerability Standards (V-1 - V-4) of FCHLPM. The review does not cover the contents of submittals to comply with the 2021 metrological, statistical, and actuarial standards of FCHLPM. The reviewer's opinion is limited to the contents of documents made available to the reviewer, the results presented by KCC's vulnerability experts, and the reviewer's prior expertise in the field. The reviewer hasn't checked the implemented code and calculations adopted for the wind vulnerability module.

KCC's methods to develop wind vulnerability models

KCC follows state-of-the-art- engineering methods to develop and update its wind vulnerability module. KCC adopts component-based reliability analysis to derive its reference wind vulnerability functions and developed variates based on sound engineering judgment and detailed analysis of insured claims. The building hurricane vulnerability functions, the contents hurricane vulnerability functions, the time element hurricane vulnerability functions, and their modifications for the impact of hurricane mitigation measures and secondary characteristics meet the 2021 Vulnerability Hurricane Standards of FCHLPM. Since the previously accepted hurricane model, the procedure used to derive vulnerability functions has not changed. However, KCC addressed three updates on the building vulnerability component of its hurricane model.

Modifications to the currently accepted vulnerability module

Since the previously accepted KCC hurricane model, the following three vulnerability updates are included in the revised version.

I. modified vulnerability functions for site-built buildings to amend the year-built effects,

II. modified vulnerability functions for manufactured homes to amend the year-built effects,

III. modified vulnerability functions for commercial residential, renters, and condominium owners when building height is unknown, and

IV. re-mapping ZIP code centroids to Florida's wind vulnerability regions.

The above-proposed modifications of the vulnerability functions reflect the enhanced performance of buildings against windstorms. The rationale for updating vulnerability functions for site-built buildings with respect to the year-built, "*Post-disaster surveys and claims data consistently confirm that newer properties, particularly residential structures, are less vulnerable to strong winds than older properties*." is sound. The year-built modifications account for the effects of (1) changes in the building codes over time, (2) improvements in construction materials and techniques that adopt effective wind mitigation measures, and (3) aging of building components on the structural resistances and integrity of buildings.

Vulnerability model modification # 1: modified vulnerability functions for site-built buildings in the Very-New year-built band

To account for the variation of the building vulnerability function with the year-built, KCC adopts four bands of site-built buildings (i) old year-built band (buildings built before 1995), (ii) Average year-built band (1995-2001), (iii) New year-built band (2002-2011) and (iv) Very-New year-built band (>2011). In the updated KCC Hurricane model, the wind vulnerability functions of site-built buildings in the Very-New year-built band are modified to account for the enhanced performance of such buildings against windstorms. The adopted modification factors balance the reduced observed loss compared to the currently accepted model prediction (presented during the online meeting) and the recent updates in the Florida Building Code (FBC) wind load provisions. The contents damage and time element losses are retained to change in proportion to the building damage as the contents and time element vulnerability functions are derived from the building vulnerability functions. The modification minimized the gap between the current model predictions and observed claimed losses for single-family site-built residential buildings. The reviewer agrees with the rationale and the degree of change of vulnerability functions of the site-built buildings in the Very-New year-built band.

Vulnerability model modification #2: Modified vulnerability functions for manufactured homes for the year-built effect.

The second modification to the KCC currently accepted wind vulnerability model is updating the vulnerability functions for manufactured homes for the year-built effects. Unlike the site-built buildings, KCC adopts the year-built bands of manufactured homes categorized consistent with the evolution of the design requirements of the US Department of Housing and Urban Development (HUD). KCC adopted four year-built bands for the manufactured homes (i) old year-built band (buildings built before 1976), (ii) Average year-built band (1976-1994), (iii) New year-built band (1995-2008), and (iv) Very-New year-built band (>2008). Results of the detailed claim analysis conducted by KCC demonstrated a deviation of predicted loss from observed loss for the manufactured homes in Florida. Consistent with observed trends of departures with the year-built band, KCC adopted modified vulnerability building functions for manufactured homes. The results presented in the review show that the updated KCC hurricane loss model gives better predictions for manufactured homes in Florida than the currently accepted model.

The reviewer agrees with the rationale presented and the degree of a modification adopted for vulnerability functions of manufactured homes in Florida.

Vulnerability model modification #3- modified vulnerability functions for commercial residential, renters, and condominium owners when building height is unknown.

The KCC model supports scenarios where exposure information input to the model does not include all attributes necessary to determine an appropriate vulnerability function. The third modification to the KCC currently accepted wind vulnerability module updates the vulnerability functions for commercial residential, renters, and condominium owners when building height is unknown to represent the weighted average of known building heights from industry exposure data.

Vulnerability model modification #4- Re-mapping ZIP codes to the wind vulnerability regions of Florida.

