The Florida Public Hurricane Loss Model

Version 6.2

May 2017

Model Overview

- The FPHLM development project for personal and commercial residential properties was funded by the FL-Office of Insurance Regulation.
- We are currently funded to operate, update and maintain the model at Florida International University.
- Model is operated by a team of experts in computer science, actuarial science, finance, statistics, meteorology and engineering.

- Our major client is the FL-OIR
- Since 2009, as required by the Florida legislature, we have provided hurricane modeling services to over thirty clients in the insurance industry.
- Model development was not influenced by either FL-OIR or the insurance industry

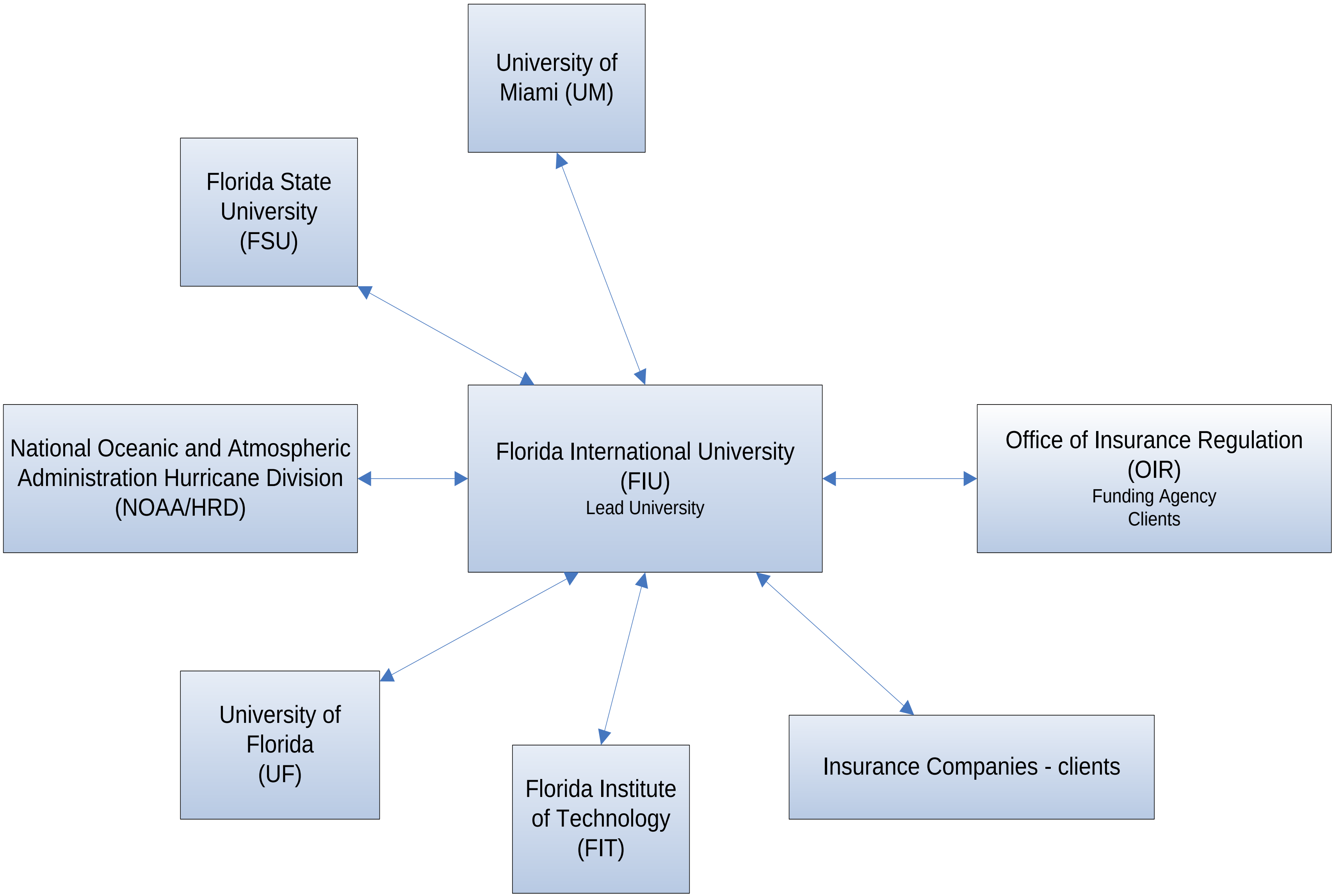
- The model was first activated in March 2006. This version was used to process the insurance company data on behalf of the Florida Office of Insurance Regulation.
- In Summer 2007 a revised and updated version 2.6 of the model was accepted by the Florida Commission on Hurricane Loss Projection Methodology and put to immediate use.
- Another revised and updated version 3.0 was accepted by the Commission in June 2008.
- Another revised and updated version 3.1 was accepted by the Commission in June 2009.
- Version 4.1 and 5.0 were accepted by the Commission in Summer 2011 and Summer 2013 respectively.
- The latest version 6.1 was accepted by the Commission in Summer 2015 and is in use.

General Comments

- The model is transparent in the sense that we make available technical reports, flowcharts etc. on the assumptions, methods, theories, component designs, and tests.
- In fact much has already been published in refereed journals and proceedings.
- Technical documents are available at the project website: www.cis.fiu.edu/hurricaneloss/
- The source code, however, is not open.

Participating Institutions

- Florida International University/ IHRC (lead institution)
- Florida State University
- Florida Institute of Technology
- University of Florida
- University of Miami
- Hurricane Research Division, NOAA
- AMI Risk Consultants


University of Miami (UM)
Florida State University (FSU)
National Oceanic and Atmospheric Administration Hurricane Division (NOAA/HRD)
Florida International University (FIU)
Lead University
Office of Insurance Regulation (OIR)
Funding Agency
Clients
University of Florida (UF)
Florida Institute of Technology (FIT)
Insurance Companies - clients

- About 18 professors and experts and a dozen student assistants were involved in the development and operation of the model.

Current Meteorology Team

• Dr. Steven Cocke	Dept of Meteorology, FSU Team leader
• Dr Dong-Wook Shin	Dept of Meteorology, FSU
• Bachir Annane	University of Miami – CIMAS
• Neal Dorst	Hurricane Research Division, NOAA

Current Engineering Team

- Dr. Jean Paul Pinelli* — Dept of Civil Engineering, FIT
  Team leader
- Dr. Kurtis Gurley — Dept of Civil Eng, UF
- Graduate students

Actuarial/Finance Team

• Dr. Shahid Hamid*	Dept of Finance and IHRC, FIU PI and Project Director
• Gail Flannery	Actuary, FCAS, AMI Risk Consultant
• Bob Ingco	Actuary, FCAS, AMI Risk Consultant
• Nino Joseph Paz	Actuary, FCAS, AMI Risk Consultant

Computer Science Team

• Dr. Shu-Ching Chen*	School of Computer Science, FIU Co-PI and team leader
• Dr. Mei-Ling Shyu	Dept. of Electrical and Computer Engineering, University of Miami
• Dr. Hisn-Yu Ha	Computer scientist at IHRC, FIU
• Raul Garcia	Computer Scientist at IHRC, FIU
• Diana Machado	Computer Scientist at IHRC, FIU
• Dr. Fausto Fleitis	Computer Science expert, consultant
• Haiman Tian	PhD candidate in CS at FIU
• Samira Poutanfar	PhD candidate in CS at FIU
• Maria Presa Reyes	PhD student in CS at FIU
• Shen Guan	PhD student in CS at FIU
• Yudong Tao	MS student in CE at UM

- Other graduate and undergraduate students

Statistics Team

- Dr. Sneh Gulati* Dept. of Statistics, FIU
- Dr. G. Kibria Dept. of Statistics, FIU

Publications

- The project team has generated over five dozen papers. Some of these have been published in top science, engineering and computer science journals and proceedings and conferences.
- Some of the publication outlets are:

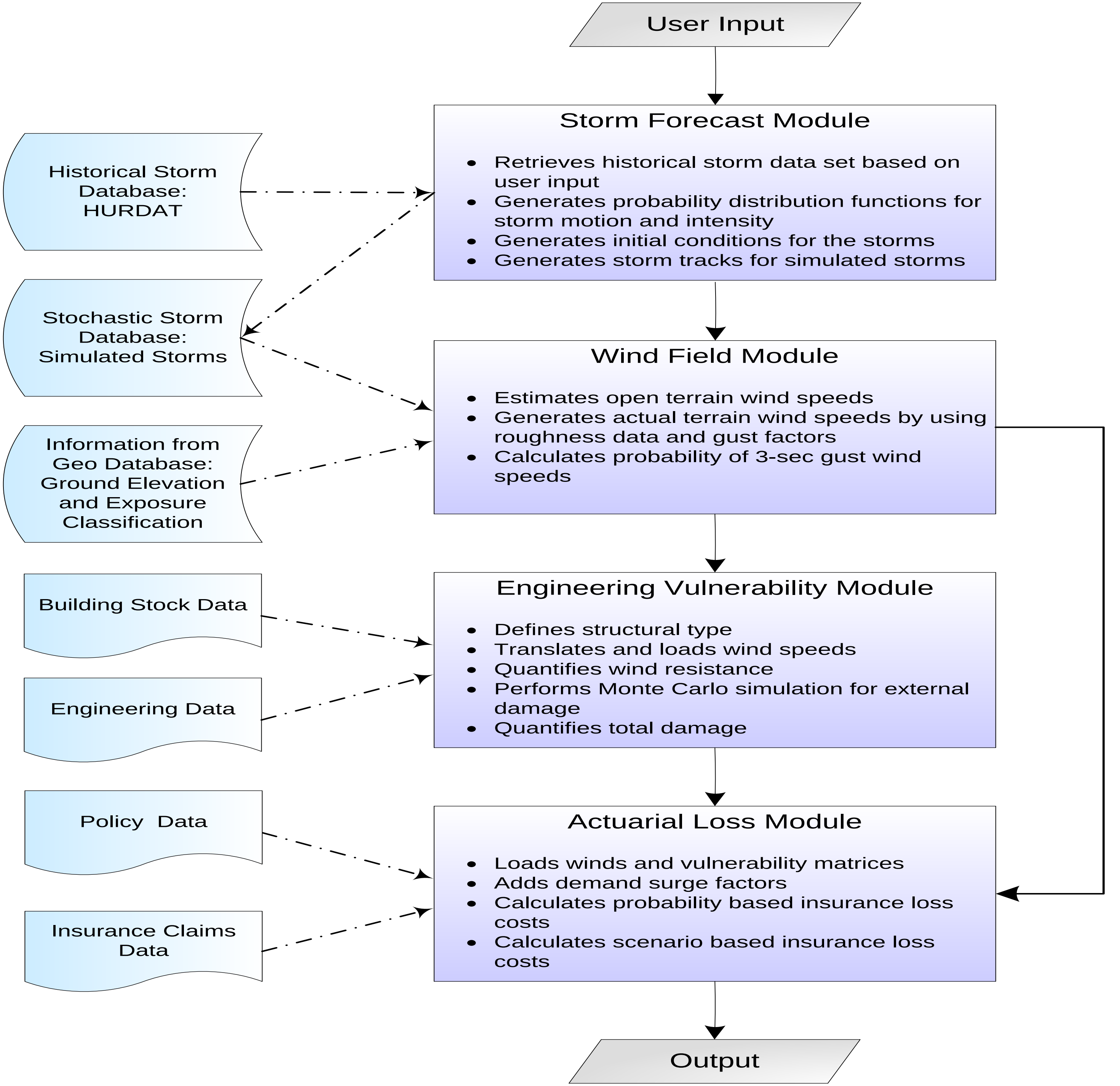
  - Nature
  - ASCE Journal of Structural Engineering
  - Software Practice and Experience
  - Natural Hazard Review
  - Numerous IEEE Proceedings
  - Journal of Wind and Industrial Engineering Aerodynamic
  - Intl Wind Engineering Proceedings
  - Reliability Engineering and System Safety Journal

Publications (continued)

- Government Information Quarterly
- Statistical Methodology
- Statistical proceedings of ASA
- Wind and Structures
- Journal of Risk and Uncertainty in Engineering Systems
- Theoretical and Applied Climatology
- Various Meteorology conferences
- Numerous engineering conference proceedings

Model Design

- The model consists of three major components: wind hazard (meteorology), vulnerability (engineering), and insured loss cost (actuarial).
- The major components were developed independently before being integrated.
- The computer platform is designed to accommodate future hookups of additional sub-components or enhancements.


User Input
Storm Forecast Module
Retrieves historical storm data set based on user input
Generates probability distribution functions for storm motion and intensity
Generates initial conditions for the storms
Generates storm tracks for simulated storms
Historical Storm Database: HURDAT
Stochastic Storm Database: Simulated Storms
Information from Geo Database: Ground Elevation and Exposure Classification
Wind Field Module
Estimates open terrain wind speeds
Generates actual terrain wind speeds by using roughness data and gust factors
Calculates probability of 3-sec gust wind speeds
Building Stock Data
Engineering Data
Engineering Vulnerability Module
Defines structural type
Translates and loads wind speeds
Quantifies wind resistance
Performs Monte Carlo simulation for external damage
Quantifies total damage
Policy Data
Insurance Claims Data
Actuarial Loss Module
Loads winds and vulnerability matrices
Adds demand surge factors
Calculates probability based insurance loss costs
Calculates scenario based insurance loss costs
Output

- In 2013 the state funded FIU to enhance the FPHLM by adding both a storm surge and fresh water flooding component.
- The proto type for the flood component will be ready this year.

Public Hurricane Loss Model v 6.2

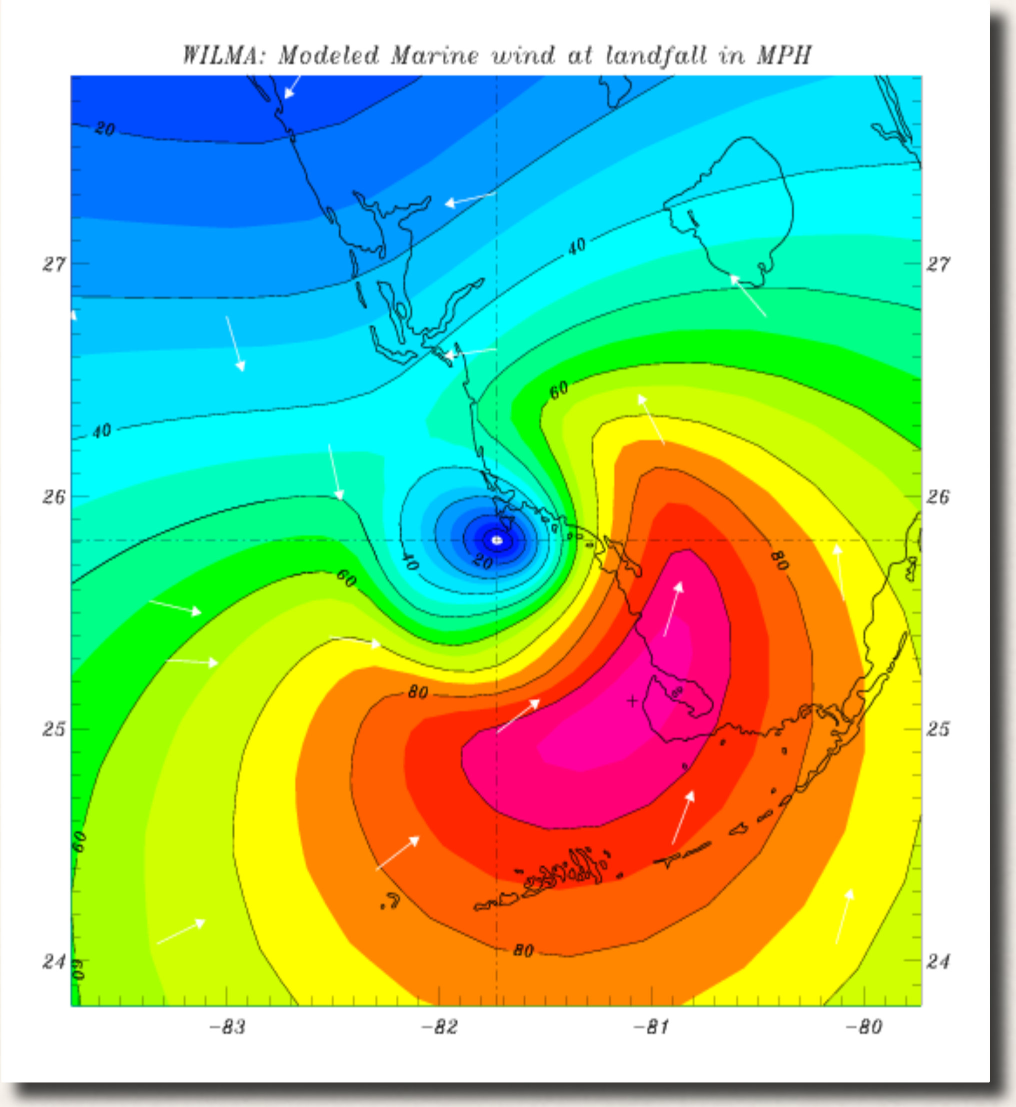
Meteorology

Steven Cocke, Florida State University

Bachir Annane, University of Miami

Dong-Wook Shin, Florida State University

Mark Powell, departed and now with RMS



Met Components

- Storm Track Generator
  - generates tracks which have position, intensity and storm parameters for duration of storm
- Wind Model
  - generates surface wind field for each storm
- Terrain Adjustment
  - adjust winds to terrain conditions and determines gusts

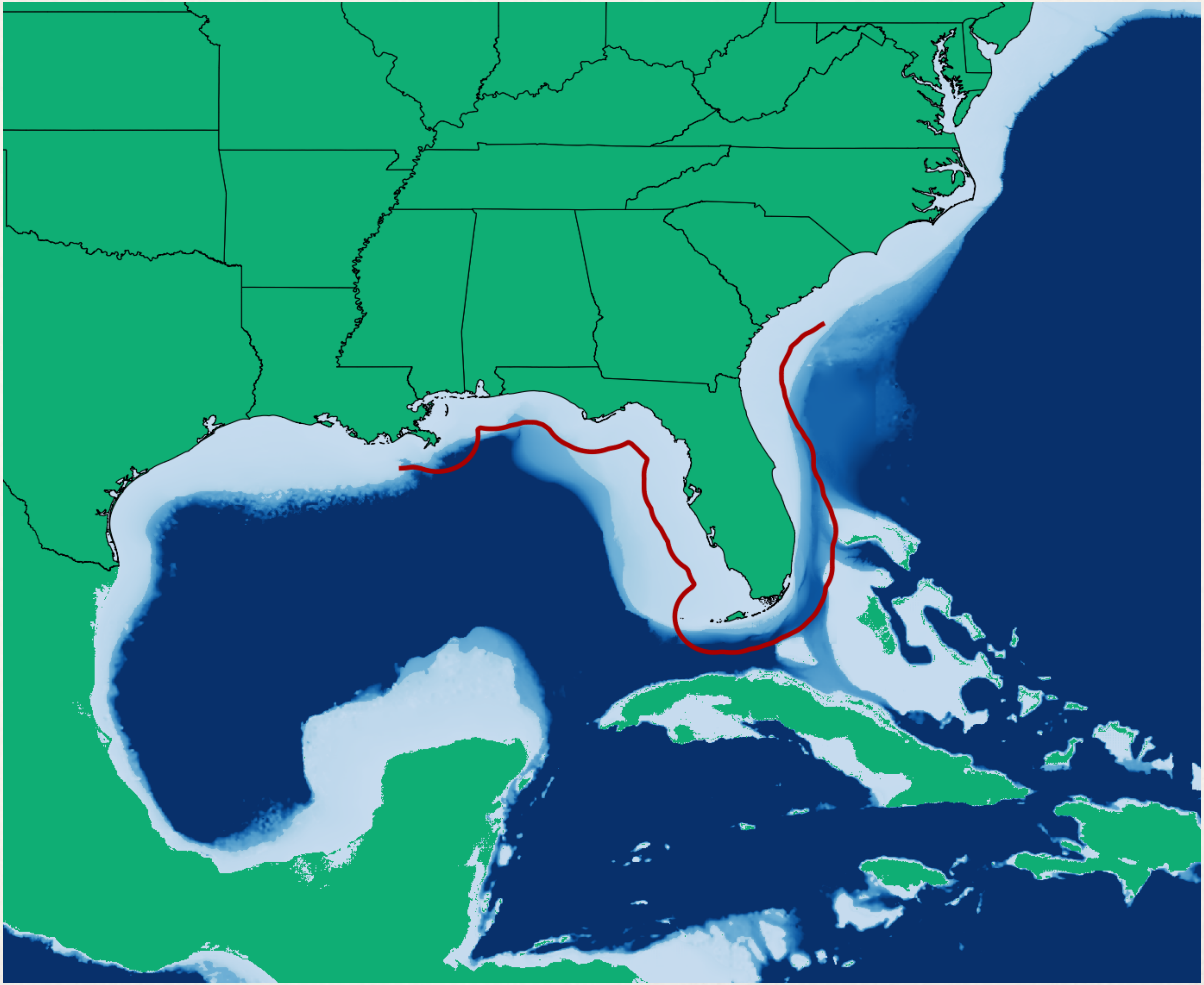
Storm Track Generator

- Storm seeds based on historical storms that entered a threat area surrounding Florida and neighboring states
  - Initial seed position started at the historical position of the storm 36 hours prior to entering threat area, plus uniform random perturbations
  - Initial speed and intensity based on historical data plus random perturbations
- Changes in speed, direction and relative intensity are sampled from empirical PDFs derived from HURDAT data, with random perturbations added. PDFs depend on location and current motion or intensity
- Storm parameters (Rmax and Holland B) are sampled from distributions derived from historical data