Based on the proximity to hurricane landfalls, various counties of Florida are subject to varying hurricane wind loss risks. The issue is addressed through spatially varying FBC design requirements for the minimum design wind speeds, High-velocity Hazard Zones (HVHZ), Wind-Borne Debris Region (WBDR) requirements, and recommended terrain roughness categories. Correspondingly, KCC adopted spatially varying wind vulnerability functions for the state of Florida consistent with the stringency of design wind speeds and debris impact requirements in those regions of Florida. Guided by this FBC wind hazard mapping, KCC identified four wind vulnerability regions of Florida (i) High-Velocity Hazard Zone (HVHZ), (ii) Wind-Borne Debris Region (WBDR), (iii) Central Florida, and (iv) North Florida. KCC vulnerability experts established the boundaries of the four designated vulnerability regions of Florida to reflect (a) USPS postal code boundaries, (b) the detailed analysis result of insurance claims data and post-disaster surveys, and (c) updated wind-resistant design requirements of FBC as of 2012. The reviewer founds that the rationale for assigning vulnerability regions to the USPS ZIP boundaries (items b and c) is consistent with the first three adopted modifications of vulnerability models. With each model update, KCC updates the population-weighted ZIP code centroids contained with the ZIP code database to reflect population changes as well as any changes to the postal codes or their boundaries as indicated the by USPS. Although the boundaries of the vulnerability regions remain unchanged from the currently accepted model, KCC experts remapped the population-weighted ZIP code centroids and boundaries associated with the KCC US Hurricane Reference Model V4.0 to the existing vulnerability regions.

Summary

The documentation I reviewed indicates that the methods adopted by KCC to derive vulnerability functions are sound and comply with the requirements of the 2021 FCHLPM Vulnerability Hurricane Standards (Standard V-1 to Standard V4). The introduction of the year-built band parameter to modify the wind vulnerability of a building is consistent with the recently observed insured claims and enhanced reserve capacity of building structures implied from the building code revisions and the evolution of construction practices with time. Based on my experience in wind engineering, the sample results disclosed in the FCHLPM vulnerability forms (Form V-1 to Form V-5) are reasonable from the perspective of the current wind engineering practice and the existing data set available to the reviewer. Given a reasonable prediction of the hurricane wind field and inputting actuarial exposure applicable to Florida, KCC's wind vulnerability module will lead to a reasonably acceptable prediction of expected values of hurricane wind loss costs.

Curriculum Vitae of Dr. Girma Bitsuamlak, PhD, PEng, F CSCE

A. EDUCATION

PhD - *Building Engineering* (October 2004)
Concordia University, Montreal, Quebec, Canada.

MTech - *Civil Engineering* (May 1998, first division with honors)
Indian Institute of Technology (IIT) Roorkee, India.

BSc - *Civil Engineering* (December 1991)
Addis Ababa University, Addis Ababa, Ethiopia.

B. EMPLOYMENT HISTORY

June 2020 - present	**Full Professor,** **Canada Research Chair in Wind Eng.** (*Tier II 2012-2022)*, **Director** – WindEEE Research Facilities (The Dome + Boundary Layer Wind Tunnel + 3LP), **Director** - WindEEE Research Institute, **Western's site leader** for Sharcnet advanced research computing, Civil & Enviro. Eng., Western University, London, ON, Canada.
Jan 2012 - June 2020	**Associate Professor,** **Canada Research Chair in Wind Eng.** (*Tier II*), **Research Director** - Boundary Layer Wind Tunnel Laboratory, **Research Director** - WindEEE Research Institute, **Western's site leader** for Sharcnet advanced research computing, Civil & Enviro. Eng., Western University, London, ON, Canada
Aug 2007- Dec 2011	**Assistant Professor,** Civil and Enviro. Eng. department and International Hurricane Research Center, *Florida International University*, Miami, FL.
Nov 2004- Aug 2007	**Senior Wind Engineer**, Wind and Microclimate Group, *RWDI Inc.*, Guelph, ON.
Jan 2004- Nov 2004	**Part-time Instructor**, Department of Building, Civil and Environmental Engineering, *Concordia University*, Montreal, QC.
May 2001 - Nov 2004	**Data Mining (AI) Research Engineer** (part-time), Globvision Inc., Montreal, QC.
May 1998 - Dec 1998	**Structural Engineer,** *Hintsawi Consulting Architects Engineers and Town Planners PLC*, Asmara, Eritrea.
Dec 1993 - Aug 1996	**Instructor and Chair**, Construction Technology Department, *Adama University,* Adama, Ethiopia.
Jan.1992 – Dec 1993	**Construction Engineer**, *Ethiopian Power Corporation*, Addis Ababa, Ethiopia.

C. AWARDS AND RECOGNITIONS

- *NSERC Discovery Accelerator & Department of National Defense Supplement Awards* (2018)
- *Faculty Scholar,* Western University (2018).
- *Associate Fellow of the Ethiopian Academy of Science* (2018).
- *Fellow of Canadian Society for Civil Engineering* (F CSCE) (2017).
- *Canada Research Chair in Wind Engineering* (Tier II) (renewal) (2017).
- *Bikila Award* (2016) for professional excellence by Bikila Award.
  Awarded by a Toronto based community organization (www.Bikilaaward.org).
- *High-end foreign expert status award.*
  Tongji University awarded the nominee a guest professorship position (2016-2018) with high end foreign expert status in the College of Civil Engineering.
- *Ontario Early Researcher Award* (2013).
- *Canada Research Chair (CRC) in Wind Engineering* (Tier II) (2012).
- *Chi Epsilon, a civil engineering honor society, faculty advisor award* (2011).
- *Florida International University's World Ahead Faculty in 2010.*
- *Florida International University President's Top Scholar of the Year award (2009).*
- *NSF CAREER award – United States - National Science Foundation (Jan 2009- Jan 2014).*