Storm Track Generator

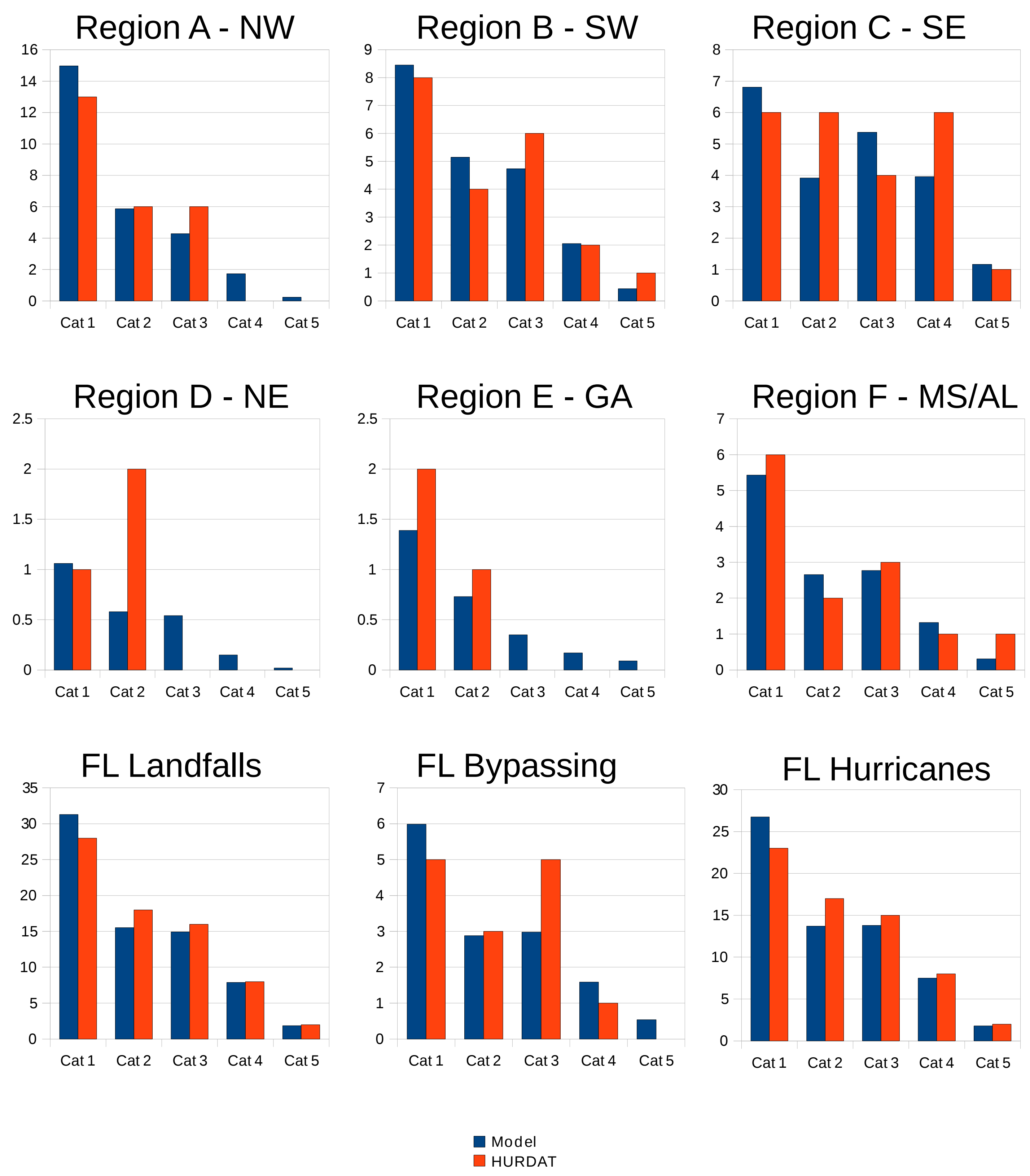
- When storm is over land, a pressure filling model is used (exponential decay of central pressure deficit in time). If storms re-enters water, intensity changes are again resampled from the PDFs derived from HURDAT.
- Storms seeds are recycled, but with new random perturbations, to generate more than 50,000 years of storms
- Storm tracks are in 1 hr increments, and includes position, intensity (pressure), date and storm parameters (Rmax, B)
- Storm terminates when it exits domain or central pressure exceeds 1011 mb

Model Domain



Sample Stochastic Tracks

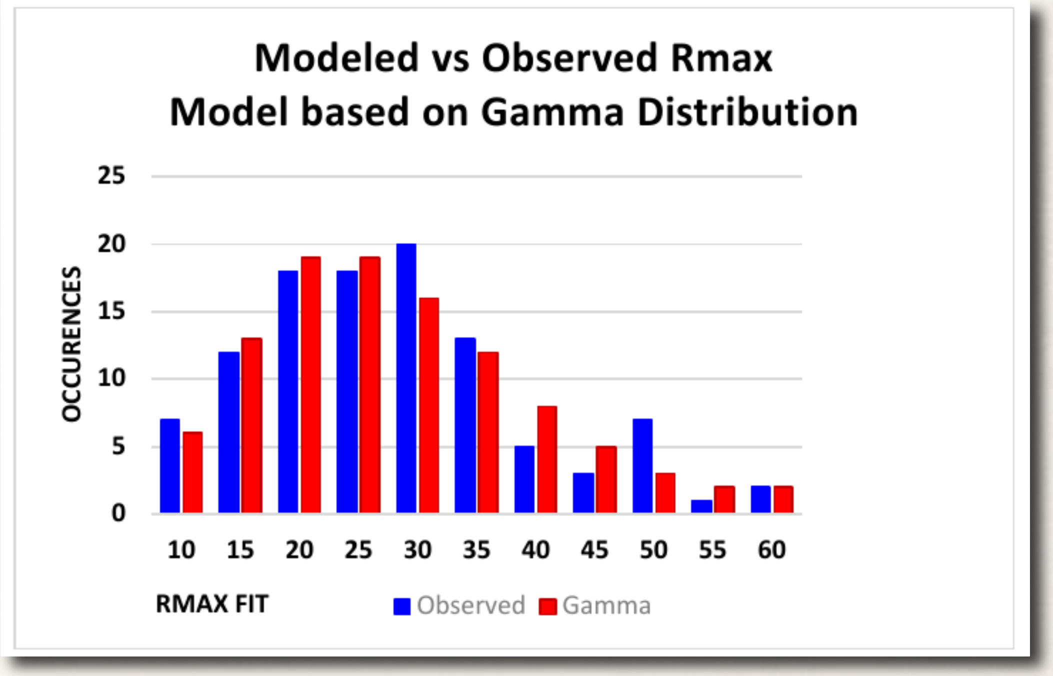
Landfall by SS Category and Region

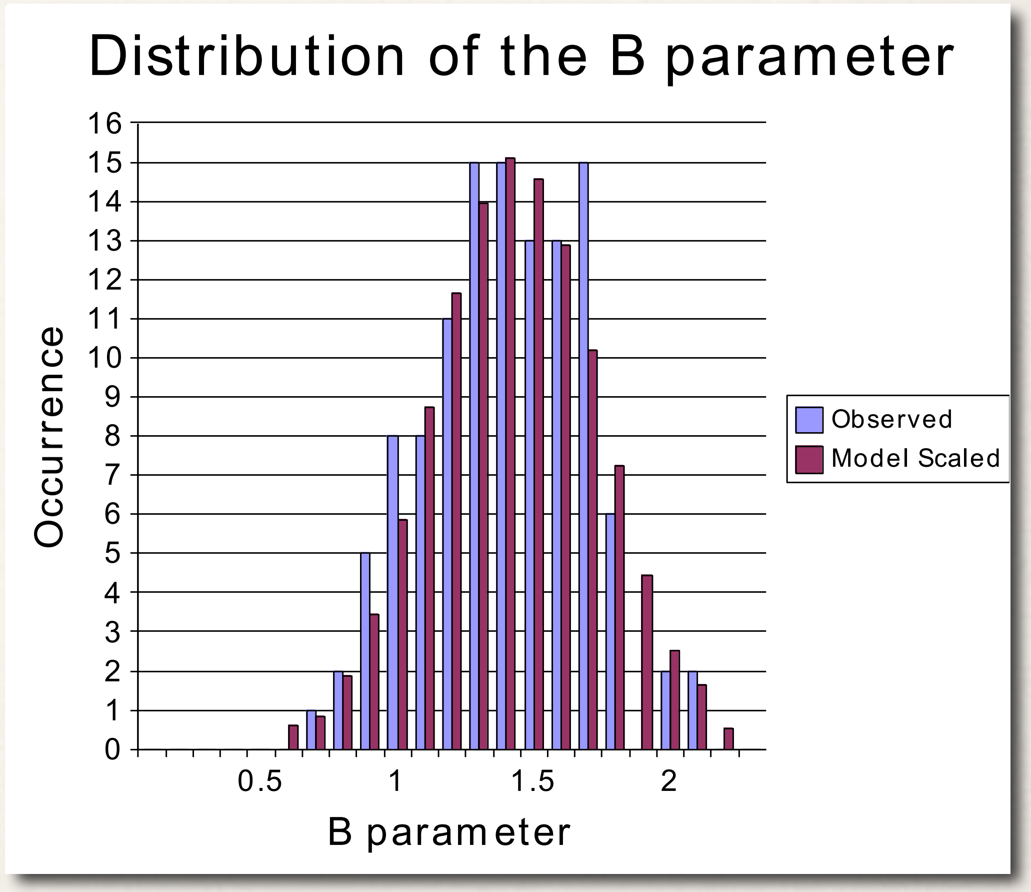


Storm Parameters

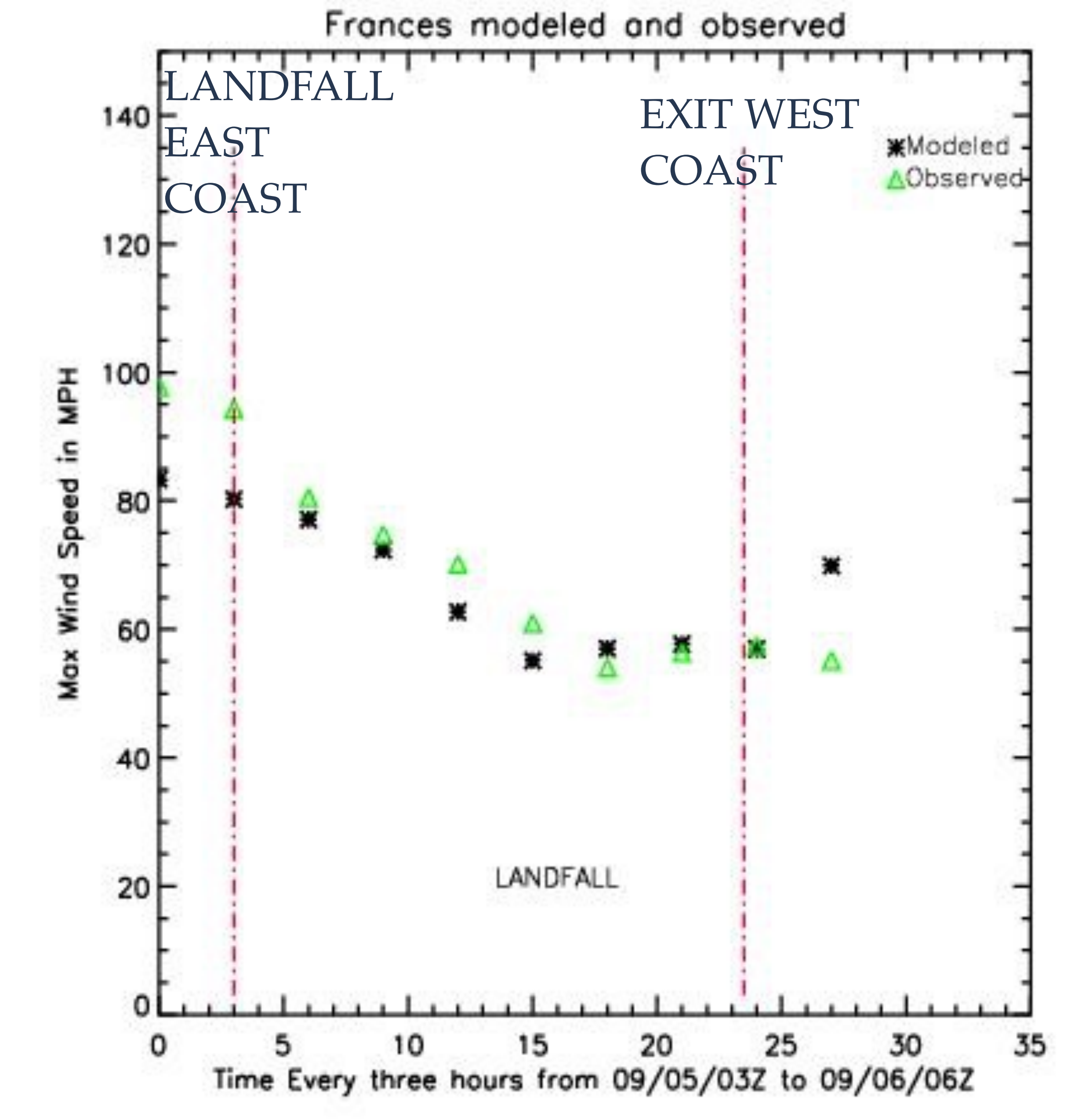
- Rmax modeled by Gamma distribution

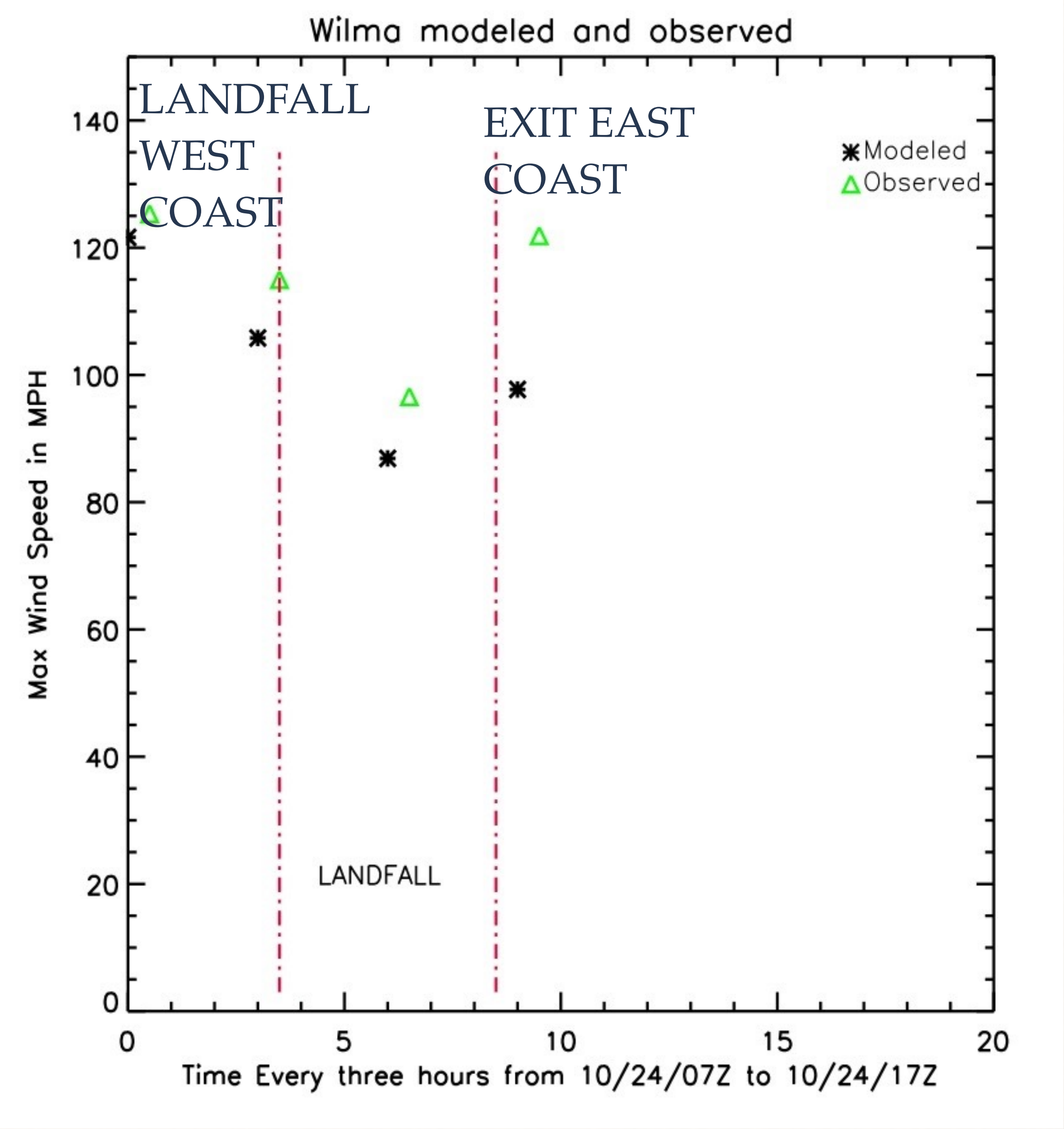
- Holland B modeled by linear regression with residual fitted by a Gaussian distribution





- Landfall decay





Wind Model

- Numerical solution of a “slab” model of the hurricane boundary layer, 450 m deep over ocean, 1 km deep over land (see Powell et al, 2005)
- Includes surface friction, with different drag coefficient over land vs water. Based on GPS sonde data.
- Initialized by a vortex in gradient balance with pressure field described by a Holland B profile.
- Mean wind of the slab is converted to a surface wind based on GPS sonde research

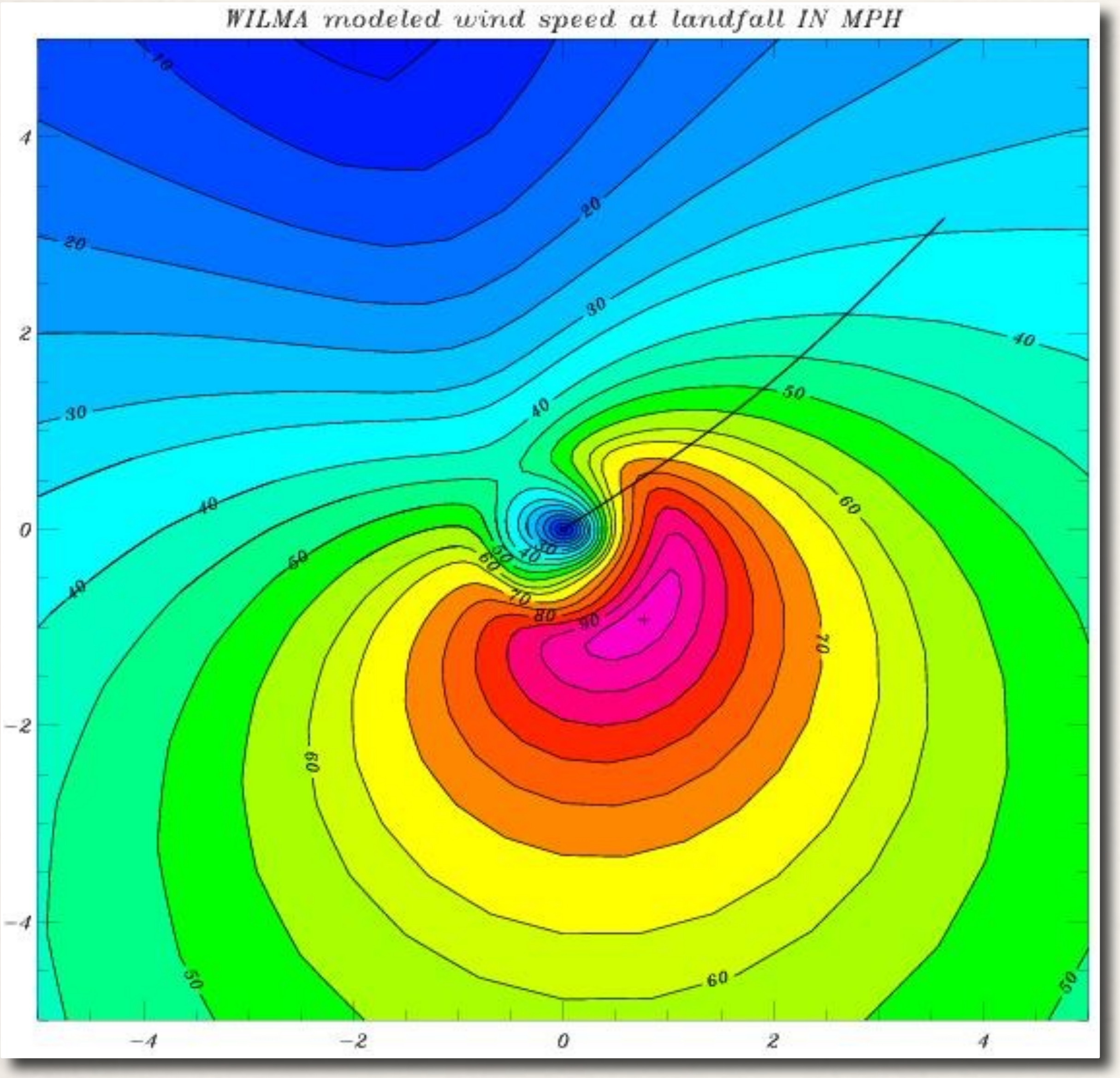
Wind Model Validation

Comparison and analysis vs H*Wind

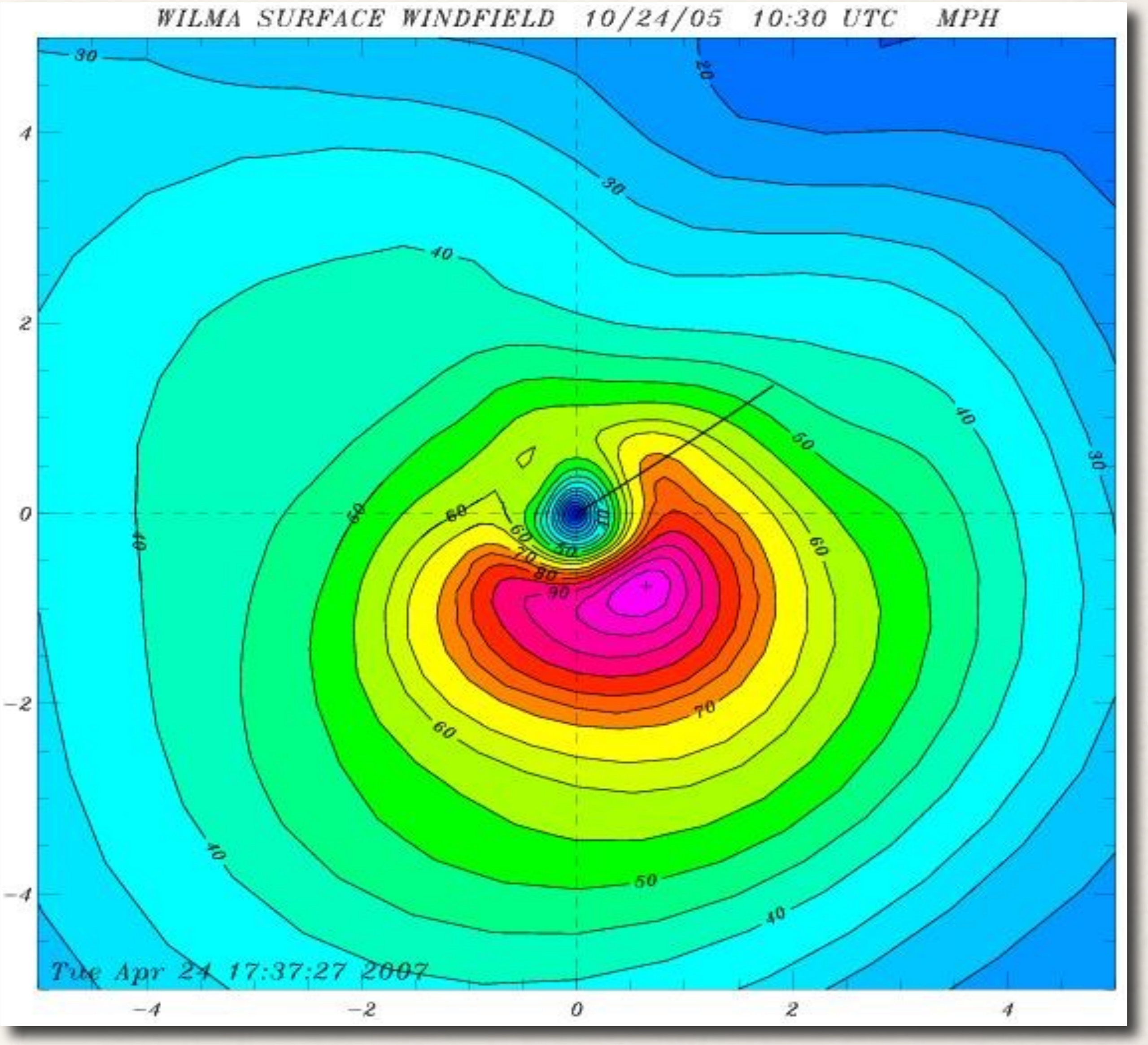
- 1992: Andrew
- 2004: Charley, Frances, Ivan, Jeanne
- 2005: Dennis, Katrina, Rita, Wilma