D. PUBLICATION RECORDS

Summary
Chapters in books or contributions to books: **5**
Articles in peer reviewed Journals: **91**
Articles in peer reviewed conferences: **130**
Presentations of professional meetings: **68**
Research Technical Reports: **30**
Consulting work report: **~100**
Submitted Manuscripts: **5**

Note: *HQP (highly qualified personnel) name including undergraduate and graduate students, and postdoctoral fellows are shown in **bold** and my former supervisor's names are underlined.*

Contributed/reviewed books or book chapters (Total = 5)

1. Bitsuamlak, G. T. **Bezabeh, M. A., Cuerrier-Auclair** (2021). Chapter 9. Wind-induced response analysis. In the 1st edition of the Modelling Guide for Timber Structures. Prepared for FPInnovations and NRC, Canada.
2. **Bezabeh,** M. A., Bitsuamlak, G. T. & Tesfamariam, S., & Popovski, M. (2020). Chapter 4.3.1: Analysis and design of tall timber buildings for wind loads. In the 2nd edition of the Technical Guide for the Design and Construction of Tall Wood Buildings in Canada14. Prepared for FPInnovations, Vancouver, Canada.
3. Application Guide for Wind Speed-up Factors. Published and distributed by CEATI (Center for Energy Advancement through Technological Innovation), Montreal, QC

4. Emil Simiu (2011). Design of Buildings for Wind: A Guide for ASCE 7-10 Standard Users and Designers of Special Structures. Wiley; 2nd edition, 2011. (Contributor and reviewer)
5. **Aly, A.M**., Bitsuamlak, G.T., Gan Chowdhury, A. and Erwin J. (2010). Design and fabrication of a new open- jet electric-fan Wall of Wind facility for coastal research. ASCE-EMI Special Publication on Coastal Hazards. Editors, W. Huang, K-H. Wang, Q.J. Chen, 137-148.

Sample Papers in peer-reviewed journals (Total = 91)

1. **Melaku, A. F**., Doddipatla, L.S. Bitsuamlak, G. T. (2022). Large-eddy Simulation of Wind Loads on a Roof-mounted Cube: Application to Interpolation of Experimental Aerodynamic Data. Journal of Wind Engineering and Industrial Aerodynamics, 105230.
2. **Geleta, T. N.,** & Bitsuamlak, G. (2022). Validation metrics and turbulence frequency limits for LES-based wind load evaluation for low-rise buildings. Journal of Wind Engineering and Industrial Aerodynamics, 231, 105210.
3. **Alemayehu, T. F.,** & Bitsuamlak, G. T. (2022). Autonomous urban topology generation for urban flow modelling. Sustainable Cities and Society, 87, 104181.
4. Chavez, M., Baskaran, A., **Aldoum, M.**, Stathopoulos, T., **Geleta, T. N.**, & Bitsuamlak, G. T. (2022). Wind loading on a low-slope gabled roof: Comparison of field measurements, wind tunnel data, and code provisions. *Engineering Structures*, 267, 114646.
5. **Bezabeh,** M. A., Bitsuamlak, G. T., & Tesfamariam, S. (2021) Nonlinear dynamic response of SDOF systems subjected to along-wind loads. Part I: Parametric study. Journal of Structural Engineering. 147(11), 04021177.
6. **Bezabeh,** M. A., Bitsuamlak, G. T., & Tesfamariam, S. (2021) Nonlinear dynamic response of SDOF systems subjected to along-wind loads. Part II: Implications for structural reliability. Journal of Structural Engineering. 147(11), 04021178.
7. **Lalonde, E. R., Vischschraper, B.,** Bitsuamlak, G., & Dai, K. (2021). Comparison of neural network types and architectures for generating a surrogate aerodynamic wind turbine blade model. *Journal of Wind Engineering and Industrial Aerodynamics*, 216, 104696.
8. **Melaku, A. F.,** & Bitsuamlak, G. T. (2021). A divergence-free inflow turbulence generator using spectral representation method for large-eddy simulation of ABL flows. *Journal of Wind Engineering and Industrial Aerodynamics*, 212, 104580.
9. **Bezabeh, M. A.**, Bitsuamlak, G.T., Tesfamariam, S. (2020) Performance-based wind design of tall buildings: Concepts, frameworks, and opportunities, *Wind and Structures*, in publication
10. **Bezabeh, M. A.**, Bitsuamlak, G.T., Tesfamariam, S., and Popovski, M. (2020) Dynamic response of tall mass-timber buildings to wind excitation. *Structural Engineering*, 146(10), 04020199
11. **Birhane, T.H.,** Bitsuamlak, G.T., **Kahsay, M., and Demsis, A.** (2020) Air permeability factors for evaluating wind load on roof pavers. *Journal of Structural Engineering*, 146(8), 04020151.
12. **Elshaer,** A., Bitsuamlak, G.T., **Abdallah, H**. (2019). Variation in wind load and flow of a low-rise building during progressive damage scenario. *Wind and Structures*, 28, 389-404.
13. **Gairola, A.,** Bitsuamlak, G.T. (2019). Numerical tornado modeling for a common interpretation of experimental simulators. *Journal of Wind Eng. & Industrial Aerodynamics* 186, 32-48.
14. **Bezabeh, M. A., Gairola, A.,** Bitsuamlak, G.T., Popovski, M., Tesfamariam, S. (2018). Structural performance of multi-story mass-timber buildings under tornado-like wind field. *Engineering Structures*, 177, 519-539.
15. **Bezabeh, M. A.**, Bitsuamlak, G.T., Popovski, M., & Tesfamariam, S. (2018). Probabilistic serviceability-performance assessment of tall mass-timber buildings subjected to stochastic wind loads: Part II-structural reliability analysis. *Journal of Wind Engineering and Industrial Aerodynamics*, 181, 112-125.