MODEL VS H*WIND snapshot

WILMA
MODELED

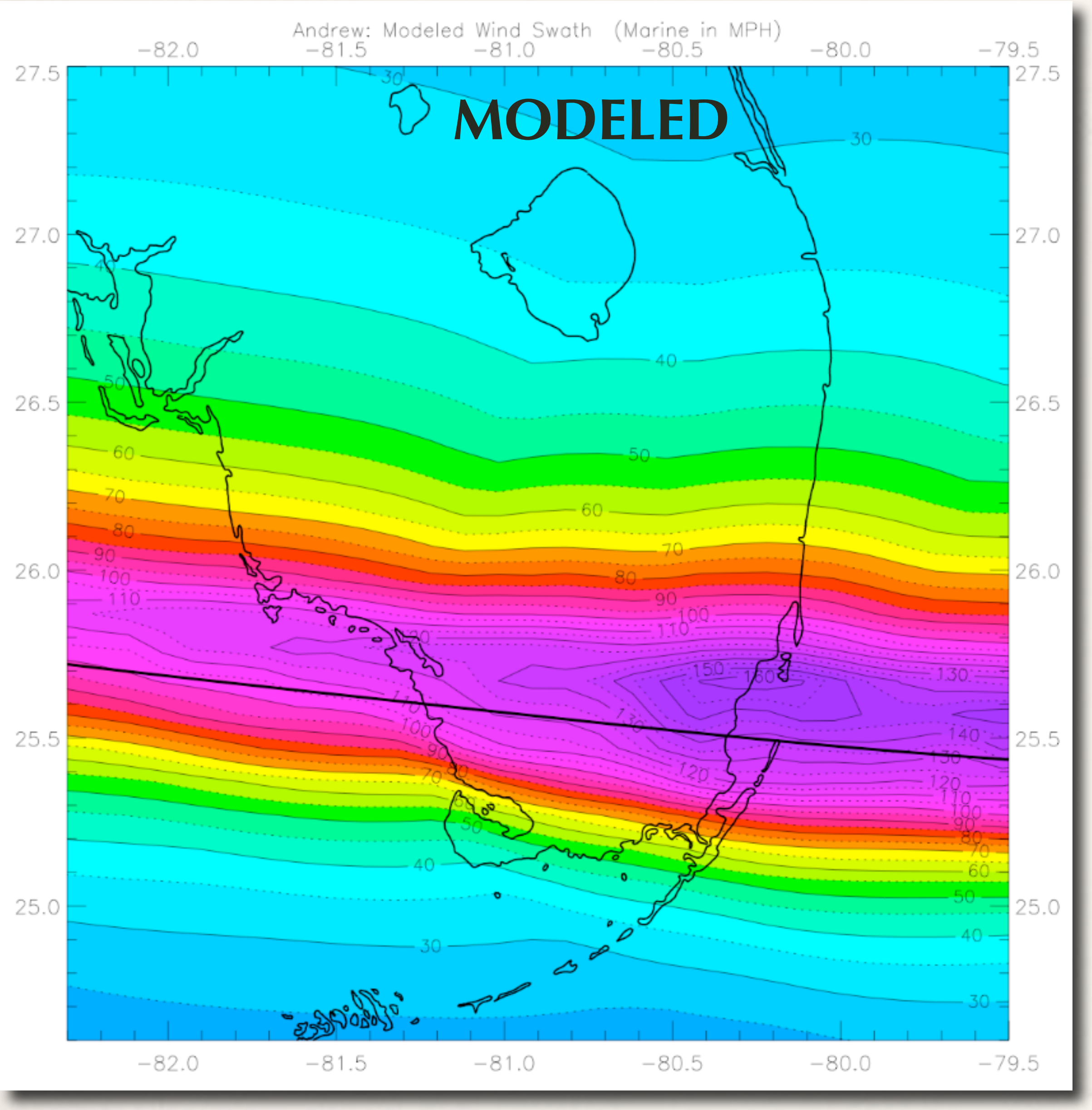


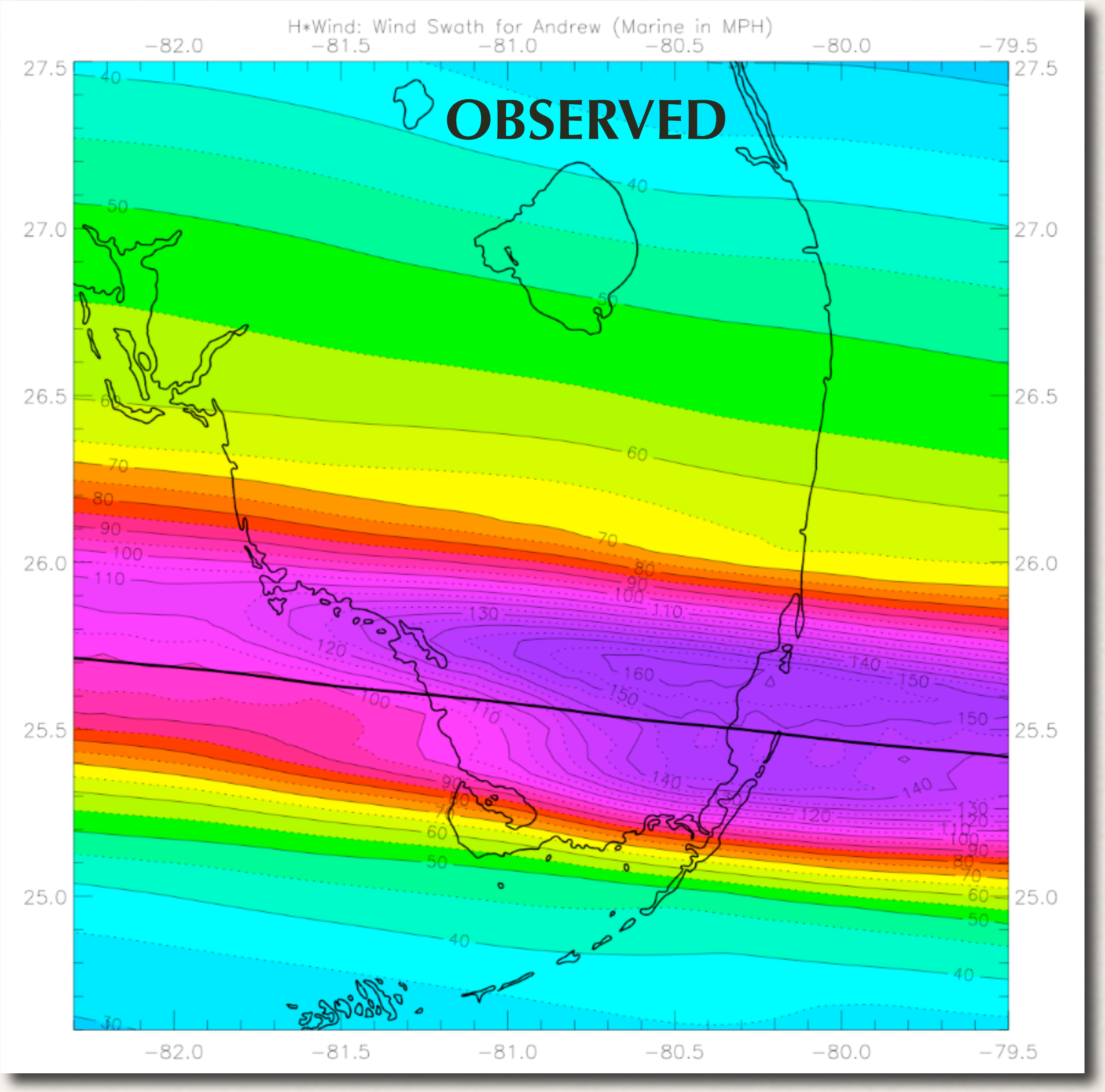
WILMA
OBSERVED



MODEL VS H*WIND SWATH

ANDREW





Terrain Adjustment

- Winds are adjusted to terrain conditions using an effective roughness model and a coastal transition function for locations near the coast

- The effective roughness model determines the effect on roughness due to upstream land cover elements in each 45 degree sector.

- Effective roughness is computed at roughly 90 m resolution over Florida. For ZIP code policies, the roughness used is the population weighted effective roughness over the ZIP code.

- Roughness derived from 2011 National Land Use / Land Cover and Florida Water Management District data (2004-2011)

Terrain Adjustment

- For locations near the coast, a coastal transition function is used to account for the transition of the wind being in equilibrium with marine roughness to subsequently being in equilibrium with land roughness.

- Gust factor model based on ESDU is used to determine 1 minute sustained and 3 second gusts at the 10 m reference level.

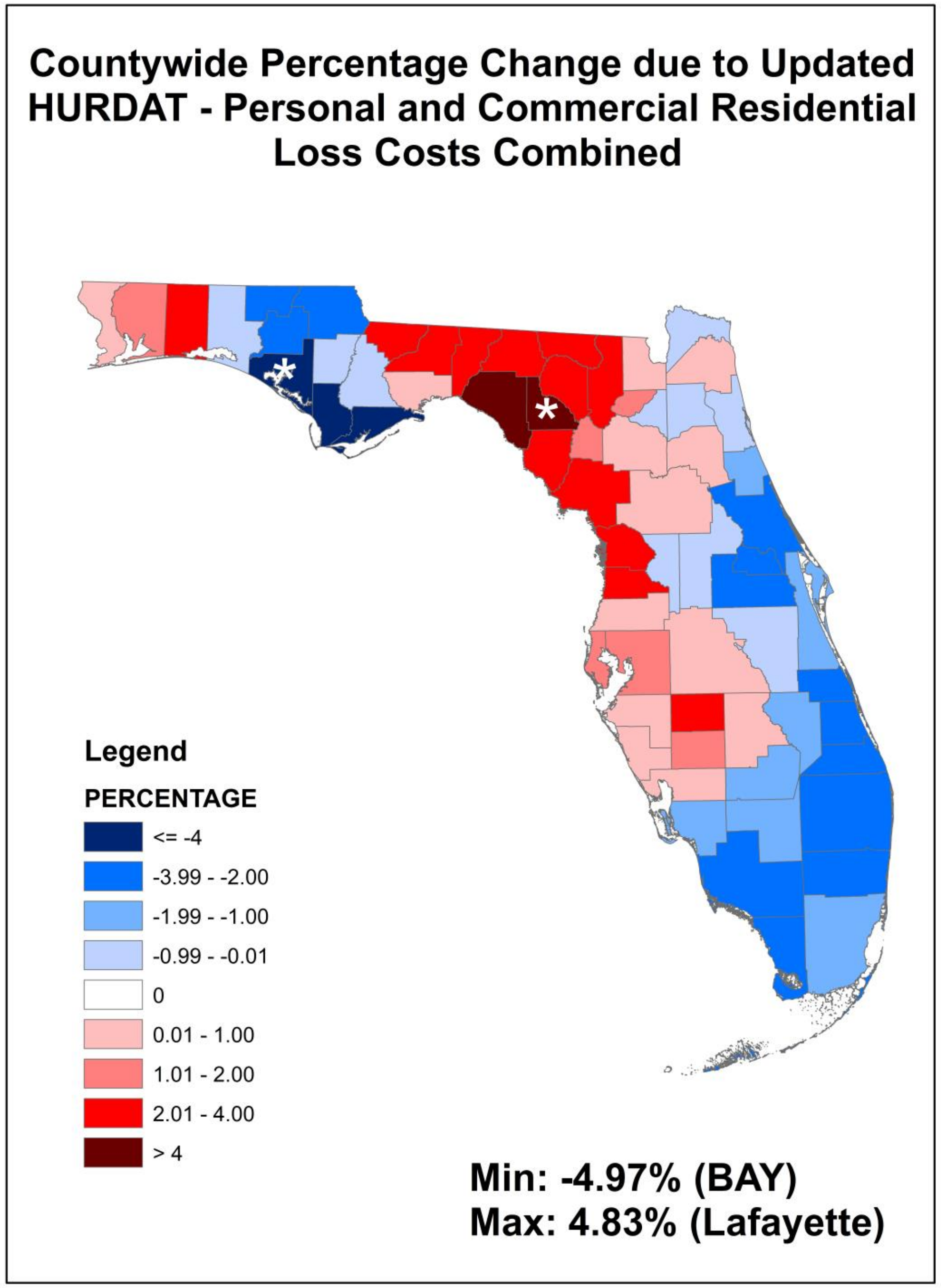
MET Changes from v6.1 to v6.2

- Storm seeds and motion/intensity change PDFs were updated using a new version of HURDAT2: FPHLM v6.2 uses the February 2016 version, while v6.1 used the April 2014 version.

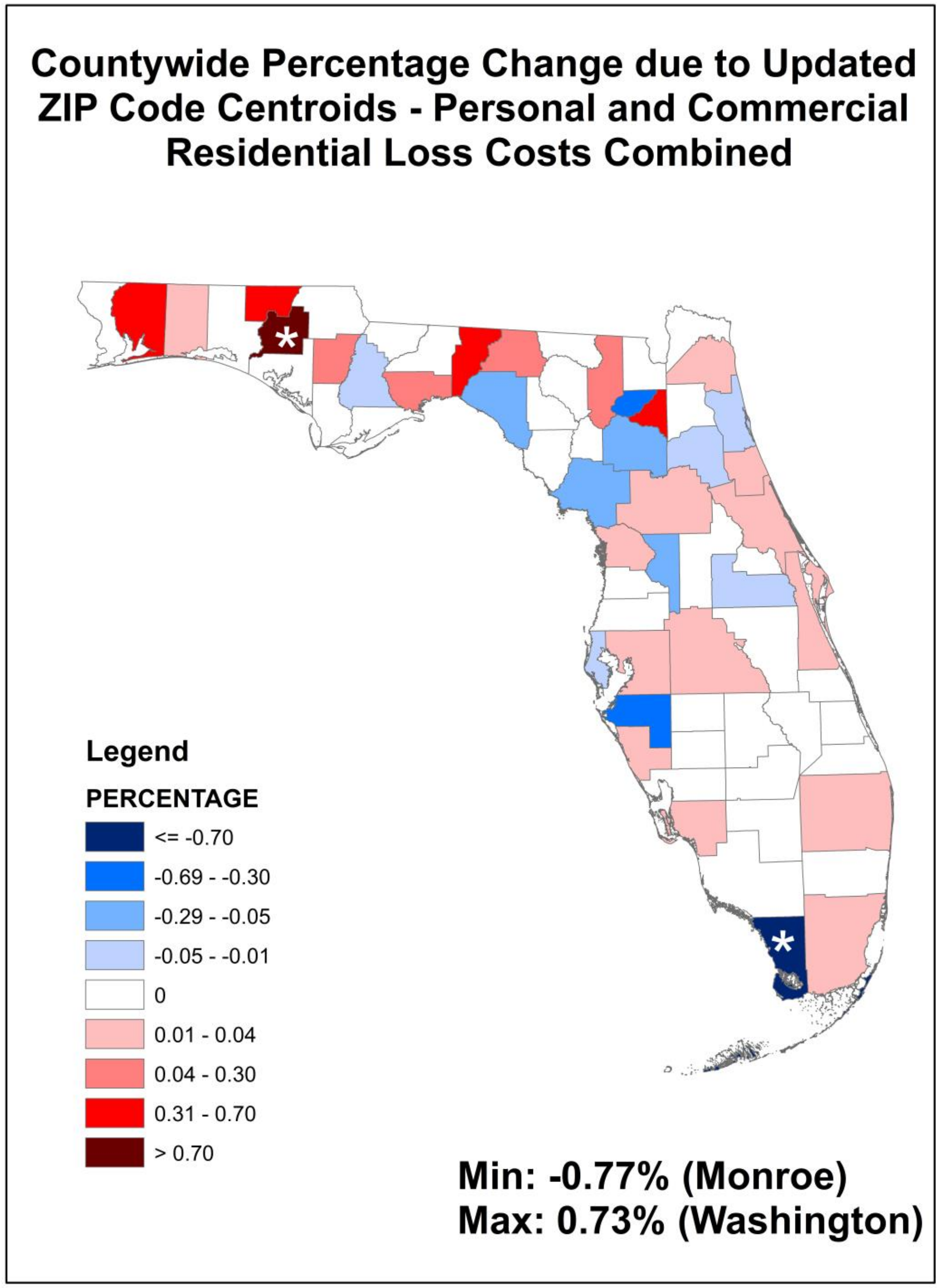
- ZIP code database was updated: FPHLM v6.2 uses the March 2015 version, whereas v6.1 used the December 2013 version.

Impact of MET Component Changes

HURDAT: -1.54%



Zip Code : -0.02%



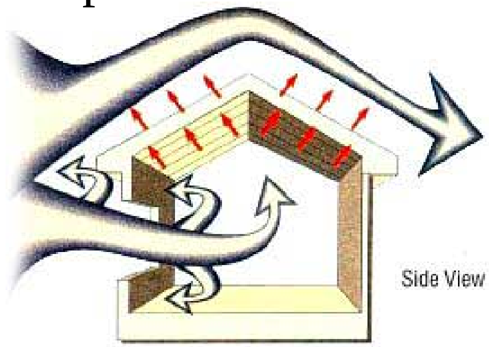
Florida Public Hurricane Loss Model

Personal Residential Model
FPHLM

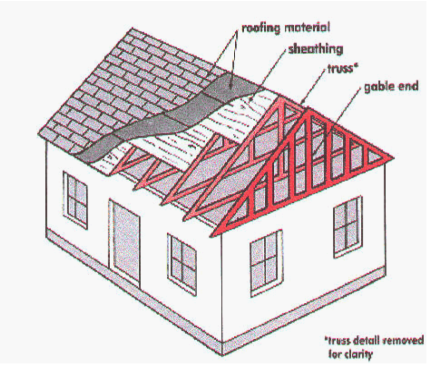
Research Objectives

Determine types

Translate wind speed into loads



Quantify wind resistance



Monte Carlo Simulation

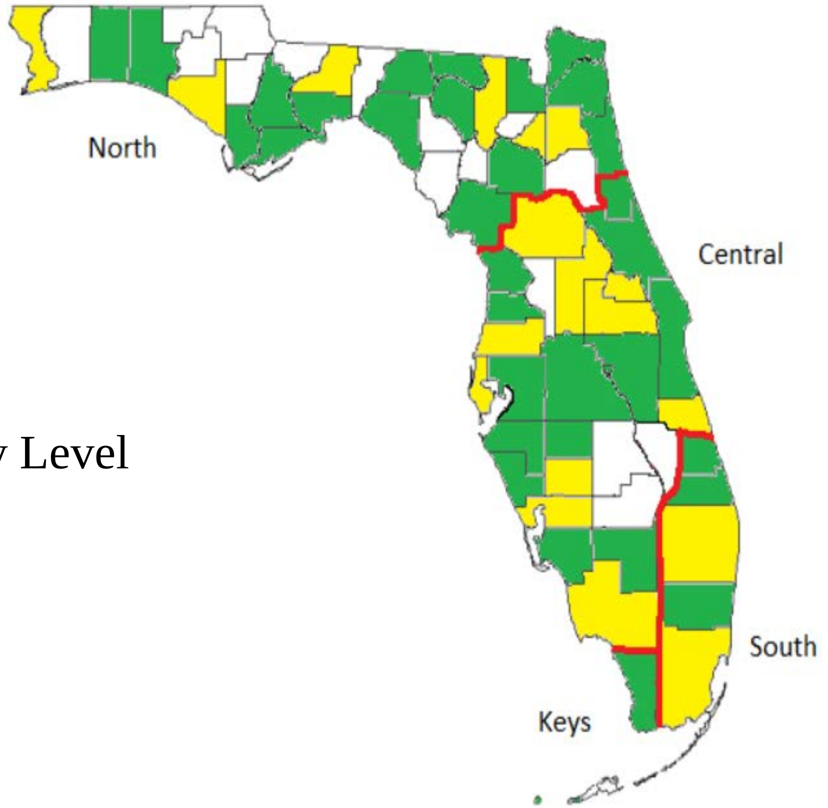
%

Quantify damages

Sampling Plan
(Surveyed Counties and Regions)

Property Appraiser Data Bases

- Varies from county to county
- 67 Counties were contacted
- Statistical Survey on 51 Counties
  - Yellow: 2014 tax roll
  - Green: pre-2014
- Population Coverage: 97%
- Statistical Data in Regional and County Level
- Statistical Data inside each Era

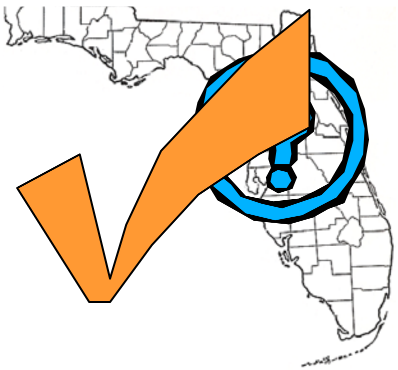


Resulting Classification

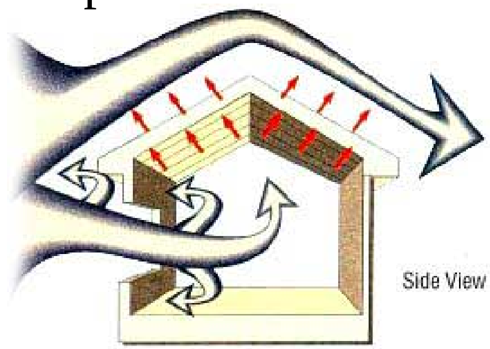
Roof Cover	Roof Type	**Exterior Wall**	Number of Story
Shingle	Gable	Wood frame	1
Tile - Metal	Hip	Masonry	2
Others	Other	Other	more

Research Objectives

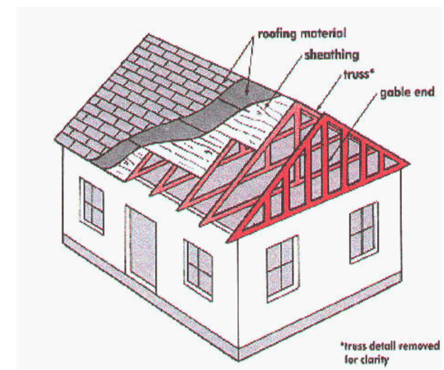
Determine types

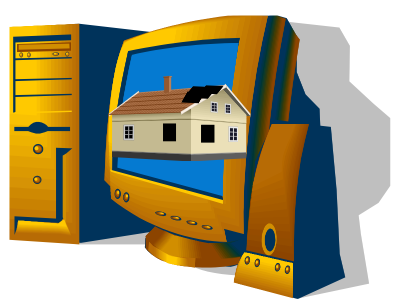


Translate wind speed into loads



Quantify wind resistance





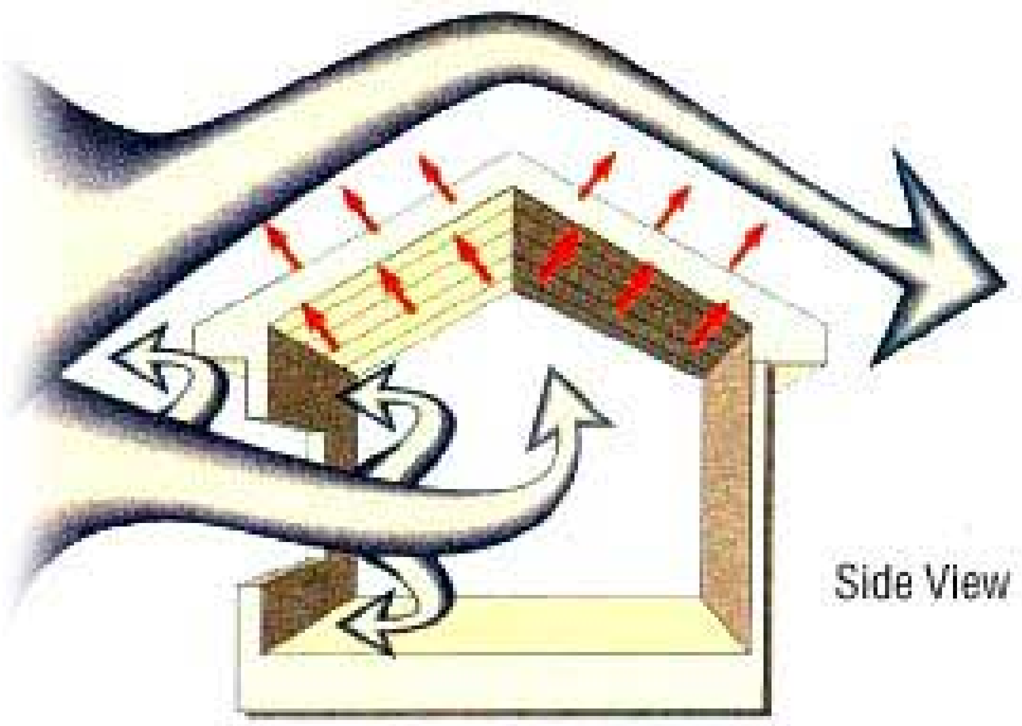
Monte Carlo Simulation

%

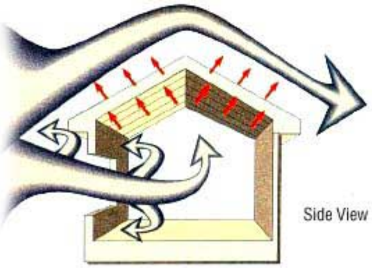
Quantify damages

Wind Speed → Wind Load

- Translate wind speed to the pressures and forces on the building

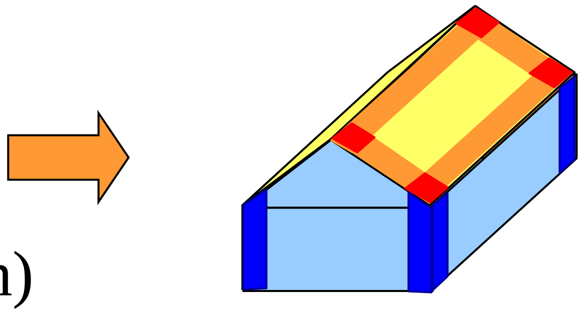


Component Wind Loads



Input

Discrete 3 sec wind speed (e.g.V = 110 mph)



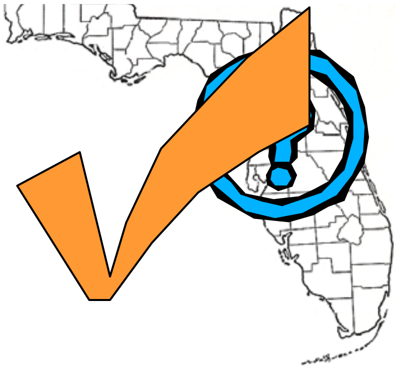
Output

Component loads/pressures (e.g. one sheathing panel)

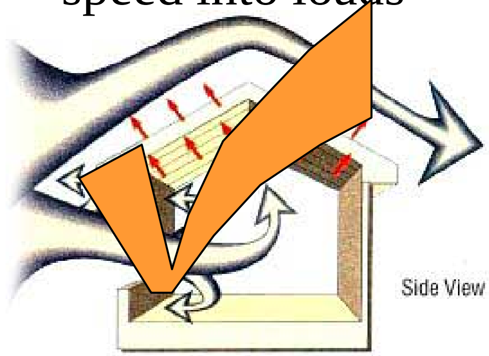
- Sources:
  - Wind load provisions in code
  - Directional modifications
  - Full scale measurement
- Influences:
  - Building shape
  - Wind direction

Research Objectives

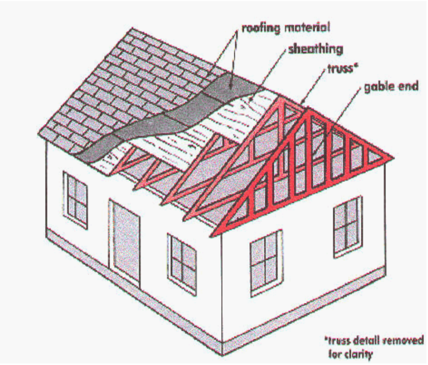
Determine types



Translate wind speed into loads



Quantify wind resistance



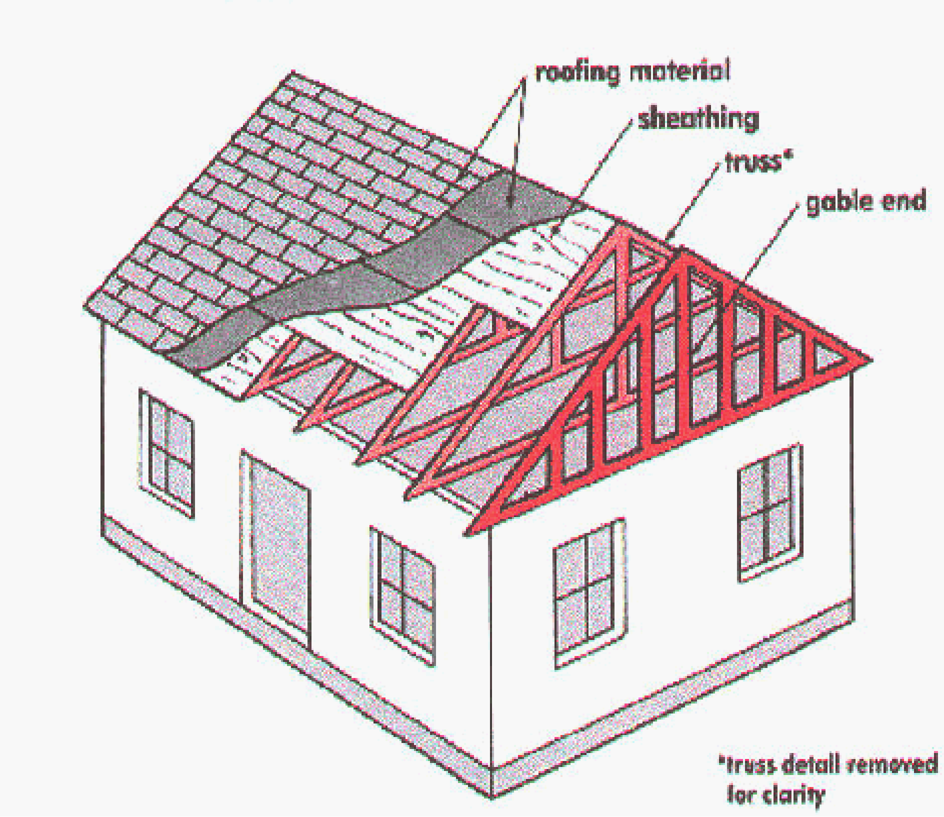
Monte Carlo Simulation

%

Quantify damages

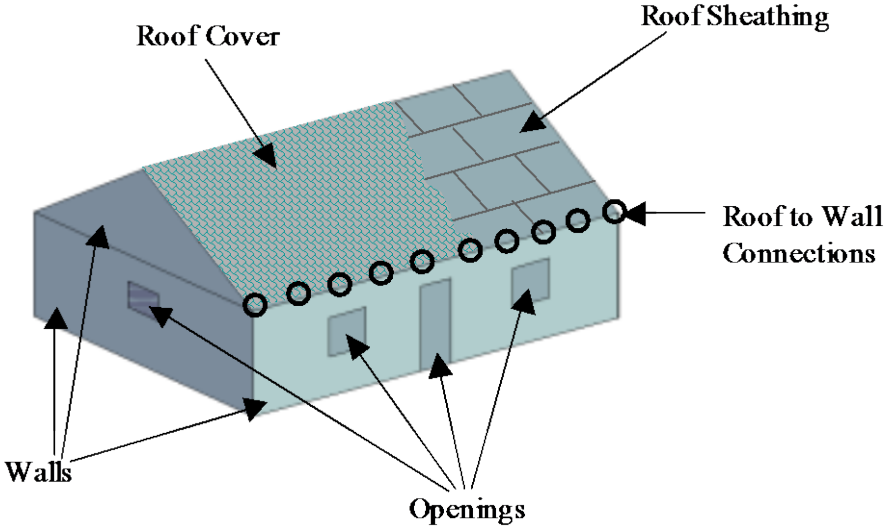
Component Resistance to Wind

- For each structural type
  - Identify major components
  - Model the capacity of each component
  - Determine Load Paths



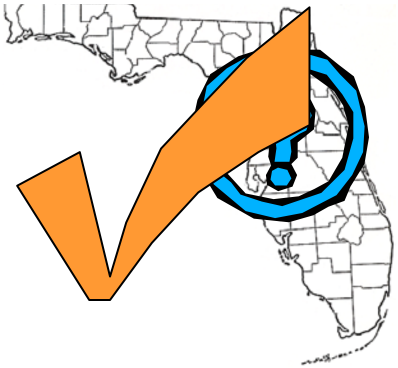
Residential Components

- Type: e.g., Concrete Block, Gable Roof
- 5 Selected components
  - Roof cover
  - Roof sheathing
  - Roof to Wall Connections
  - Walls (frame, masonry)
  - Openings

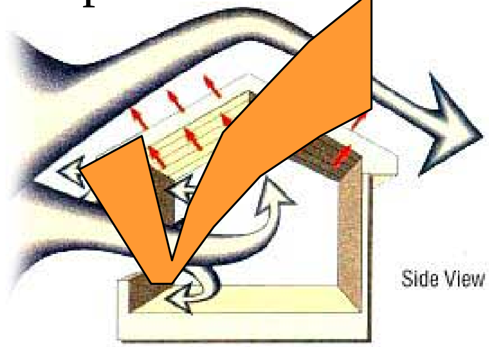


Research Objectives

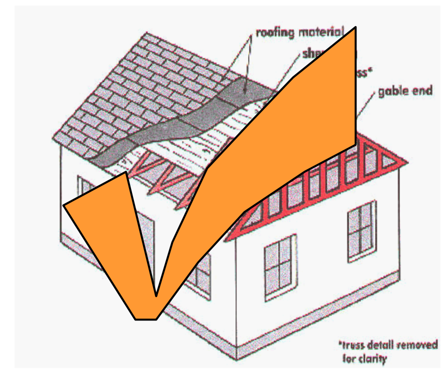
Determine types

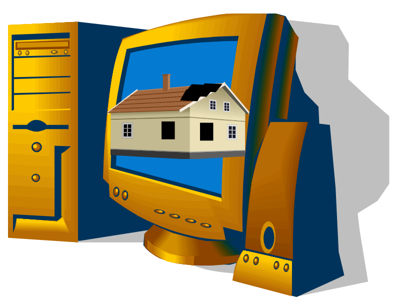


Translate wind speed into loads



Quantify wind resistance



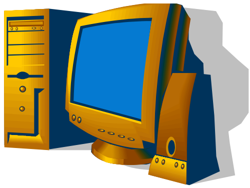


Monte Carlo Simulation

%

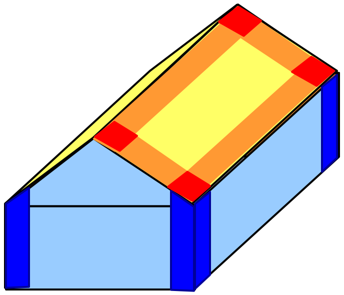
Quantify damages

Monte Carlo Simulation Engine

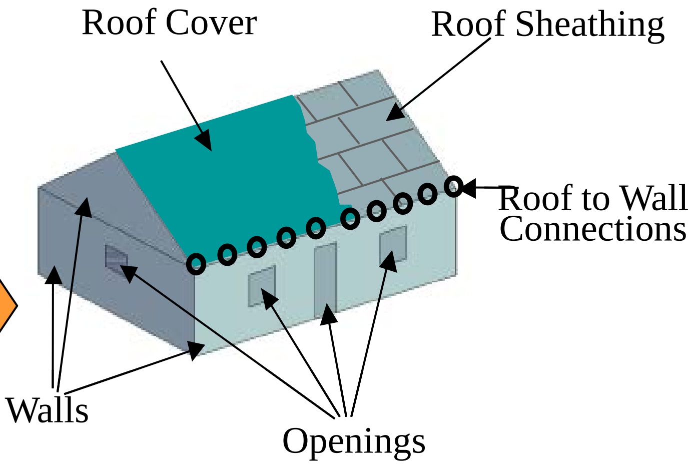


INPUT

Random 3 sec wind speed (e.g.V = 110 mph With COV = 0.1)



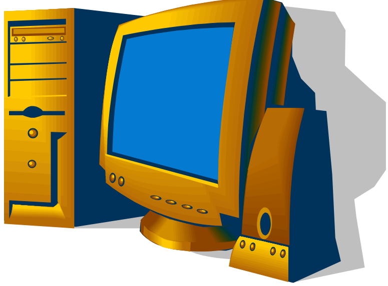
LOAD: Modified Pressure Coefficients from ASCE 7 Randomized



DAMAGE

Random component capacities

Damage Prediction



- Damage Matrix for:
  - Each structural type
  - Wind speeds 50 – 250 mph in steps of 5 mph
  - Eight wind directions

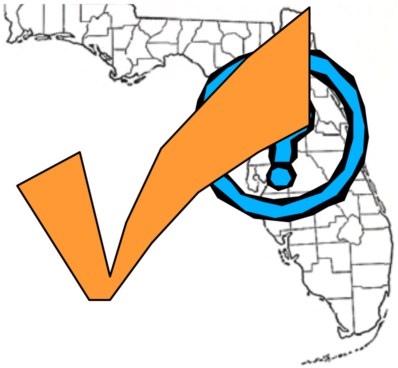
Example Damage Matrix

- Partial sample of an output file for a concrete block home, in South FL, with a gable roof, and no hurricane shutters, subjected to a 150 mph 3-sec wind gust at an angle of 45 degrees

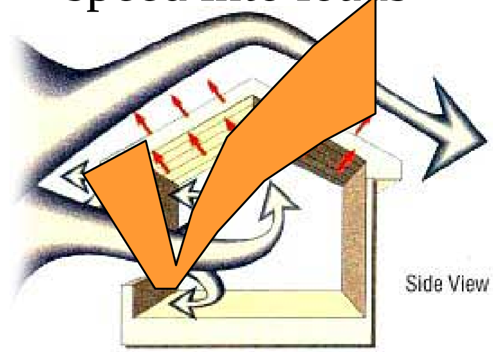
% failed Sheathing	% failed roof cover	% failed Connections	# failed walls	# of failed windows	# of failed doors	failed Garage (1=yes, 0=no)	Breach of Enveolpe (1=yes, 0=no)	# of failed windows by impact	% Gabel Ends Damaged
7.21	23.56	6.76	0.00	2.00	1.00	0.00	1.00	2.00	0.00
13.46	24.52	0.00	0.00	4.00	1.00	0.00	1.00	3.00	3.85
12.02	22.12	9.46	0.00	3.00	1.00	0.00	1.00	1.00	3.85
5.77	19.71	0.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00
9.62	25.00	0.00	0.00	2.00	1.00	0.00	1.00	1.00	0.00
6.25	15.87	0.00	0.00	2.00	0.00	0.00	1.00	1.00	3.85
7.69	23.08	4.05	0.00	5.00	1.00	0.00	1.00	3.00	11.54
10.10	26.92	0.00	0.00	3.00	1.00	0.00	1.00	2.00	0.00
7.21	24.52	0.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00
2.88	21.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.37	23.56	2.70	0.00	2.00	1.00	0.00	1.00	2.00	0.00
8.65	23.08	1.35	0.00	4.00	1.00	0.00	1.00	3.00	3.85
5.29	29.33	0.00	0.00	3.00	0.00	0.00	1.00	2.00	0.00

Research Objectives

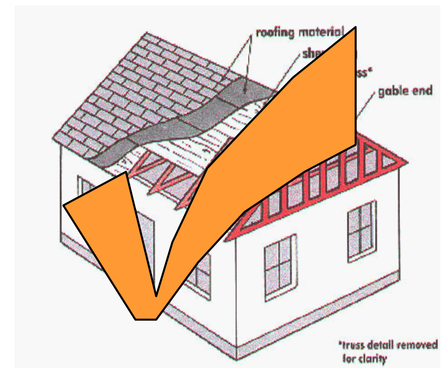
Determine types



Translate wind speed into loads



Quantify wind resistance



Monte Carlo Simulation

%

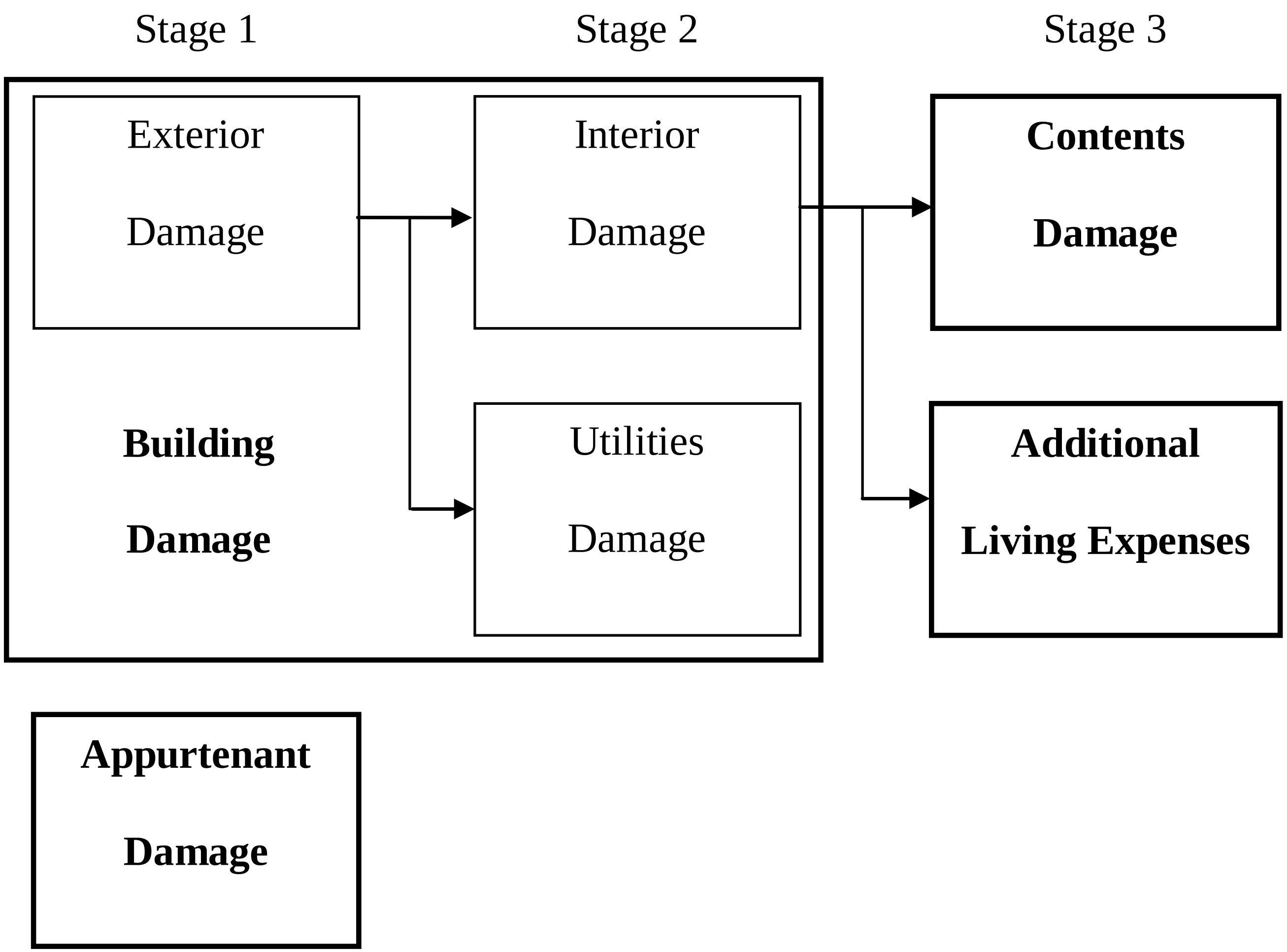
Quantify damages

Cost Estimation Model

- From the Damage Matrices
  - Convert modeled physical damages into monetary damages
  - Define the vulnerability of different homes types
  - Provide a logical method for prediction damage to other coverage’s
  - Validate the damage predictions
  - Input from experts (adjusters, etc.)