16. **Bezabeh, M. A**., Bitsuamlak, G.T., Popovski, M., & Tesfamariam, S. (2018). Probabilistic serviceability-performance assessment of tall mass-timber buildings subjected to stochastic wind loads: Part I-structural design and wind tunnel testing. *Journal of Wind Engineering and Industrial Aerodynamics*, 181, 85-103.
17. **Elshaer, A.,** and Bitsuamlak, G.T. (2018). Multi-objective aerodynamic optimization through openings to reduce wind loads on of tall buildings. *Journal of Structural Engineering,* 140 (10) http://dx.doi.org/10.1061/(ASCE)ST.1943-541X.0002199.
18. **Nasir Z**., and Bitsuamlak, G.T. (2018). Topographic effect on a tornado like vortex. *Wind and Structures,* 27(2), 123-136.
19. **Adamek, K.,** Vasan, N., **Elshaer, A,** English, E., and Bitsuamlak, G.T. (2017), "Pedestrian level wind assessment through city development: A study of the financial district in Toronto", Sustainable Cities and Societies, 35, 178-190.
20. **Elawady, A., Aboshosha**, H., El Damatty, A. Bitsuamlak, G.T., Hangan, and H. **Elatar, A**. (2017). Aeroelastic testing of multi-spanned transmission line subjected to downbursts. *Journal of Wind Engineering and Industrial Aerodynamics*. 169, 194-216.
21. **Elshaer, A., Gairola, A., Adamek, K.,** and Bitsuamlak, G.T. (2017). Variations in wind load on tall buildings due to urban development. *Sustainable Cities and Society*, 34, 264-277.
22. Chowdhury, A.G., Zisis, I., Irwin, P. Bitsuamlak, G.T., and Jean -Paul Pinelli. (2017). Large-scale experimentation using the 12-fan wall of wind to assess and mitigate hurricane wind and rain impacts on buildings and infrastructure systems, *Journal of Structural Engineering*, 143(7).
23. **Abdelkader, A., Aly, A.M.,** Bitsuamlak, G.T., El Naggar, M.H. (2017). On the Evaluation of Wind Loads for Wind Turbines' Foundation Design: Experimental and Numerical Investigations. *The structural design of tall and special buildings*, 6(9).
24. **Araya, D.B., Grolinger, K., El Yamany, H.F.,** Miriam A.M. Capretz, M.A.M, Bitsuamlak, G.T. (2017). An Ensemble Learning Framework for Anomaly Detection in Building Energy Consumption. *Energy and Buildings*, 144(1), 191-206.
25. **Hamada, A.,** King, J.P.C., El Damatty, A., Bitsuamlak, G.T., **Hamada, A.M.** (2017). The response of a guyed transmission line system to boundary layer wind. *Engineering Structures*, 139,135-152.
26. **Elshaer, A.,** Bitsuamlak, G.T. and El Damatty, A. (2017). Enhancing the wind performance of tall buildings using corner aerodynamic optimization. *Engineering Structures*, 136, 133-148.
27. Dai, K., **Sheng. C., Zhao, Z., Yi, Z**., Camara, A., and Bitsuamlak, G.T. (2017). Non-linear response history analysis and collapse mode study of a wind turbine tower subjected to cyclone wind. *Wind and Structures*, 25(1), 79-100.
28. **Elshaer, A., Aboshosha,** H., Bitsuamlak, G.T. El Damatty, A. and Dagnew, A. (2016). LES evaluation for wind induced responses of a tall building with isolated and complex surrounding. *Engineering Structures*, 115, 179-195.
29. **Abdi, D.** and Bitsuamlak, G.T. (2016). Wind flow simulations in idealized and real built environments with models of various level of complexity, *Wind & Structures*, 22 (4), 503-524.
30. **Aboshosha, H., Elshaer, A.,** Bitsuamlak, G.T. and El Damatty, A. (2015). *Consistent inflow turbulent generator for LES evaluation of wind-induced responses for tall buildings. Journal of Wind Eng. & Industrial Aerodynamics,* 142, 198-216.
31. **Aboshosha,** H., Bitsuamlak, G.T and El Damatty, A. (2015). Turbulence characterization of downbursts using LES. *Journal of Wind Eng. & Industrial Aerodynamics*, 136, 44-6
32. **Warsido, W.** and Bitsuamlak, G.T. (2015). Synthesis of wind tunnel and climatological data: A Copula based approach. *Structural Safety*, 57, 8-17.
33. **Baheru, T.,** Gan Chowdhury, A., Jean -Paul Pinelli, Bitsuamlak, G.T. (2014). Distribution of wind-driven rain deposition on low-rise buildings: Direct impinging raindrops versus surface runoff. *Journal of Wind Eng. & Industrial Aerodynamics*, 133, 27-38.

34. **Warsido, W.,** Bitsuamlak, G.T., Gan Chowdhury, A., **Barrata, J.** (2014). Influence of spacing parameters on the wind loading of solar array. *Journal of Fluids and Structure*, 48, 295–315.
35. **Fu, T-C.**, Gan Chowdhury, A., Bitsuamlak, G.T., **Baheru, T**. (2014). Partial turbulence simulation and aerodynamic pressures validation for an open-jet testing facility. *Wind and Structures*, 19(1), 15-33.
36. **Dagnew, A.,** Bitsuamlak, G.T. (2014). Computational evaluation of wind loads on standard tall building using a large eddy simulation, *Wind & Structures*, 18(5), 567-598.
37. **Baheru, T.,** Gan Chowdhury, A., Bitsuamlak, G.T., Masters, F.J., Tokay, A. (2014). Simulation of wind-driven rain associated with tropical storms and hurricanes using the 12-fan Wall of Wind, *Building and Environment*, 76, 18–29
38. **Aly, A.M.,** Bitsuamlak, G.T. (2014). Wind-induced pressures on solar panels mounted on residential homes. *Journal of Architectural Engineering*, 20(1), 1943-5568.
39. **Warsido, W.,** Bitsuamlak, G.T. (2013). A dual aerodynamic data analysis framework for tall buildings, *Journal of Wind Engineering*, 10(2), 18-40.
40. **Aly, A.M.,** Bitsuamlak, G.T. (2013). Aerodynamics of ground-mounted solar panels: test model scale effects, *Journal of Wind Engineering and Industrial Aerodynamics*, 123, 250-260.
41. **Aly, M.A.,** Fossati, F., Bitsuamlak, G.T, Franchi, A., Crespi, P., Longariniand, N. and Gan Chowdhury (2013). Estimation of wind load on trees for a vegetated building envelope: a multi-scale experimental study. *Wind and Structures*, 17(1), 69-85.
42. **Dagnew, A**., Bitsuamlak, G.T. (2013). Computational evaluation of wind loads on buildings: A review. *Wind and Structures*, 16(6), 629-660.
43. **Tecle, A.,** Bitsuamlak, G.T., Suksawang, N., Gan Chowdhury, A., Feuze Lekem, S. (2013). Ridge and field tile aerodynamics for a low-rise building: a full-scale study", Wind & Structures, 16(4) 301-322
44. **Tecle**, A., Bitsuamlak, G.T., A., Gan Chowdhury, A. 2012. "Large-scale measurements of wind induced internal pressures in low-rise buildings", Journal of Architectural Engineering, ASCE, 10.1061/(ASCE) AE.1943-5568.0000101 (Jul. 16, 2012).
45. **Tecle, A.,** Bitsuamlak, G.T., Aly, A.M. 2013. "Internal pressure in a low rise building with existing envelope openings and sudden breaching", Wind and Structures, 16(1), 25-46
46. Bitsuamlak, G.T., Gan Chowdhury, **A., Sambare**, D. (2009). Development of full-scale testing facility for water intrusion. *Building and Environment,* 44 (12), 2430-2441.
47. **Merrick, R.,** Bitsuamlak, G.T., (2009). Shape effects on the wind-induced response of high-rise buildings. *Journal of Wind Engineering*, 6 (2), 1-18.
48. Gan Chowdhury, A., **Huang, P.,** Bitsuamlak, G.T. (2008). Wind flow simulation for mitigating coastal disaster under hurricanes. *Disaster Advances*, 1(4), 9-19.
49. Bitsuamlak, G.T., Stathopoulos, T., Bédard, C. (2007). Effect of topography on design wind load combined numerical and neural network approach", Journal of Computing in Civil Engineering, ASCE, 21 (6), 384-392.
50. Bitsuamlak, G.T., Stathopoulos, T., Bédard, C. 2006. "Effect of upstream hills on design wind load: a computational approach. *Wind and Structures*, 9(1), 37-58.
51. Bitsuamlak, G.T., Stathopoulos, T., Bédard, C. (2004). Numerical evaluation of turbulent flows over complex terrains: A review, *Journal of Aerospace Engineering*, 17(4), 135-145.

Sample conference publications (Total = 130)

1. **Younis, M, Kahsay, M,** and Bitsuamlak, G.T., BM-CFD integrated sustainable and resilient building design for northern architecture. Oct. 2020, 2020 Building Performance Modeling Conference and SimBuild co-organized by ASHRAE and IBPSA-USA At: Chicago, IL.