Different Types of Damage

%



Vulnerability Matrices

- Model Type - Specific to each Monte Carlo model (36 models) plus additional considerations for each (6*36 = 216)

Damage\Wind Speed (mph)	48.5 to 52.5	52.5 to 57.5	57.5 to 62.5	62.5 to 67.5	67.5 to 72.5
0% to 2%	1	0.99238	0.91788	0.77312	0.61025
2% to 4%	0	0.00725	0.0805	0.21937	0.36138
4% to 6%	0	0.000375	0.001375	0.007	0.0235
6% to 8%	0	0	0.000125	0.000375	0.0025
8% to 10%	0	0	0	0	0.000375
10% to 12%	0	0	0	0	0.000375
12% to 14%	0	0	0	0	0.000625
14% to 16%	0	0	0	0	0.0005
16% to 18%	0	0	0	0	0.000125
18% to 20%	0	0	0	0	0.000125
20% to 24%	0	0	0	0	0.00025
24% to 28%	0	0	0	0	0

Weighted Matrices

Insurance Portfolio
Location: Define region and sub region.
Year Built: use as proxy for Strength (Weak, Medium, Strong).
Type of exterior wall.

- Roof shape, roof cover, number of stories, and opening protection options are undefined.

- The weighted matrices are the sum of the corresponding vulnerability model matrices weighted on the basis of the statistical distributions;

- The user has the option to predict the type of the building (use non_weighted) or use weighted matrices.

Mapping of Vulnerabilities to Insurance Policies

case 1 is the case where all parameters are known

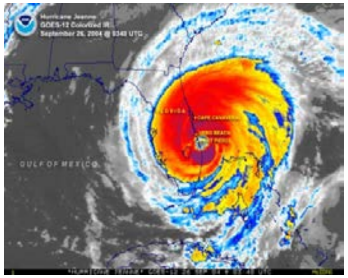
Insurance Portfolio Data	Year Built	Exterior Wall	Vulnerability Matrix
Case 2	known	Known or unknown	use **weighted** matrix or replace all unknown and other randomly based on stats and use **un-weighted** matrix
Case 3	known	other	use the **other weighted** matrix
Case 4	unknown	known	use **age weighted** matrix or replace all unknown and other randomly based on stats and use **un-weighted** vulnerability matrix
Case 5	unknown	other	Use ***other* age weighted** matrix

Note: in cases 2 to 5 the attributes for # of stories, roof shape, roof cover, & opening protection are in any combination of known, unknown or other.

Mitigation

- The model has the capacity to model different mitigation measures either individually or in combinations
- Details are provided in discussion of form V-2

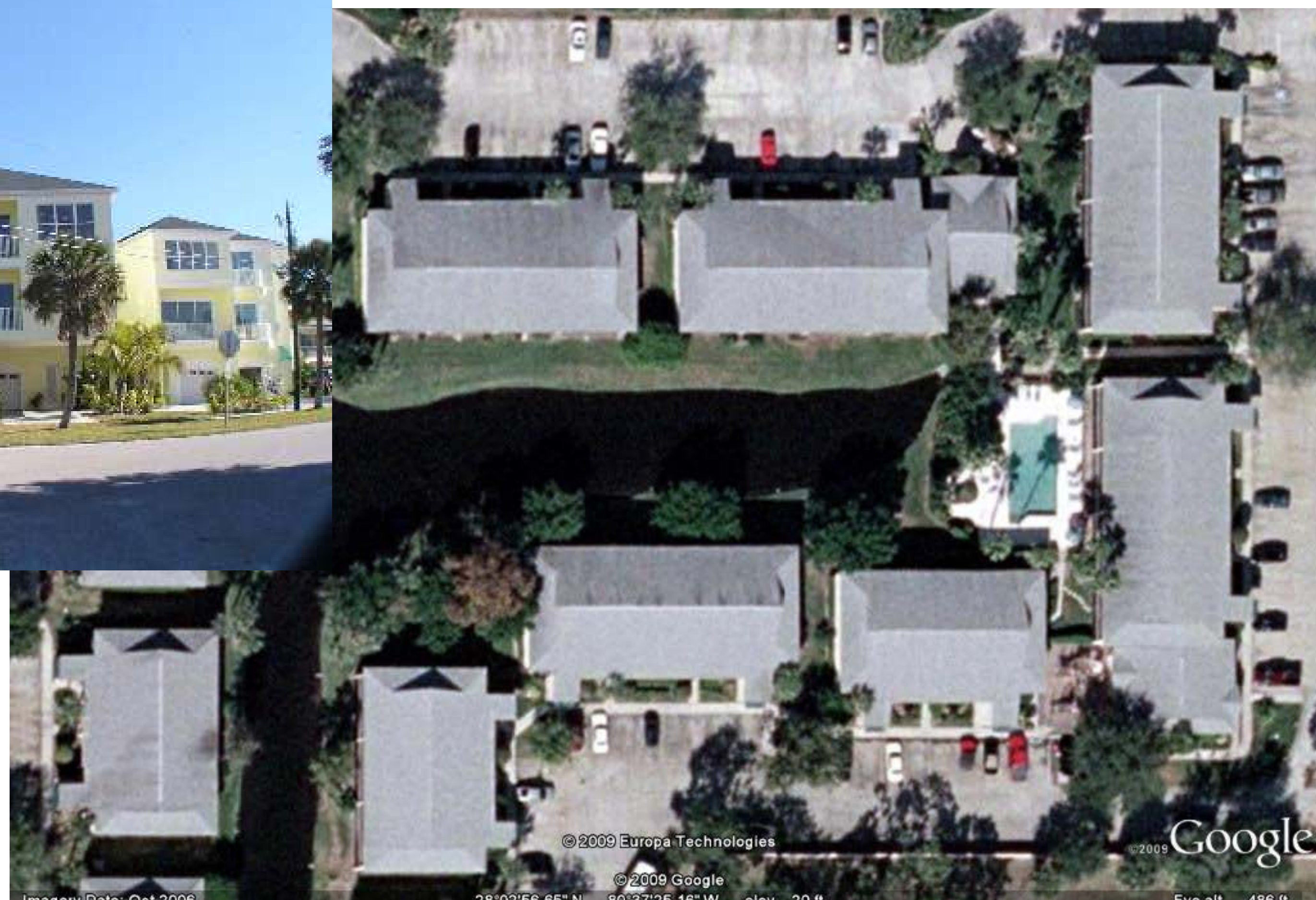
Florida Public Hurricane Loss Model



Commercial Residential Model FPHLM

Low-Rise

Low-rise commercial residential:1-3 stories mainly apartment buildings

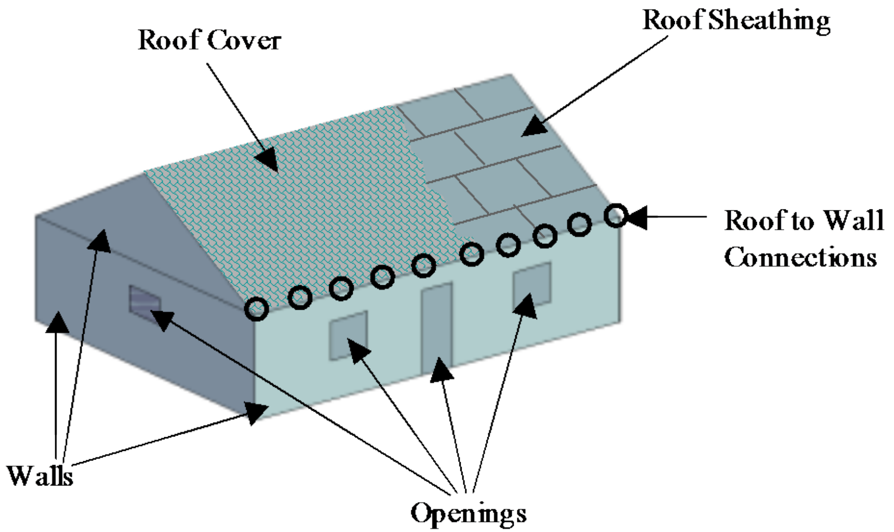


Low-rise Modeling

- Low-rise buildings are ***very similar*** to single-family-homes
  - Can be categorized in a few typical generic buildings
  - Can suffer substantial external structural damage (in addition to envelope and interior damage) including complete collapse
  - Modeling approach is similar to single family homes: **the building is modeled as a whole**

Low-Rise Buildings
Components

- Type: e.g., Concrete Block, Gable Roof
- Selected components
  - Roof cover
  - Roof sheathing
  - Overhang
  - Gable end trusses
  - Roof to wall connections
  - Wall covering
  - Wall sheathing
  - Openings: windows, sliding doors, entry doors
  - Soffits

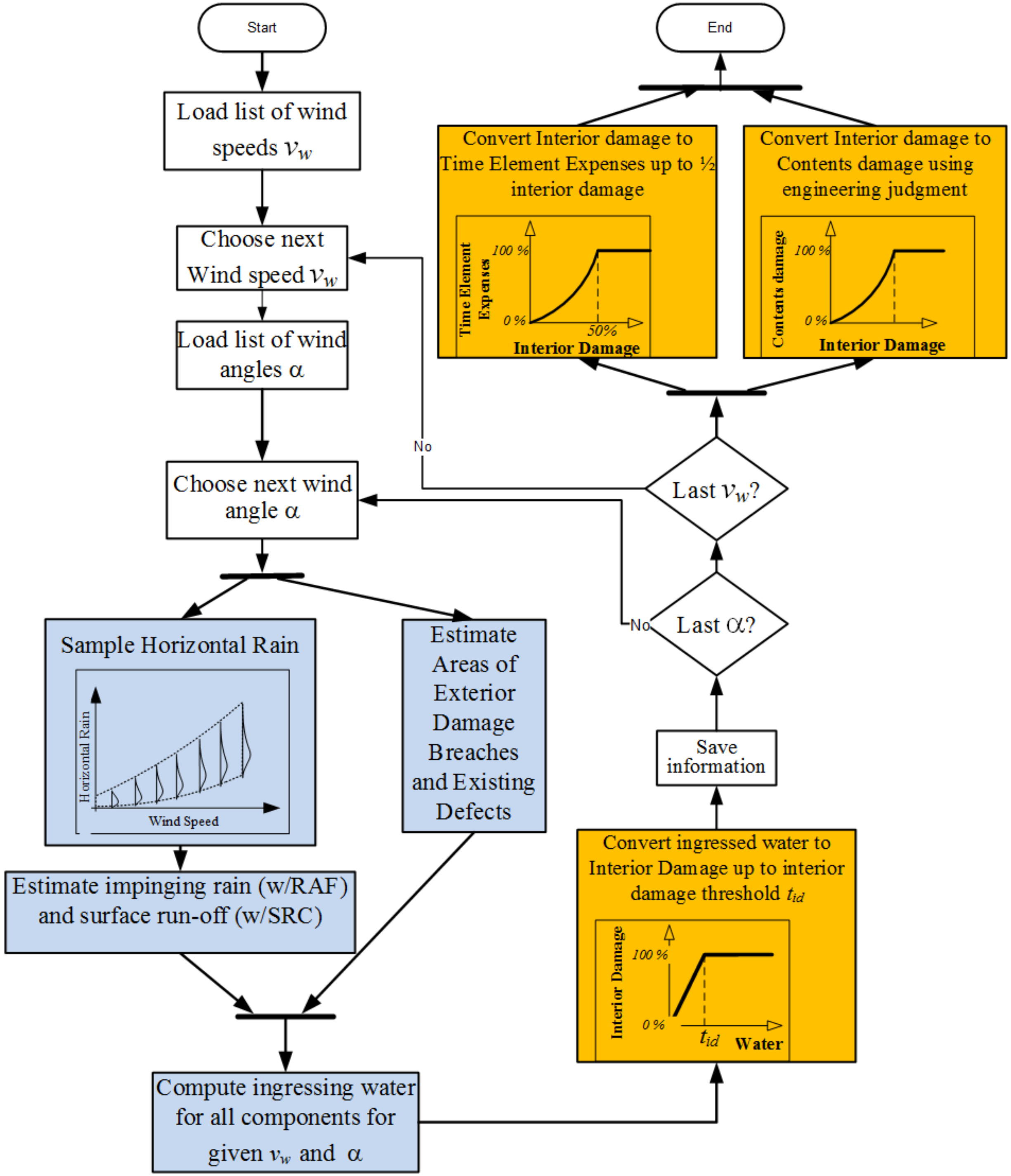


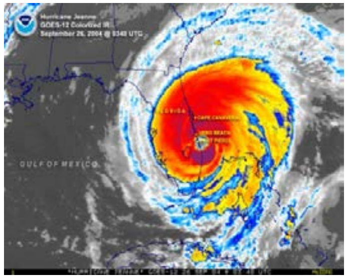
Low-rise building main types

Table 4: LR most prevalent buildings types

Category	Wall type	Roof Cover	Roof Type
Main Building types	CB	Shingles	Gable
	CB	Shingles	Hip
	Wood	Shingles	Gable
	Wood	Shingles	Hip
Windows	Shuttered / Impact-resisting / Not impact-resisting		
No. of Stories	1 / 2 / 3		
Building strength	Strong, Medium, Weak		
Alternative Roof Cover	Metal or Tiles		

Low rise model





Florida Public Hurricane Loss Model

Commercial Residential Model
FPHLM

Mid/High-Rise

Variety of mid/high-rise buildings: 4+ stories mainly condominium buildings

Mid-rise Modeling

- Mid-rise buildings are ***very different*** to single-family-homes
  - They are highly variable in shape, height, material, etc
  - Cannot be categorized in a few generic building types
  - Engineered structures that suffer little external structural damage and are unlikely to collapse
  - Can suffer extensive cladding and opening damage leading to water penetration and interior damage
  - FPHLM adopts a **modular approach : the building is treated as a collection of apartment units**

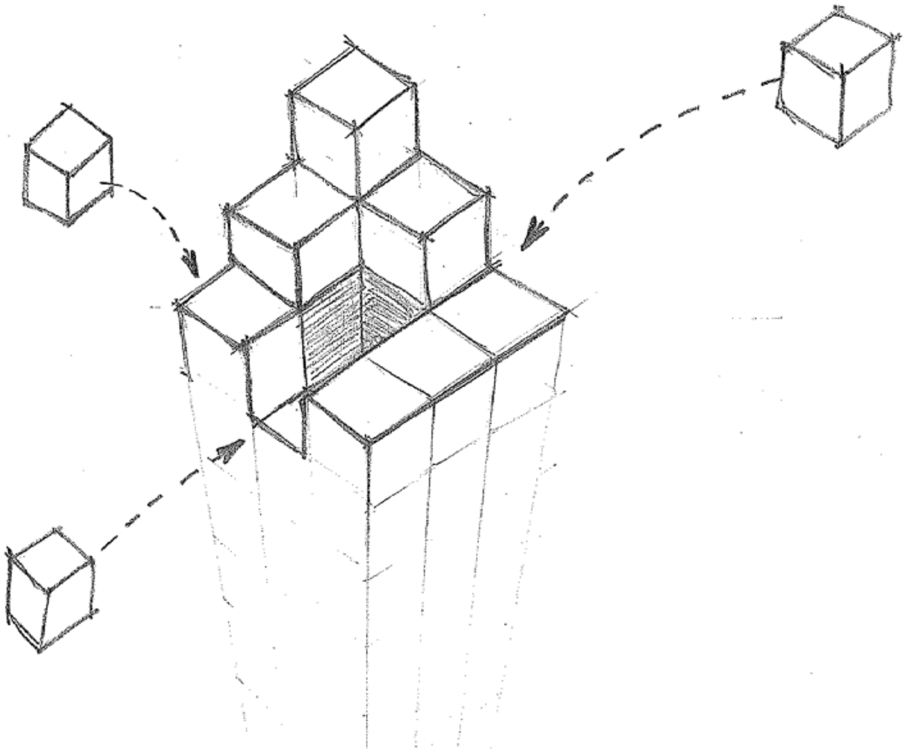
Mid-high rise
buildings characterization

Closed Building

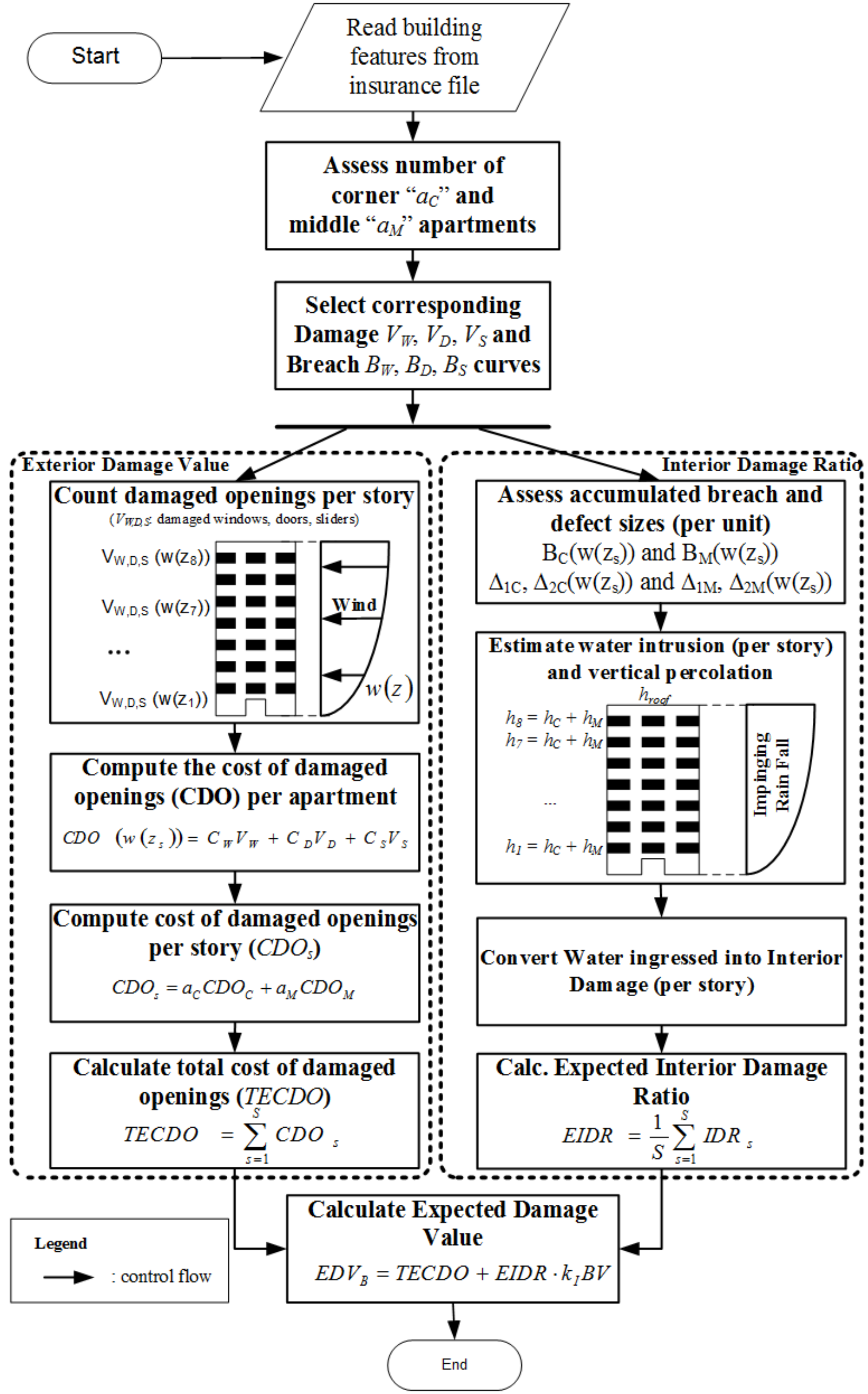
Open Building

MHRB
Modular Unit Components

- Type: e.g., Enclosed building, Corner Unit, No shutters, 6 windows
- Selected components
  - Windows
  - Entry Door
  - Sliding Door
- Action
  - Pressure
  - Impact
- State
  - undamaged
  - Damaged but not breached
  - Damaged and breached



Vulnerabilty Model of mid/high-rise buildings (MHRB)



Florida Public Hurricane Loss Model

Vulnerability Model Changes

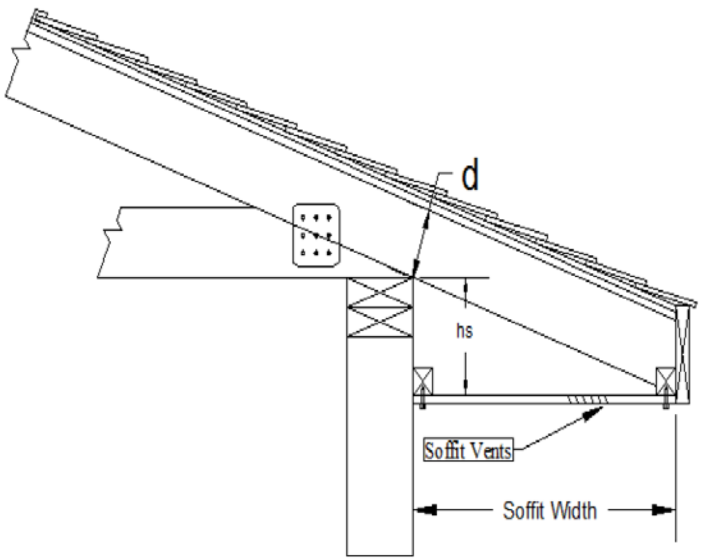
Changes

- Low-rise Commercial Residential Model:
  - Calculation of soffit areas
  - Updates to wind driven rain model
  - Update of exposure statistics, leading to changes in the weighted matrices.

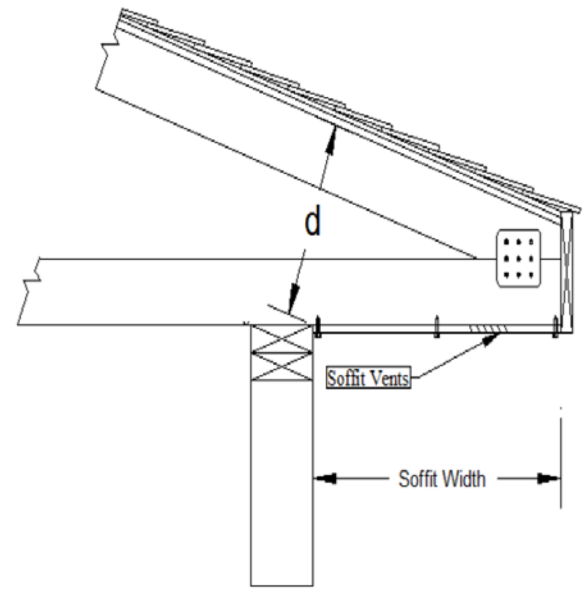
- Personal Residential Model:
  - Update of exposure statistics, leading to changes in the weighted matrices

Soffit area

V6.1 Recessed soffit



V6.2 Flush soffit



- Effect of the change is an increase in vulnerability, mainly at wind speeds under 200mph.