2. **Bezabeh, M. A.,** Bitsuamlak G., Tesfamariam, S. (2018). Risk-based wind design of tall mass timber buildings. The 2018 Canadian Society for Civil Engineering, Structural Specialty Conference, Fredericton, NB, Canada.
3. **Bezabeh, M. A.,** Bitsuamlak G., Popovski, M., Tesfamariam, S. (2017). Serviceability risk assessment of tall mass timber buildings: A probabilistic performance-based wind engineering approach. ASCE Structural Congress, Denver, Colorado, USA
4. **Geleta, T. N., Elshaer, A., Melaku, A.,** & Bitsuamlak, G. T. (2018). Computational Wind Load Evaluation of Low-Rise Buildings with Complex Roofs Using LES. The 7th International Symposium on Computational Wind Engineering. 2018. June 18-22, 2018 in Seoul, Republic of Korea.
5. **Woldeyes, K**., Shifferaw, Y., **Birhane, T.H**., and Bitsuamlak, G.T. (2017). Numerical evaluation of wind effects on low and mid-rise hybrid structures. 2017 Americas Conference on Wind Engineering, Gainesville, United States
6. **Birhane, T.H**., Bitsuamlak, G.T., and King, J.P. (2017). Computational aerodynamic shape optimization of long-span bridge decks –optimal fairing design for H-shaped decks. 2017 Americas Conference on Wind Engineering, Gainesville, United States
7. **Melaku, A**., Bitsuamlak, G.T., **Elshaer, and A., Aboshosha, H.** (2017). Synthesized inflow turbulence generation methods for LES study of tall building aerodynamics. 2017 Americas Conference on Wind Engineering, Gainesville, United States
8. **Samani, Z**., Bitsuamlak, G.T., and Hangan, H. (2016). Full-scale evaluation of wind load on a solar panel. 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, United States
9. **Elshaer A.,** Bitsuamlak G.T., El Damatty A. (2016). Aerodynamic shape optimization of tall buildings using twisting and corner modifications, 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, USA June 2016.
10. **Nasir, Z**., Bitsuamlak, G.T. (2016). Tornado like vortex induced load on a bluff-body with and without openings", 8th International Colloquium on Bluff-Body Aerodynamics and Applications, Boston, USA, June 7 – 11, 2016.

Presentations (Invited talks =58 and keynote=7, Total =68, Panellist=3. Note this summary does not include paper presentation in conferences)

1. <u>Panellist:</u> Natural Science Foundation, Natural Hazards Engineering Research Infrastructure (NHERI) – Natural hazard summit, Washington DC. Oct 7, 2022.
2. <u>Panellist:</u> European Research Infrastructures for European Synergy, Pavia University, JN 11, 2022.
3. <u>Panellist</u> -Digital Research Needs in Canada – Digital Research Alliance of Canada – Industry partnership workshop, Ottawa, ON, Oct 20,2021.
4. Climate resilient and sustainable buildings, 3rd International Conference on New Horizons in Green Civil Engineering, Victoria, British Columbia, Canada, April 2022. <u>Keynote</u>
5. Reducing the risk of extreme wind induced damage, Institute for Catastrophic Loss (ICLR), *Webinar* (one hr. long), ICLR Friday Forum, Sep 2019. <u>Invited.</u>
6. <u>Training</u>- Research proposal writing: A civil engineer perspective, Training to BahirDar Institute of Technology faculty members, BahirDar Ethiopia. July 3, 2021. <u>Invited</u>
7. Generation of tornado-like vortices for wind engineering applications, Boundary Layer Wind Tunnel Simulation of Transient and Non-synoptic Wind Events, University of Florida NSF NHERI Experimental Facility. May 19, 2021 <u>Keynote</u>
8. Tall Mass Timber Building Aerodynamic Modification , Side Walks Lab presentation, May 28, 2020, <u>Invited</u>.

9. Dynamic Response of Tall Mass-Timber Buildings to Wind Excitation, George Mason University Workshop, March 31, 2021. , Invited.
10. Computational and experimental generation of tornado-like vortices, Physics Colloquium, Western University, Feb 21, 2021. Invited.

Sample project reports (Total ~ 30)

1. Expert Review report 1: CPP's solar tracker system aeroelastic testing review report submitted to NexTracker, June 2020
2. Expert Review 2: CPP's solar tracker system aeroelastic testing review report for NexTracker, Feb 2020.
3. Expert Review 3: Structural design for hurricane and earthquake for Dominica: review, World Bank. June 2019.
4. Computational aerodynamic wind analysis and optimization for tall mass timber buildings, Side Walk Lab, June 2020.
5. Helipad airflow and turbulence analysis (CFD) for Theakston Environmental, August 22, 2020.

Sample wind loading consulting project reports (Total ~ 100)

The following boundary layer wind tunnel studies (Structural, cladding wind loads and roof studies)[1] *were carried out while the applicant was working either as a Senior Wind Engineer (PEng) with RWDI Inc Consulting Engineers and Scientists, Guelph, ON (Oct. 2004- Aug. 2007) or Research Director at the Boundary Layer Wind Tunnel Laboratory at Western.*

Sample aeroelastic study (tall buildings) reports:

1. Aeroelastic Model Study Wind-induced Structural Responses, Burj Dubai (renamed Burj Khalifa recently), Dubai, UAE. August 2007.
2. Aeroelastic Model Study Wind-induced Structural Responses, Freedom Tower, New York, New York. September 2006.
3. Aeroelastic Model Study Wind-induced Structural Responses (Reanalysis), Simcoe Hotel/Residential Tower, Toronto, Ontario, Canada. October 2006.
4. Aeroelastic Model Study Wind-induced Structural Responses, Simcoe Hotel/Residential Tower, Toronto, Ontario, Canada. June 2006.
5. Aeroelastic Model Study Wind-induced Structural Responses, Moscow City Site 14 Tower, Moscow, Russia. September 2006.

[1] *Structural wind response studies are mostly aimed at determining the mean and fluctuating wind forces and moments (torsional and bending) on a structural system. It also includes estimation of building accelerations on the top occupied floors for tall buildings to insure the comfort of the occupant by using dynamic analysis methods. In some adverse situations, it also includes recommendation of engineering solutions that involves either design revisions or addition of supplementary damping systems. A structural response study adopts either Aero-elastic or rigid model tests including High Frequency Force balance or High frequency Pressure integration methods.*

Roof Studies deal with structural wind load evaluations for the structural design of the main roof support system of large roofs (Sport Facilities, Casinos etc.).

Cladding load studies focuses in estimating wind pressure contours on the building envelope for design of individual elements of a building such as windows, wall cladding, roof systems, soffits, and skylights; wind suctions or pressures at building intakes, exhausts, and at doorways, stack effect and green building enclosure technology etc.

<u>Sample long span roof study reports:</u>

1. Structural Wind Load Study, Orlando Airport Terminal 2, Orlando, FL. February 2006.
2. Preliminary Cladding/Structural Wind Load Study, Real Salt Lake Soccer Stadium, Salt Lake City, Utah. December 2006.
3. Structural Wind Load Study, Miami Intermodal Center, Miami, FL. August 2006.
4. Structural Wind Load Study, Yankees Stadium, New York, New York. May 2006.
5. Structural Wind Load Study, 51 Louisiana Avenue, Washington, DC. October 2006.

<u>Sample structural load (high-rise building) aerodynamic study reports:</u>

1. Wind-induced Structural Responses, Logik Tower, Miami, Florida. January 2006.
2. Wind-induced Structural Responses, One Bedford at Bloor, Toronto, ON. January 2006.
3. Wind-induced Structural Responses, 830 (Park) Michigan, Chicago, IL. December 2006.
4. Wind-induced Structural Responses, Villa Magna- South and North Towers, Miami, Florida. December 2006.
5. Wind-induced Structural Responses (Revised), The cosmopolitan-East Tower, Las Vegas, Nevada. December 2006.

<u>Sample cladding load (high-rise building) study reports:</u>

1. Cladding Wind Load Study, 50 Biscayne Tower, Miami, Florida. February 2005.
2. Cladding Wind Load Study, Neo Wind at River Front, Miami, Florida. May 2005.
3. Cladding Wind Load Study, The Ivy at River Front, Miami, Florida. April 2005.
4. Cladding Wind Load Study, Turnberry Village, Florida. April 2005.
5. Cladding Wind Load Study, Grand Central, Florida. February 2005.

E. SERVICE PROFILE

Editorial Activities:

- Co-Editor, Journal of Wind Engineering, Journal (since 2014)
- Associate Editor, ASCE Natural Hazards Review, Journal (since 2014)
- Associate Editor, Canadian Journal of Civil Engineering (since 2018)
- Associate Editor, ASCE Journal of Structural Engineering (since 2020)
- Editorial board member, Wind and Structure Journal (since 2020).
- Guest Editor, Sustainable Cities, and Societies (Elsevier)- Special issue on "Urban resiliency for extreme climate", Journal (2016-2018)
- Expert Panel, CTBUH's Expert Panel, representing the field of Wind Engineering (2014-2019)

Memberships

- Fellow of Canadian Society of Civil Engineers,
- Associate Member American Society of Civil Engineers,
- Professional Engineer, Ontario, Canada; Addis Ababa, Ethiopia and Asmara, Eritrea,
- Member of Council of Tall Buildings and Urban Habitat.
- Member of ASCE Future of Wind Engineering special task committee (2015),
- Member of NIST panel on Roadmap for Wind Engineering (2013),

- Chair of CSCE Structural Dynamics Committee,
- Chair of ASCE Computational Wind Engineering task committee,
- Member ASCE Environmental Wind Engineering Committee,
- Member ASCE Wind load on Solar Panel committee

Conference organizer and Chair:

- Chair, Computational Wind Engineering Conference - CWE 2024, Conference,
- Session Chair (Sustainable Development), CSCE annual conference - Leadership in sustainable infrastructure, Conference, 2017/6 - 2017/6
- Session Chair (Buildings and Energy), CSCE annual conference - Leadership in sustainable infrastructure, Conference, 2017/6 - 2017/6
- Session Chair (Computational Wind Engineering and Cyberphysical Modeling), 13th Americas' conference in wind engineering, Conference, 2017/5 - 2017/5
- Chair, Natural Disaster Mitigation Specialty Conference, CSCE, Conference, 2016/6 -2016/6
- Organizing committee member for the CSCE 2016 conference in London.
- Session Chair (Environmental flows – full scale, CFD and experimental method), 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, MA, Conference, 2016/6 - 2016/6
- Scientific Committee Member, 8th International Colloquium on Bluff Body Aerodynamics and Applications, Boston, MA, Conference, 2016/6 - 2016/6
- Scientific committee Member, 14th International Conference on Wind Engineering, Porto Alegre, Brazil, Conference, 2015/6 - 2015/6
- Scientific committee member- 14th International Conference on Wind Engineering, Porto Alegre, Brazil, June 21-26, 2015.
- Scientific committee member- 2014 Computational Wind Engineering Conference (2014 CWE), Hamburg, Germany, June 2014.
- Fluid structure interaction session organizer, CWE 2014 Conference (2014 CWE), Hamburg, Germany, June 2014.
- Architectural practices, passive designs and innovations secession chair – International Sustainable Built Environment Conference, Doha, Qatar, January 29, 2014.
- Wind Engineering Innovation session chair, WindEEE Scientific Symposium, October 2013.
- Scientific committee member, 13th International Conference in Wind Engineering, Amsterdam, Netherlands, www.13ICWE.org – 13 ICWE, 2012.
- Low-rise building session chair, 2012 workshop, American Association of Wind Engineering, August 12-14, 2012, Hyannis, MA, USA.
- Organizing/host and scientific committee member, and chair for a special session "computational evaluation of wind induced external and internal pressure", The 5th International Symposium in Computational Engineering, CWE2010, Charlotte, NC. www.cwe2010.org.
- Chair for a special session "Building envelope water tightness", International Conference on Building Envelope Systems and Technologies, Vancouver, Canada, ICBEST 2010.