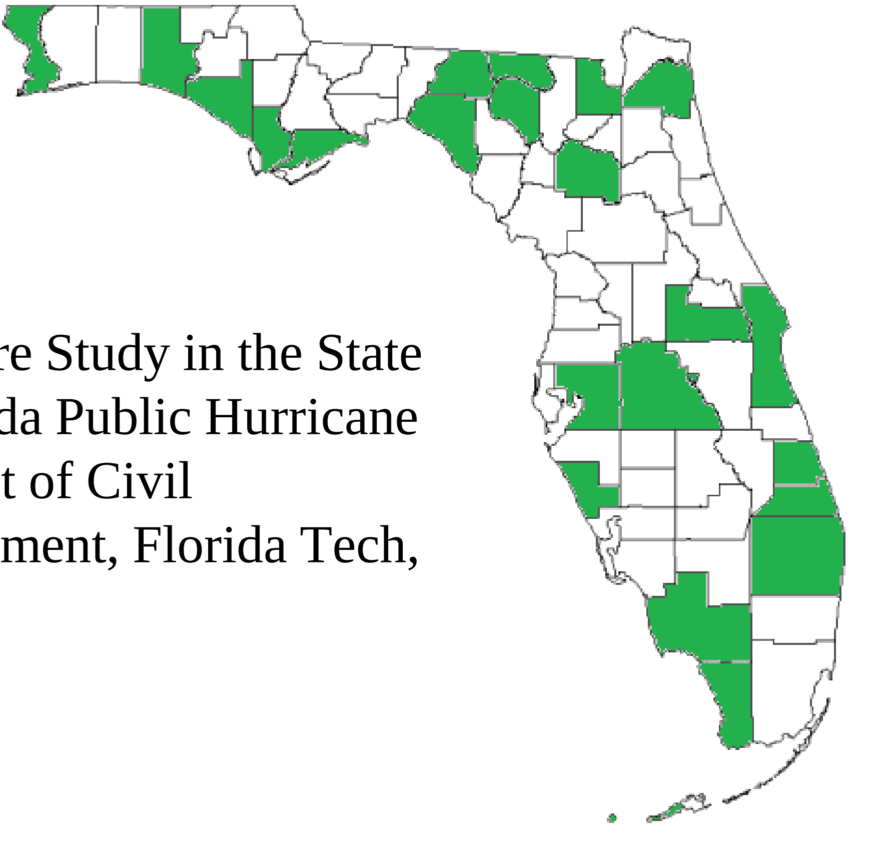
Wind Driven Rain Model

- Two minor adjustments made to the method of sampling wind driven rain parameters

- Effects: the two changes come close to cancelling each other out, with minimal change in overall loss

Exposure Statistics: Low-rise commercial residential

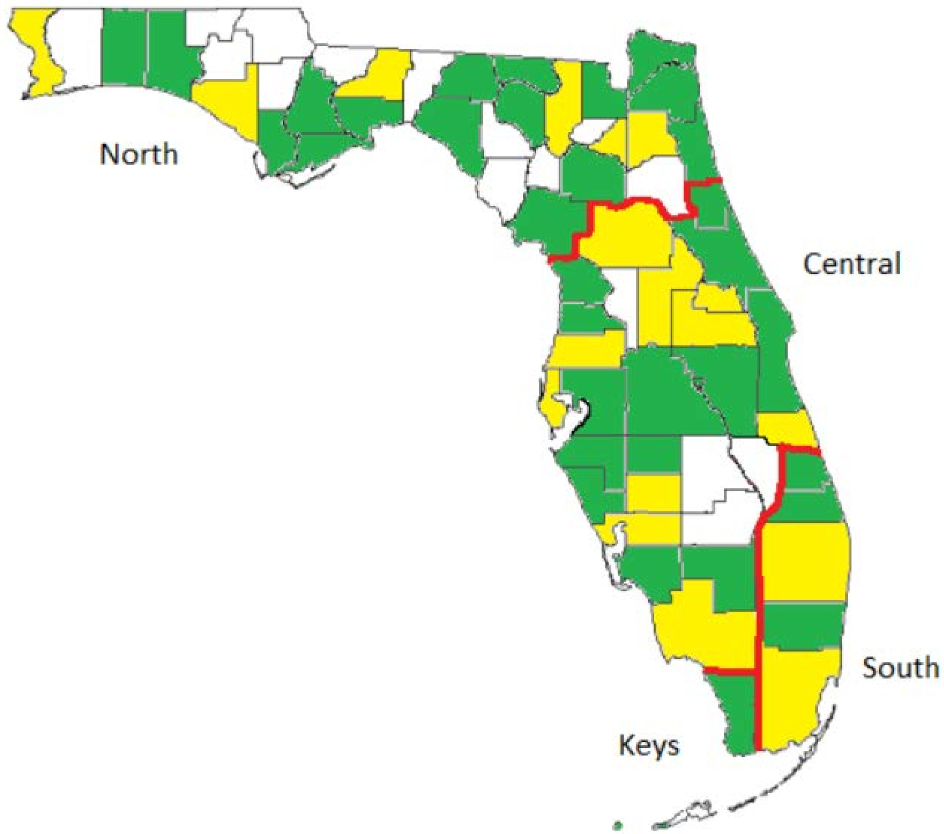
- A new exposure study involved 22 Florida counties leading to a new set of statistics used to weight the vulnerability matrices.



- Michalski, J., (2016) Building Exposure Study in the State of Florida and Application to the Florida Public Hurricane Loss Model, Master thesis, Department of Civil Engineering and Construction Management, Florida Tech, Melbourne, FL.

Exposure Statistics: Personal Residential

- A new exposure study brought the dataset up to 51 counties, accounting for approximately 97% of Florida’s population.



Florida Public Hurricane Loss Model
V 6.2

General standards

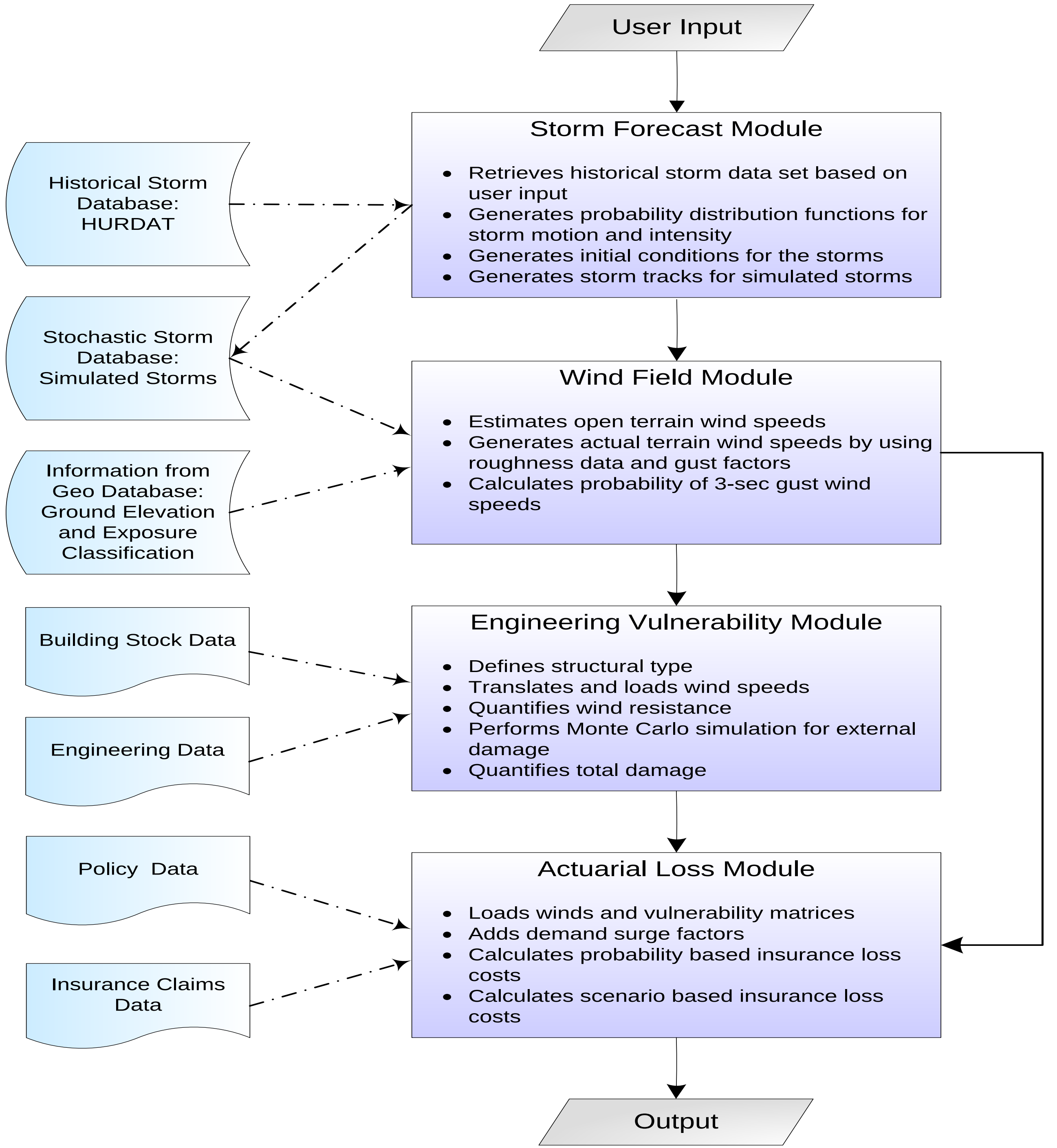
G-1 Scope of the Model and Its Implementation

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

- The Florida Public Hurricane Loss Model estimates loss costs and probable maximum loss from hurricane events for personal and commercial lines residential property. The losses are estimated for building, appurtenant structure, content and additional living expense (ALE).

- The model name is Florida Public Hurricane Loss Model. The current version is 6.2 and the release date is November 1, 2016.

- A summary of the model is provided in the overview.


User Input
Storm Forecast Module
Retrieves historical storm data set based on user input
Generates probability distribution functions for storm motion and intensity
Generates initial conditions for the storms
Generates storm tracks for simulated storms
Historical Storm Database: HURDAT
Stochastic Storm Database: Simulated Storms
Wind Field Module
Estimates open terrain wind speeds
Generates actual terrain wind speeds by using roughness data and gust factors
Calculates probability of 3-sec gust wind speeds
Information from Geo Database: Ground Elevation and Exposure Classification
Building Stock Data
Engineering Data
Engineering Vulnerability Module
Defines structural type
Translates and loads wind speeds
Quantifies wind resistance
Performs Monte Carlo simulation for external damage
Quantifies total damage
Policy Data
Insurance Claims Data
Actuarial Loss Module
Loads winds and vulnerability matrices
Adds demand surge factors
Calculates probability based insurance loss costs
Calculates scenario based insurance loss costs
Output

B. ***The modeling organization shall maintain a documented process to assure continual agreement and correct correspondence of databases, data files, and computer source code to slides, technical papers, and/or modeling organization documents.***

- The FPHLM group members follow the process specified in the flowchart below in order to assure continual agreement and correct correspondence of databases, data files, and computer source code to slides, technical papers, and FPHLM documents.

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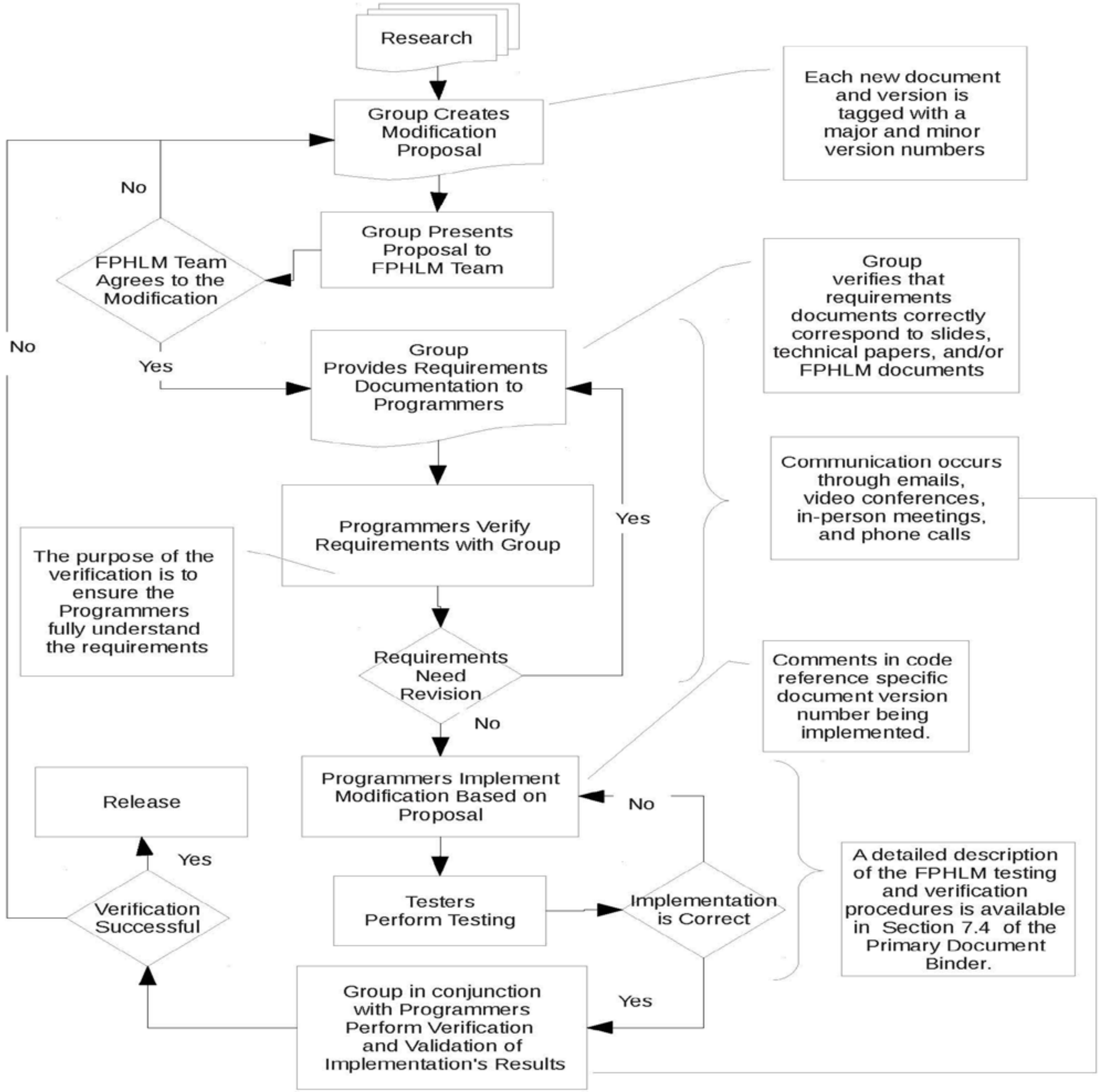


FPHLM Team: All members of the FPHLM
Groups: Meteorology, Engineering, Statistics, Actuarial, and Computer Science

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

- All model related software and data are within the scope of the computer science standards and are located in model level file areas

.

Changes to the meteorology component include:

- Update to a recent version of HURDAT2 (2/17/2016) which includes storms up through the 2015 hurricane season.
  - The estimated change in statewide loss costs due to the update of HURDAT is 1.54% decrease.

- Updated zip code database to the March 2015 ZIP code boundaries as per Standard G-3.
  - The estimated change in statewide loss costs due to the update of zip code centroids is 0.02% decrease.

Changes to the vulnerability component include:

Low Rise Commercial Residential Model Changes (v6.1 to 6.2):

- Calculation of soffit areas of hip and gable roof buildings
- Update of exposure statistics, leading to changes in the weighted matrices.
- Correction in the handling of WDR2
- Removal of rain sampling bounds
  - Estimated change in statewide loss cost due to statistics update is 0.72% decrease
  - Estimated change in statewide loss cost due to other revisions is 22.79% decrease

Changes to the vulnerability component include:

Personnal Residential Model Changes (v6.1 to 6.2):

- Update of exposure statistics, leading to changes in the weighted matrices
  - Estimated change in statewide loss cost is 0.11% decrease

- **G-2 Qualifications of Modeler Personnel and Consultants Engaged in Development of the Model**

A) 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 model was developed, tested, and evaluated by a multi-disciplinary team of professors and experts in the fields of meteorology, wind and structural engineering, computer science, statistics, finance, economics, and actuarial science.

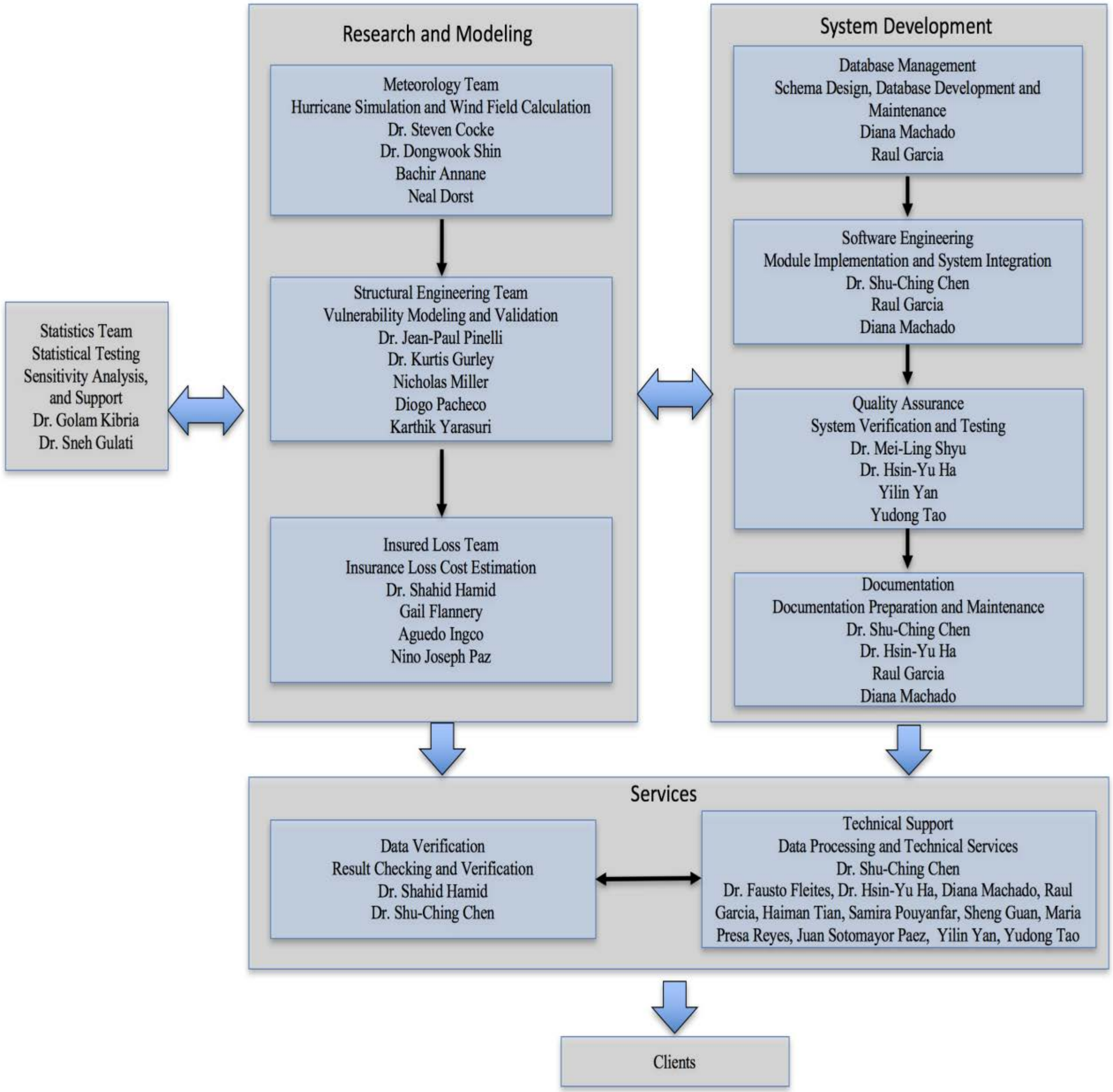
- The experts work primarily at Florida International University, Florida Institute of Technology, Florida State University, University of Florida, Hurricane Research Division of NOAA, University of Miami, and AMI Risk Consultants.

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

- The model has been reviewed by modeler personnel and consultants in the required professional disciplines. These individuals abide by the standards of professional conduct as adopted by their profession.
- The model was developed independently by a multi-disciplinary team of professors and experts. The lead university is the Florida International University. The model was commissioned by the FL-Office of Insurance Regulation.

- The Florida Office of Insurance Regulation contracted and funded Florida International University to develop the Florida Public Hurricane Loss Model.
- The model is based at the Laboratory for Insurance, Financial and Economic Research, which is part of the International Hurricane Research Center at Florida International University.
- The OIR did not influence the development of the model.
- The copyright for the model belongs to OIR, but Florida International University has long term license to operate the model for research and commercial purposes.
- FL-OIR is the major client for the model.
- Since January 2009 model services are available to the insurance and reinsurance firms. The model has been used by about 30 insurance companies.
- In 2013 the state funded FIU and collaborating universities to enhance the FPHLM by adding both a storm surge and fresh water flooding component.

- The model was first activated in March 2006. This version was used to process the insurance company data on behalf of the Florida Office of Insurance Regulation.
- In Summer 2007 a revised and updated version 2.6 of the model was accepted by the Florida Commission on Hurricane Loss Projection Methodology and put to immediate use.
- Another revised and updated version 3.0 was accepted by the Commission in June 2008.
- Another revised and updated version 3.1 was accepted by the Commission in June 2009.
- Version 4.1 was accepted by the Commission in August 2011.
- Version 5.0 was accepted by the Commission in Summer 2013.
- Version 6.1 was accepted by the Commission in Summer 2015 and has been used since.



Florida Public Hurricane Loss Model Workflow

G-3 Insured Exposure Location

A. ZIP Codes used in the model shall not differ from the United States Postal Service publication date by more than 24 months at the date of submission of the model. ZIP Code information shall originate from the United States Postal Service.

- Our model uses ZIP Code data from a third-party developer, which bases its information on the ZIP Code definitions issued by the United States Postal Service. The version we used has a USPS vintage of March 2015. The ZIP Code data have been changed in the current release of the model from last year's submission.

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

- ZIP Code centroids used in the model are population centroids.

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

- The ZIP Code information is checked for consistency by experts developing our model.