Journal reviewer

- Journal of Wind Engineering and Industrial Aerodynamic (*Elsevier*),
- Building and Environment(*Elsevier*),
- Engineering Structures(*Elsevier*),
- Journal of Fluids and Structures (*Elsevier*),
- Structural Safety (*Elsevier*),
- Journal of Building Engineering(*Elsevier*),

- Energy and Buildings (*Elsevier*),
- Applied Energy (*Elsevier*),
- Sustainable Cities and Societies (*Elsevier*),
- Wind and Structures (Techno press),
- Journal of Wind Engineering,
- ASCE Natural Hazard Review,
- ASCE Journal of Structural Engineering,
- ASCE Journal of Engineering Materials,
- ASCE Journal of Architectural Engineering,
- ASCE Journal of Bridge Engineering,
- ASCE Journal of Infrastructure.

Appendix G: Acronyms

AAL: Average Annual Loss

ACAS: Associate of the Casualty Actuarial Society

AIR: AIR Worldwide

ALR: Aerodynamic load/resistance component method

API: Application programming interface

ASC: Analysis Server Cluster

ASTM: American Society for Testing and Materials

ATC: Applied Technology Council

CDF: Cumulative Distribution Function

CE: Characteristic Event

CF: Conversion factor

CP: Central pressure

CPI: Consumer price index

CSV: Comma separated values

DB: Database

DBAN: Darik’s Boot and Nuke (software for cleaning drives)

DEV: software development environment

DF: Damage Function (Vulnerability Function)

DL: Documentation Lead

EIFS: Exterior Insulation and Finish System

ELT: Event Loss Table

ENSO: El Niño-Southern Oscillation

EP: Exceedance Probability

EPR: Expected Percentage Regression

FBC: Florida Building Code

FFP: Far field pressure

FHCF: Florida Hurricane Catastrophe Fund

FPHLM: Florida Public Hurricane Loss Model

GIS: Geographic Information System

GPD: Generalized Pareto Distribution

HUD: US Department of Housing and Urban Development

HURDAT2: Hurricane Database

HVHZ: high velocity hazard zone

IBHS: Insurance Institute for Business and Home Safety

ILS: Insurance Linked Securities

IPCC: Intergovernmental Panel on Climate Change

ISO: International Organization for Standardization

JPM: Joint Probability Method

JS: JavaScript

KCC: Karen Clark & Company

km: kilometer

LOB: Line of Business
LULC: Land Use Land Cover
m: meter
MBE: Mean bias error
MFA: Multi-factor authentication
MDR: Mean Damage Ratio
mi: miles
mph: miles per hour
MRLC: Multi-Resolution Land Characteristics Consortium
NAHB: National Association of Home Builders
NDA: Non-disclosure agreement
NHC: National Hurricane Center
NLCD: National Land Cover Database
NWFL: Northwest Florida
NWS: National Weather Service
OEF/OEF2: Open Exposure Format
OSB: Oriented Strand Board
P&C: Property and Casualty
PDF: Probability Distribution Function
PGP: Pretty Good Privacy
PML: Probable Maximum Loss
QA: Quality Assurance
RDP: Remote Desktop Protocol
RI: RiskInsight®
R_{max}: Radius of maximum winds
RMS: Risk Management Solutions
RMSD: Root-mean-square deviation
SA: Sensitivity analysis
SCS: Severe Convective Storm
SEFL: Southeast Florida
SFTP: Secure File Transfer Protocol
SID: System ID
SMB: Server Mail Message Block protocol
SME: Subject Matter Expert
SQL: Structured Query Language
SRC: Standardized Regression Coefficients
SRF: Surface Roughness Factor
SSD: Solid State drive
SST: Sea Surface Temperature
TD: Track direction
TFS: Microsoft Team Foundation Server
TIV: Total Insured Value

TSV: Tab separated values

UA: Uncertainty Analysis

UI: User Interface

USGS: US Geological Survey

USPS: US Postal Service

V_{max}: Velocity of maximum winds

VPN: Virtual Private Network

VT: Forward Speed

WBDR: wind-borne debris region

YLT: Year Loss Table

ZCTA: ZIP Code Tabulation Area

ZIP: Zone Improvement Plan