D. If any hazard or any model vulnerability components are dependent on ZIP Code databases, the modeling organization shall maintain a logical process for ensuring these components are consistent with the recent ZIP Code database updates.

- All ZIP Code-dependent components are recreated using the latest update of the ZIP code data in the model.

E. Geocoding methodology shall be justified.

- The FPHLM uses an enterprise class geocoding engine for converting street addresses to latitude-longitude values.

G-4 Independence of Model Components

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

- The meteorology, vulnerability, and actuarial components of the model are theoretically sound and were developed and validated independently before being integrated. The model components were tested individually.

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.***
- The current submission document has been reviewed and edited by person, who is qualified to perform such tasks, and is listed in Form G-7.
- Several Word tools are utilized to automate the process of formatting and editing the document.
- Word processing software with track change capability is used to prepare the document.

M-1 Base Hurricane Storm Set

- Hurricane frequencies for model validation and calibration based on February 2016 HURDAT2 (1900-2015)
- No trends, weighting, or partitioning are conducted
- Calibration and validation uses the complete base hurricane storm set
- PDFs updated to include new seasons (2014-2015) and HURDAT reanalysis of storms (1951-1955).
- Discussed with Pro Team: updates of HURDAT2; due to Reanalysis, a new storm added (Hazel, 1953) and there was a revision of Florence (1953). Forms M-1/S-1 reviewed by pro team
- FPHLM v6.2 is in compliance with Standard M-1

M-2 Hurricane Parameters and Characteristics

- Methods based on information documented in currently accepted scientific literature
- Parameters graphically described and justified
- Discussed with Pro team: graphical comparison of changes in asymmetry for various fixed Rmax, B and CP. No changes in parameter distributions.
- FPHLM v6.2 is in compliance with Standard M-2

M-3 Hurricane Probabilities

- Modeled probability distributions consistent with historical Atlantic basin hurricanes
- Landfall probabilities consistent with historical base set for coastal segments of Florida and neighboring states
- Intensity based on modeled max 1-min wind speed at 10 m and is consistent with Saffir-Simpson scale wind speed ranges
- Discussed with Pro Team: No changes in parameter distributions or changes in the process for developing landfall frequency distributions
- FPHLM v6.2 is in compliance with Standard M-3

M-4 Hurricane Wind Field Structure

- Wind fields consistent with observed historical storms, e.g. Charley, Katrina, Wilma
- Development of roughness from land use land cover is consistent with the state of the science and is consistent with 2011 NLCD or later as required.
- Vertical variation of wind speed is used to model losses of multistory buildings
- Discussed with Pro Team: Previous version of FPHLM already incorporated NLCD 2011, so no change required. Discussed changes in roughness to due to changes in ZIP code boundaries/centroids.
- FPHLM v6.2 is in compliance with Standard M-4

M-5 Landfall and Over-land Weakening Methodologies

- Method for hurricane wind speed decay over land is based on scientific literature and consistent with historical record
- Wind speed transition from ocean to land is consistent with current state of science
- Discussed with Pro Team: no changes in over-land weakening methodology
- FPHLM v6.2 is in compliance with Standard M-5

M-6 Logical Relationships of Hurricane Characteristics

- Wind field asymmetry increases with storm translation speed, all other factors held constant
- Mean wind speed decreases with roughness, all other factors held constant
- Discussed with Pro Team: demonstrated that the FPHLM has the above logical relationships to risk; Wind Radii quartiles, especially for weaker storms, reported in Form M-3
- FPHLM v6.2 is in compliance with Standard M-6

Florida Public Hurricane Loss Model (FPHLM 6.2)

STATISTICAL STANDARDS

Sneh Gulati and Golam Kibria
Department of Mathematics and Statistics
Florida International University

Standard S-1: Modeled Results and Goodness of Fit

- ***The use of historical data in developing the model shall be supported by rigorous methods published in currently accepted scientific literature.***

  FPHLM is in compliance with S-1 A. The historical data for the period 1900-2015 were modeled using scientifically accepted methods that have been published in accepted scientific literature.

- ***Modeled and historical results shall reflect agreement using currently accepted scientific and statistical methods for the academic disciplines appropriate for the various model components or characteristics.***

  FPHLM 6.2 is in compliance with S-1 B. Modeled and historical results are in agreement as indicated by appropriate statistical and scientific tests.

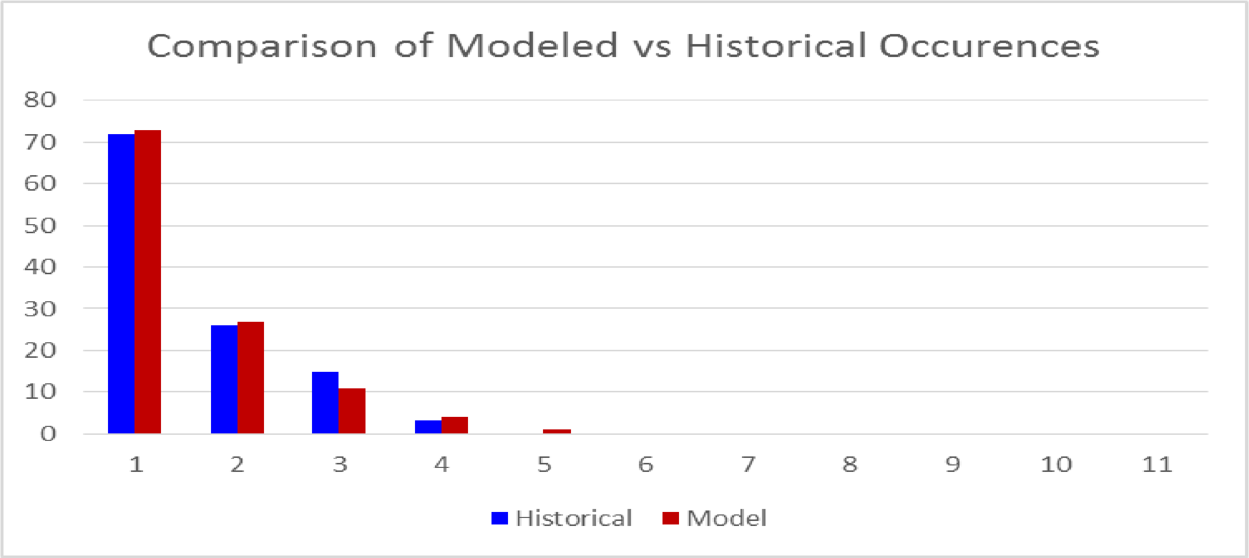
S-1: Modeled Results

- Stochastic Form of Distributions
- Stochastic Hurricane Parameters fit to distributions:
  - Holland B Error Term – Normal
  - Rmax : Gamma
  - Pressure Decay Error Term – Normal

Statistical Procedures to test the fits included chi-square goodness of fit tests, Kolmogorov Smirnov tests and graphical comparisons. The tests indicated that the fits were reasonable.

S1: Modeled Results and Goodness of Fit (GOF)

Comparison of modeled vs historical occurrences



Comparison of modeled vs historical occurrences

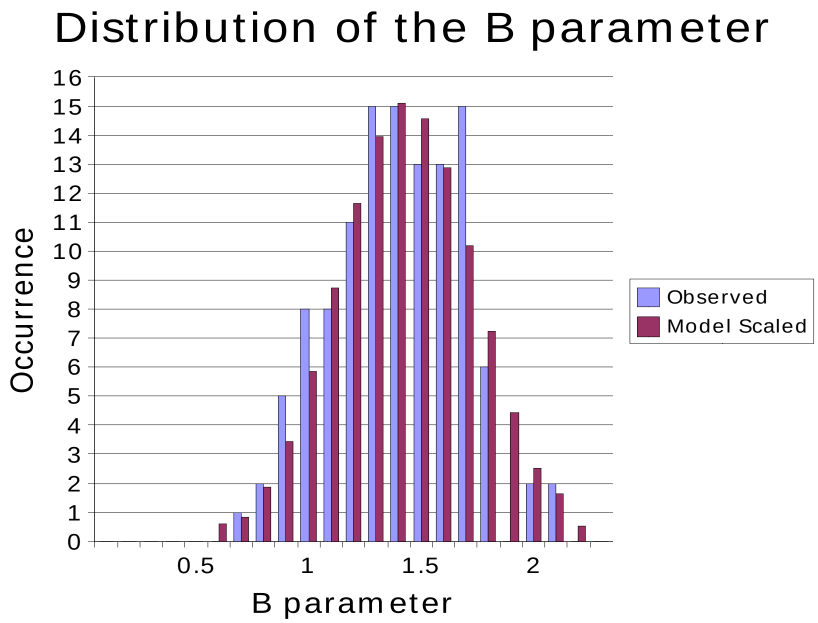
H_0: Historical and modeled data follow the same distribution

H_a: They are from different distributions.

Chi-square test statistic

- Chi square goodness of fit, p-value =0.512 (DF=3)
- Given the data, the probability of rejecting the true null hypothesis is 0.512. So, we can not reject the null hypothesis at 5% level of significance.

Comparison between observed and modeled Holland B



Goodness of Fit for the Holland B Parameter

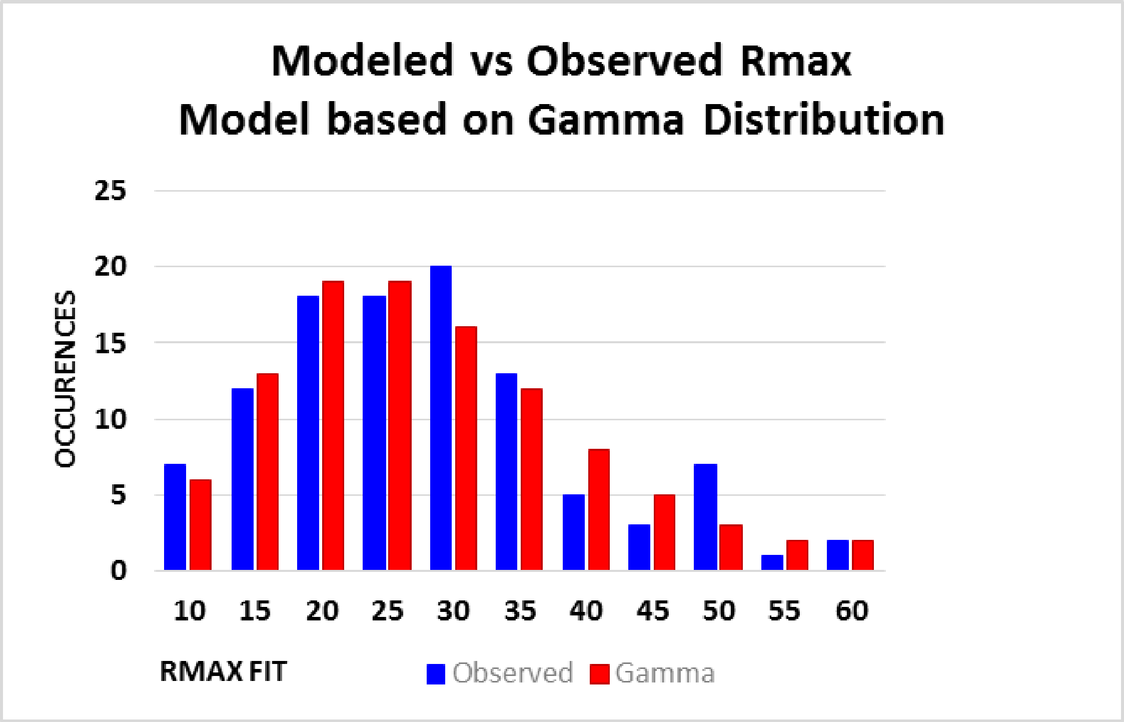
- Chi square goodness of fit Test:

  p-value = 0.57 (DF=8)

- Kolmogorov-Smirnov goodness of fit Test:

  p-value= 0.845

Comparison between observed and modeled R Max



Model Rmax by Gamma Distribution

- Maximum likelihood estimators:

$$shape = 4.76 \quad scale = 5.41$$

Chi square goodness of fit test: *p*-value= 0.59 (DF=6)

KS- goodness of fit test: p-value = 0.8327

S-2 Sensitivity Analysis (SA) for 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 currently accepted scientific and statistical methods in the appropriate disciplines and have taken appropriate action*.**

FPHLM v 6.2 is in compliance with Standard S-2. We performed sensitivity analysis on the temporal and spatial outputs of the model using currently accepted scientific and statistical methods. We examined the effects of five input variables on the expected loss cost. (Note: Results were submitted to the commission in 2010.)

S-3 Uncertainty Analysis for Loss Costs

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

FPHLM v 6.2 is in compliance with Standard S-3. We performed uncertainty analysis on the temporal and spatial outputs of the model using currently accepted scientific and statistical methods. We examined the effects of five input variables on the expected loss cost. (Results were submitted to the commission in 2010.

S-4: County Level Aggregation

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

FHPLM is in compliance with Standard S-4. The error in the county level loss costs induced by the sampling process can be quantified by computing standard errors for the county level loss costs. These loss costs have been computed for all counties in the state of Florida using 58,000 years of simulation. The results indicate that the standard errors are less than 2.5% of the average loss cost estimates for all counties.

S-5 Replication of Known Hurricane Losses

The model shall estimate incurred 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 experience may be used to replicate structure-only and contents-only losses. The replications shall be produced on an objective body of loss data by county or an appropriate level of geographic detail and shall include loss data from both 2004 and 2005.

FPHLM V6.2 is in compliance with Standard S-5. Validation studies show reasonable agreement between actual losses and modeled losses for personal residential losses. This is true for different events and different companies. Tests used include Paired Sample t-test and Wilcoxon Signed Rank Test among others which indicated that there was no significant difference between modeled and actual losses.

A sufficient body of data was not available for a formal comparison of modeled and actual commercial residential loss data.

S-6 Comparison of Projected Loss Costs

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

FPHLM V6.2 is in compliance with standard S-6. The 95% CI on the difference between the mean of the historical and modeled losses contains 0 indicating that the modeled losses do not differ significantly from historical losses.

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

Number Of Hurricanes Per Year	Historical Probabilities	Modeled Probabilities	Historical Frequencies	Modeled Frequencies
0	0.6207	0.6344	72	73
1	0.2241	0.2327	26	27
2	0.1293	0.0926	15	11
3	0.0259	0.0320	3	4
4	0.0000	0.0078	0	1
5	0.0000	0.0005	0	0
6	0.0000	0.0000	0	0
7	0.0000	0.0000	0	0
8	0.0000	0.0000	0	0
9	0.0000	0.0000	0	0
10 or more	0.0000	0.0000	0	0

Form S2: Sample Loss Exceedance Estimates – PART A

Return Period (Years)	Probability of Exceedance	Estimated Loss Notional Risk Data Set	Estimated Personal and Commercial Residential Loss FHCF Data Set
Top Event	NA	$63,486,448	$121,018,216,896
10000	0.01%	$58,378,901	$103,763,622,717
5000	0.02%	$54,184,657	$94,290,808,651
2000	0.05%	$48,147,737	$84,328,264,743
1000	0.10%	$42,326,432	$74,570,514,142
500	0.20%	$37,540,114	$67,704,797,087
250	0.40%	$32,968,781	$59,574,436,024
100	1.00%	$26,314,384	$48,365,037,802
50	2.00%	$20,885,939	$39,771,144,376
20	5.00%	$13,704,128	$26,521,182,296
10	10.00%	$8,335,061	$17,214,290,512
5	20.00%	$2,938,342	$6,721,601,935

Form S2A

Part B

Mean (Total Average Annual Loss)	$2,346,855	$4,658,623,287
Median	$0	$824
Standard Deviation	$5,415,047	$10,267,160,145
Interquartile Range	$1,529,005	$3,141,090,043
Sample Size	58000	58000

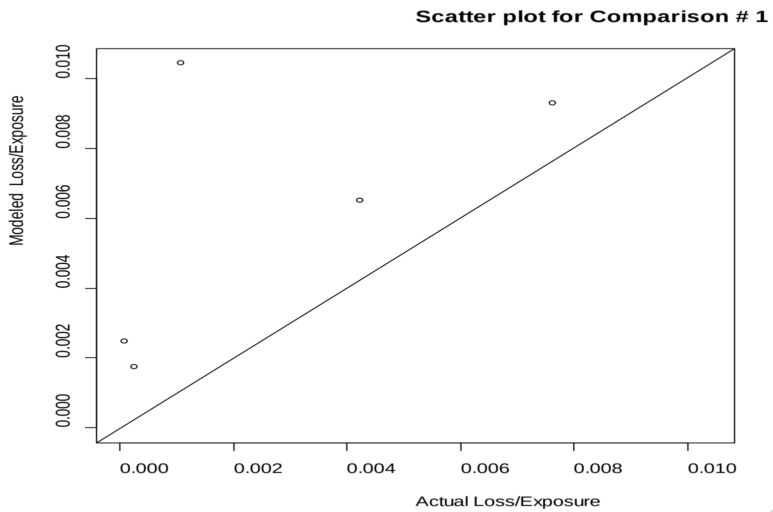
Form S-3 Distributions of Stochastic Hurricane Parameters

Stochastic Hurricane Parameter (Function or Variable)	Functional Form of Distribution	Data Source	Year Range Used	Justification for Functional Form
Holland B Error term	Normal	Willoughby and Rahn (2004)	1977-2000	The Gaussian Distribution provided a good fit for the error term. See Standard S-1, Disclosure 1.
Rmax	Gamma	Ho et al. (1987) , supplemented by the extended best track data of DeMaria (Penington 2000), NOAA HRD research flight data, and NOAA-HRD H*Wind analyses (Powell et al. 1996, 1998).	1901-2012	Rmax is skewed, nonnegative and does not have a long tail. So the gamma distribution was tried and found to be a good fit. We limit the range of Rmax to the interval (4, 120). See Standard S-1, Disclosure 1.
Pressure decay Term	Normal	Vickery (2005)	1979-1996	From Vickery (2005)
Storm initial location perturbation	Uniform	N/A	N/A	Plausible variations in initial storm locations are assumed to be uniform
Storm initial motion perturbation	Uniform	N/A	N/A	Plausible variations in initial storm motion are assumed to be uniform
Storm change in motion and intensity distributions	Empirical	HURDAT	1900-2013	Sampling from historical data See Standard G-1, Disclosure 2 for details

Form S-4: Validation Comparisons

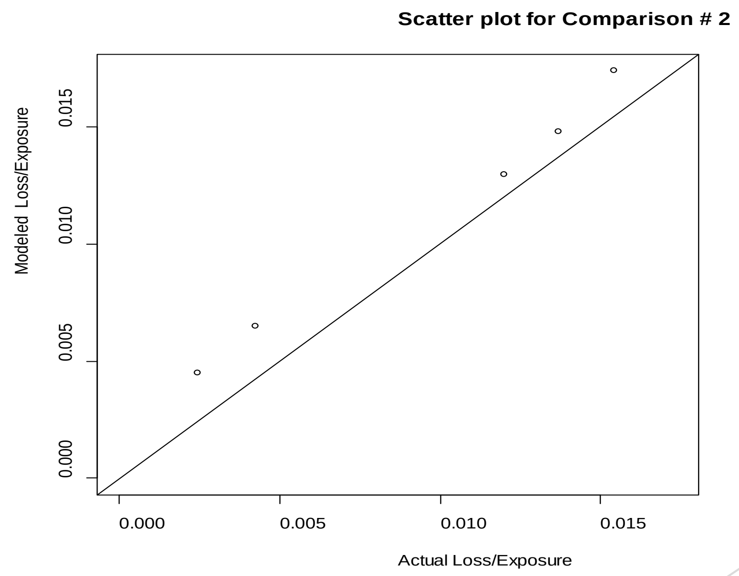
- Comparison #1: Hurricane Charley and Company O by Coverage

Coverage	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
Building	0.00764	0.00927	-0.00163
Contents	0.00007	0.00247	-0.00240
Appurtenants	0.00107	0.01042	-0.00935
ALE	0.00025	0.00174	-0.00149
Total	0.00424	0.00650	-0.00226



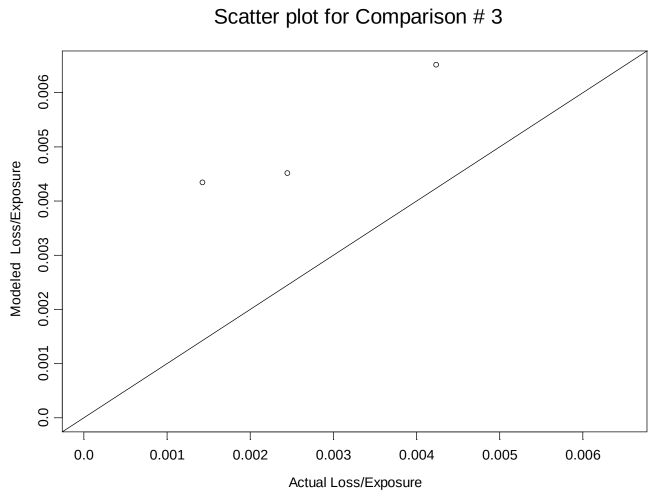
Comparison #2: Different Companies by Different Hurricanes

Company	Event	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
J	Jeanne	0.01370	0.01477	-0.00107
N	Wilma	0.01201	0.01294	-0.00093
B	Charley	0.01544	0.01737	-0.00193
O	Frances	0.00245	0.00450	-0.00205
O	Charley	0.00424	0.00650	-0.00226



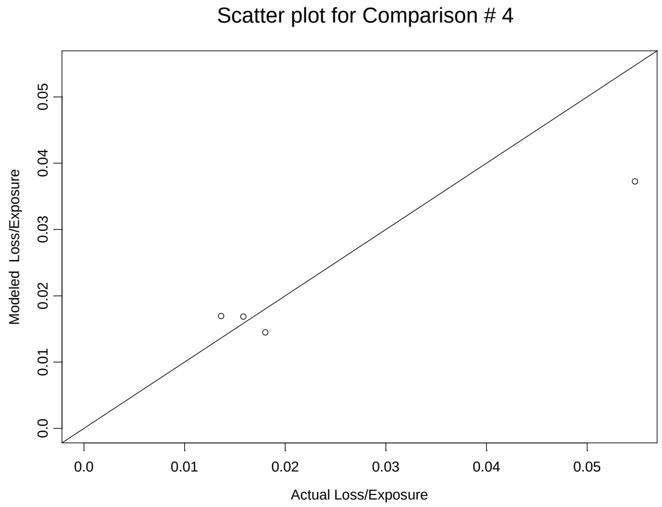
Comparison #3: Company O by Hurricane Frances, Charley and Jeanne

Company	Event	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
O	Frances	0.00245	0.00450	-0.00205
O	Charley	0.00424	0.00650	-0.00226
O	Jeanne	0.00143	0.00433	-0.00290



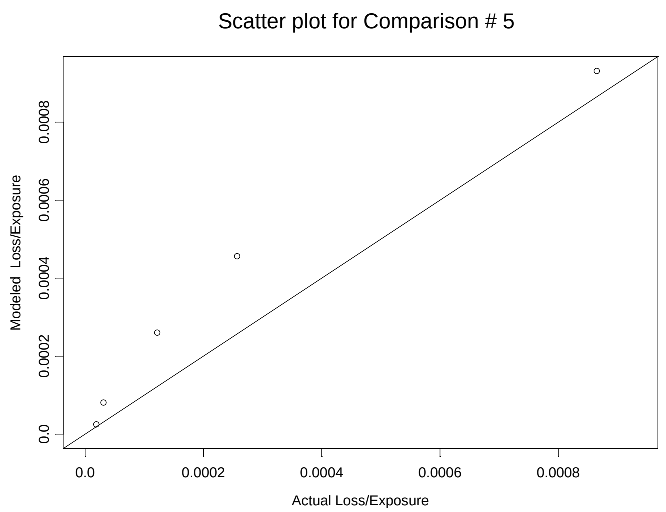
Comparison #4: Construction Type for Hurricane Charley

Construction	Company	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
Frame	B	0.01363	0.01695	-0.00332
Masonry	B	0.01584	0.01687	-0.00103
Manufactured	Q	0.05476	0.03724	0.01752
Other	A	0.01803	0.01450	0.00353



Comparison #5: County wise for Company A and Hurricane Frances

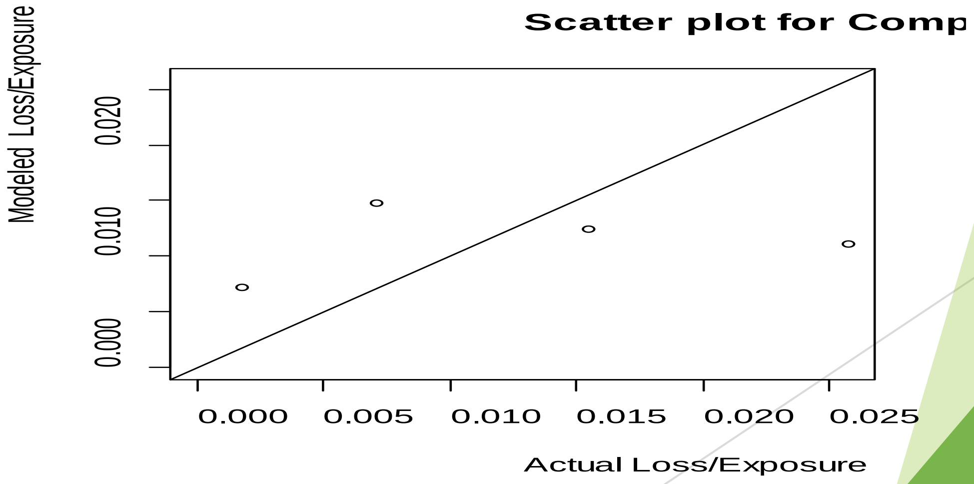
County	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
Lee	0.000019	0.000025	-0.000007
Sarasota	0.000122	0.000259	-0.000137
Collier	0.000031	0.000081	-0.000050
Madison	0.000924	0.000994	-0.000070
Manatee	0.000262	0.000465	-0.000203



Commercial Residential

Comparison # 1: Company D and Q by Hurricane Jeanne, Katrina, and Wilma

Company	Event	Company Actual Loss/Exposure	Modeled Loss/Exposure	Difference
D	Jeanne	0.00716	0.01470	0.00754
D	Katrina	0.00183	0.00714	0.00531
D	Wilma	0.01555	0.01243	-0.00313
Q	Wilma	0.02579	0.01108	-0.01471



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

Time Period	Historical Hurricanes	Produced by Model
Current Submission	$5,388.52	$4,658.62
Previously Accepted Model* (2013 Standards)	$5,681.92	$4,921.29
Percent Change Current Submission/ Previously Accepted Model*	-5.2%	-5.3%

The 95% confidence interval between the mean of historical and modeled losses is between -1.19 and 2.65 billion dollars. Since the interval contains 0, we are 95% confident that there is no significant difference between the historical and the modeled losses.

Florida Public Hurricane Loss Model

Standard V-1

Derivation of Vulnerability Functions

Florida Public Hurricane Loss Model

Standard V-1

A. Development of the building 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 vulnerability functions based on rational structural analysis, post-event site investigations, and laboratory of field testing shall be supported by historical data.

The development of the vulnerabilities is based on a component approach that combines engineering modeling, simulations with engineering judgment, and insurance claim data. The determination of external damage to buildings is based on structural calculations, tests, and Monte Carlo simulations. The wind loads and strength of the building components in the simulations are based on laboratory and in-situ tests, manufacturer's data, expert opinion based on post-hurricane site inspections of actual damage, and codes and standards, and are calibrated and validated against insurance claim data. The internal and content damage are extrapolated from the external damage on the basis of expert opinion and site inspections of areas impacted by recent hurricanes and are confirmed using insurance claims data.

Florida Public Hurricane Loss Model

Standard V-1

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

The method used in the derivation is based on extrapolating the results of Monte Carlo simulations of physical exterior damage through simple equations based on engineering judgment, expert opinion, and claims data. Uncertainties at each stage are accounted for by distributing the damage according to reasonable probability distributions and are validated with claims data.

The Monte Carlo component models take into account many variations in structural characteristics, and the result clearly filters through the cost estimation model. There are also different and clearly defined costing considerations applied to each structural type. These adjustments come directly from resources developed exclusively for defining repair costs to structures and therefore are theoretically sound.

Florida Public Hurricane Loss Model

Standard V-1

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

A detailed exposure study was carried out to define the most prevalent construction types and characteristics in the Florida residential building stock. Models were built for each of the identified common structural types. The low-rise models include differing wall types, roof shapes, roof-to-wall connections, window types, opening protection, garage doors, and story options.

Models of varying combinations of the above characteristics were created. The probabilistic capacities of the various components were determined by a variety of sources, including test results in the literature, in-field data collection, manufacturer's specifications and manufacturer's test data.

In the case of the mid-/high-rise commercial residential model, the models include different apartment units corresponding to different building layouts, different locations within the floor plan, different heights, and different openings and protection options.

Florida Public Hurricane Loss Model

Standard V-1

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 vulnerability functions.

The models include options that represent building code revisions. Three models were derived for each structural type: weak, medium, and strong construction. The assignment of a given strength is based on the age of the home and the available information on construction practice in that era of construction. FBC requirements that apply to the repair of existing homes are also taken implemented. Separate models were also developed for manufactured housing constructed based on pre- and post-1994 HUD regulations and for different wind zones.

In addition to the construction type, region, and era of construction options, each model has additional strength features that can be adjusted to represent combinations of mitigation features. For example the model is capable of reflecting weak original construction and new, strong roof sheathing and roof cover mitigation.

Florida Public Hurricane Loss Model

Standard V-1

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

The commercial and personal residential building structures, mobile homes, and appurtenant structures are independently derived.

Florida Public Hurricane Loss Model

Standard V-1

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

The minimum one-minute average sustained wind speed at which some damage is observed is 38 mph (3-second gust 50 mph) for appurtenant structures. Site-built and manufactured homes have a very small probability of some very minor damage at 42 mph (3-second gust 55 mph). This probability becomes more significant at 46 mph (3-second gust 60 mph) and increases with higher wind speed. Simulations are run for 3-second gusts from 50 mph to 250 mph in 5 mph increments.

Florida Public Hurricane Loss Model

Standard V-1

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

The vulnerability functions do not explicitly include damage due to flood, storm surge, or wave action. The vulnerability functions for all models (site-built residential, manufactured homes, low-rise commercial residential, and mid-/high-rise commercial residential) include damage due to wind pressure, missile impact and water infiltration.

Florida Public Hurricane Loss Model

Standard V-2

Derivation of Contents and Time Element Vulnerability Functions

Florida Public Hurricane Loss Model

Standard V-2

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

The development of the vulnerabilities is based on a component approach that combines engineering modeling, simulations with engineering judgment, and insurance claims data. The content and time element vulnerabilities are extrapolated from the building damage on the basis of expert opinion and post-events site investigations of areas impacted by recent hurricanes and are confirmed using historical claims data.

Florida Public Hurricane Loss Model

Standard V-2

B. The relationship between the modeled building and contents vulnerability functions and historical building and contents losses shall be reasonable.

The relationship between the modeled structure and the contents vulnerability functions is reasonable, on the basis of the relationship between historical structure and contents losses.

Florida Public Hurricane Loss Model

Standard V-2

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

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

Florida Public Hurricane Loss Model

Standard V-2

D. The relationship between the modeled building and time element vulnerability functions and historical building and time element losses shall be reasonable.

For Personal Residential risks the model uses time element vulnerability functions derived from the relationship between building damage and additional living expense. The vulnerability functions have been calibrated using historical claims data on building and additional living expense.

For Commercial Residential risks the relationship between modeled structure and time element loss costs is reasonable. Since no historical loss data were available for calibration, the relationship combines engineering and actuarial judgment.

Florida Public Hurricane Loss Model

Standard V-2

E. Time element vulnerability functions used by the model shall include time element coverage claims associated with wind, flood, and storm surge damage to the infrastructure caused by a hurricane.

The time element vulnerability functions produced by the model consider time element claims arising from wind, flood, and storm surge damage to the infrastructure. The model does not distinguish explicitly between direct and indirect loss. For Personal Residential risks the time element vulnerability functions were calibrated against claims data that include both types of losses. For Commercial Residential risks the recognition of claims due to indirect loss is based on judgment since no historical loss data were available for calibration.

Florida Public Hurricane Loss Model

Standard V-3
Mitigation Measures

Florida Public Hurricane Loss Model

Standard V-3

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

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

Modeling of mitigation measures to improve a building's hurricane wind resistance, the corresponding effects on vulnerability, and their associated uncertainties is theoretically sound and consistent with fundamental engineering principles.

Standard V-3

Part A: Continued

The following structures were modeled:

- Base case as defined by Commission
- Mitigated case as defined by Commission
- Base plus one mitigation at a time

The mitigations included gable bracing, rated shingles, metal roof, stronger sheathing capacity, stronger roof-to-wall connections, stronger wall-to-sill connections, reinforced masonry walls, multiple opening protection options, and wind/missile resistant glass.

Florida Public Hurricane Loss Model

Standard V-3

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

The base cases are very weak cases, where the interior damage is governed by the sheathing loss at low to moderate wind speeds. Application of mitigation measures are justified, as they reduce damage relative to the base case individually, and compound the reduction of damage in combination.

Florida Public Hurricane Loss Model

Response to Commission issues

Reference Document: FPM Deficiency Letter 15 Standards
December 14, 2016

Investigate the condo-unit floor location impact on loss costs. How is lack of floor location treated?

- Loss increases with unit height due to wind speed

- Lack of floor location treatment:
  - Compute loss at each floor height and take the average

Investigate aspects of the model and inputs that could lead to the greatest reduction in the uncertainty in model outputs (e.g., hurricane frequency, damage functions, incorrect data input, granularity of exposure location (ZIP Code centroid versus street address) data input).

- Contents of portfolios and T.A. databases with respect to structural features
- Inconsistencies within data (missing fields, etc.)
- Capturing of pulled permits for re-roofing (claims and portfolios)

Investigate how contamination of claims data (flood loss counted as wind loss) impacts validation and model output.

Wind claims data with contamination from flood damage are excluded from the validation sets.

For example, Hurricane Ivan in certain regions of the panhandle are very likely contaminated, and therefore not used.

Investigate how the treatment of inland versus coastal exposures has an effect on the spatial evaluation of vulnerability functions.

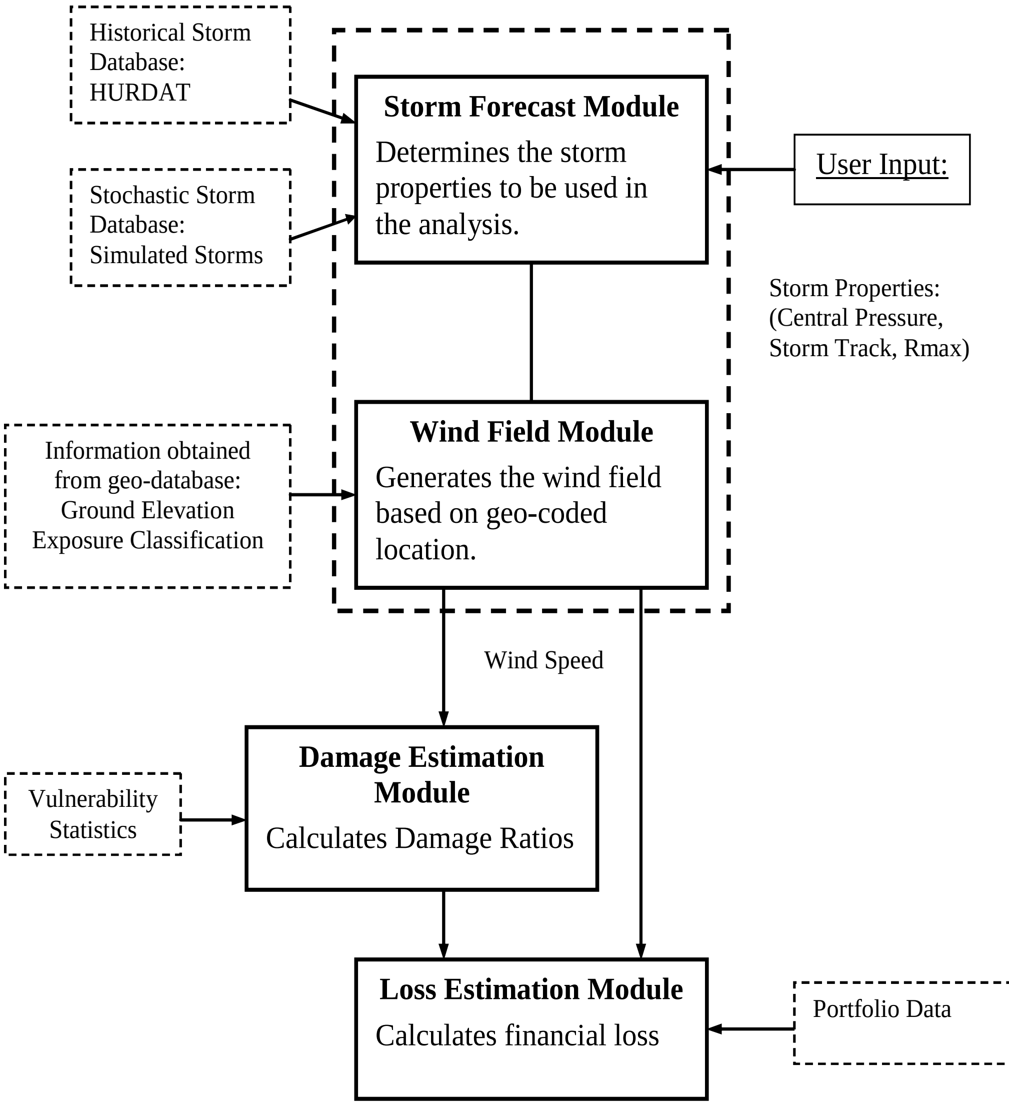
The spatial distribution of appropriate vulnerability functions vary by region according to the county-by-county exposure study. Primarily the age of the structure is used to assign an appropriate vulnerability model with strength consistent with construction in that era. The distribution of age varies among regions.

With respect to coastal vs inland, coastal vulnerability models are more heavily weighted toward window protection versions. Miami-Dade HVHZ is accounted for with its own high-strength model to reflect code requirements.

Florida Public Hurricane Loss Model
Computer/Information Standards

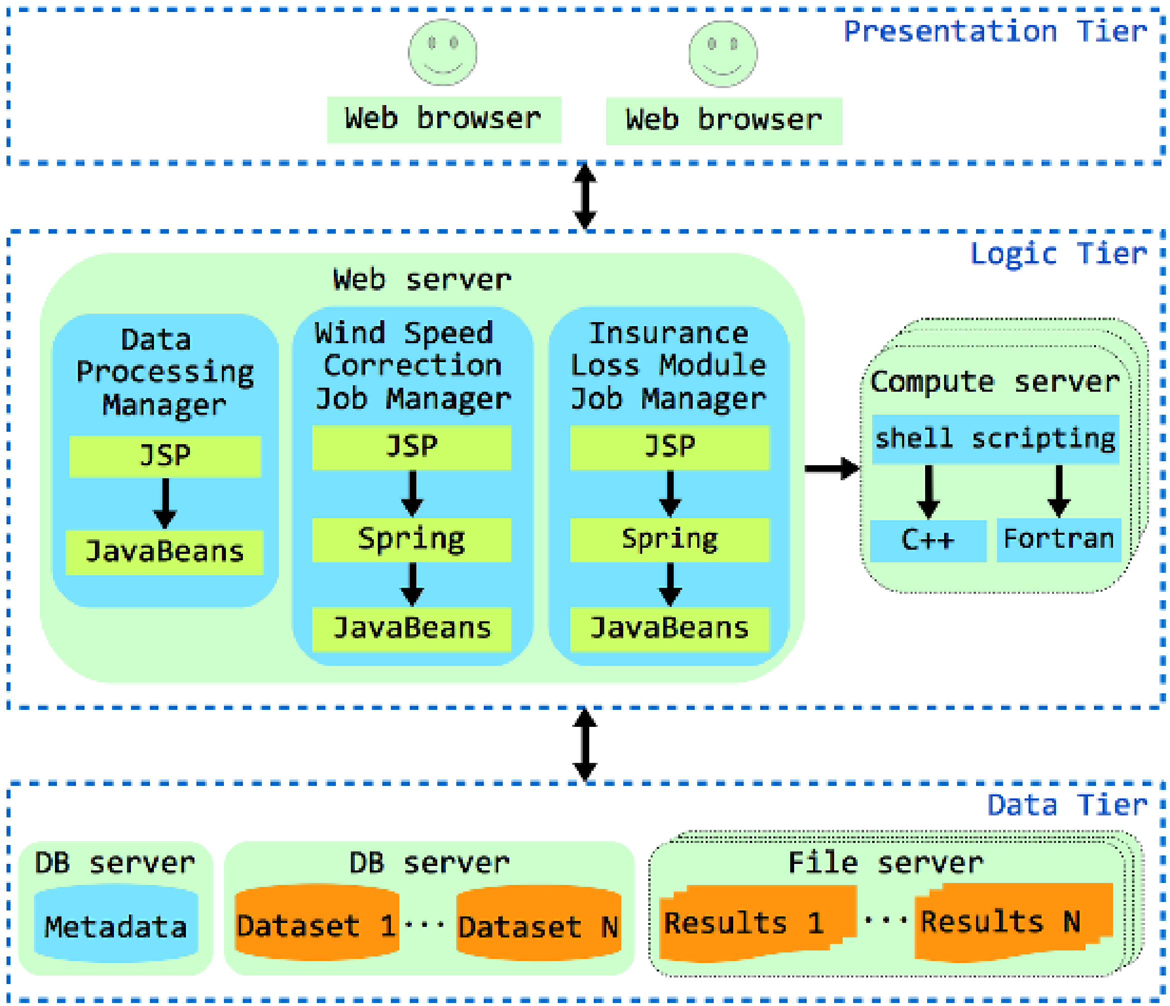
Dr. Shu-Ching Chen
School of Computing and Information Sciences
Florida International University

Model Flowchart



- Use cases
  - Storm Track Generation
  - Wind Field Model
  - Wind Speed Correction
  - Monte Carlo Simulation Model
    - Personal Residential
    - Commercial Residential
  - Vulnerability
    - Personal Residential
    - Commercial Residential
  - Insurance Loss Module
    - Personal Residential
    - Commercial Residential

System Architecture



CI-1 Documentation (1/2)

- Primary document – Done
  - Specify the model structure, detailed software description, and functionality.
- Computer software consistently documented and dated – Done
  - The primary document consists of all the required documents grouped into sections. The documentation follows accepted model development and software engineering practices.

CI-1 Documentation (2/2)

- Tables of changes (1) from the prior year's submission to this year's initial submission and (2) since this year's initial submission are maintained in the primary document – Done
- Documentation is created separately from the source code – Done

CI-2 Requirements (1/2)

- Maintain a complete set of requirements for each software component – Done
  - Detailed document for each module using standard software practices
- Maintain a complete set of requirements for databases/data files – Done
  - Database document: data processing, schemas, etc.
  - Data file document: file format, parameters, etc.

CI-2 Requirements (2/2)

- Documentation for interface, human factors, functionality, documentation, data, human and material resources, system models, security, and quality assurance – Done
  - Documents are maintained as required
    - Primary document contains sections for
      - Quality assurance
      - Hardware and software specifications
      - Human resources management
      - Model revisions
      - …
    - Testing report
    - User Manual

CI-3 Model Architecture and Component Design (1/2)

- Maintain and document detailed control and data flowcharts – Done
  - Presented in the primary document

- Maintain and document interface specifications for each software component – Done
  - Presented in the primary document

CI-3 Model Architecture and Component Design (2/2)

- Maintain and document schema definitions for each database and data file – Done
  - Presented in database and data file documents

- Maintain and document flowcharts illustrating model-related flow of information and its processing by modeling organization personnel or consultants – Done
  - Presented in the primary document

- Maintain and document system model representations associated with model components – Done
  - Presented in the primary document

CI-4 Implementation (1/4)

- Maintain a complete procedure of coding guidelines – Done
  - Guidelines for code development, version control, code revision, etc. maintained in the primary document.
- Maintain a complete procedure in creating, deriving, or procuring and verifying database or data files – Done
  - Presented in database document
  - Presented in module document for data files

CI-4 Implementation (2/4)

- All components are traceable – Done
  - Maintained throughout the system documentation from requirements to code
- Maintain a table of software components – Done
  - Presented in the primary document
- Each component is sufficiently and consistently commented – Done
  - Code-level comments
    - File headers
    - In-line comments

CI-4 Implementation (3/4)

- The documentation of all components contain (1) all equations and formulas with definitions of all terms and variables and (2) cross-referenced tables of implementation source code terms and variable names corresponding to (1) – Done
  - Each component in the primary document has a section with tables that map variables and terms in the source code to equations and formulas in the documentation

CI-4 Implementation (4/4)

- Hardware, operating system, other software and all computer languages required to use the model – Done
  - Server side
    - Hardware: Linux servers
    - Operating system: Linux
    - Software and computer languages: JSP, C++, Fortran, shell scripting, PostgreSQL
  - End-user
    - Hardware: PC
    - Operating system: Windows, Linux, Mac OS
    - Software and computer languages: Web browser

CI-5 Verification (1/3)

- Maintain fully time-stamped procedures for verification – Done
  - Three-stage verification
    - By pair-programming – combined work for software development, code-level debugging, calculation cross-checks, etc.
    - By system modeler – check sample input/output (black box testing)
    - By testing group – unit, regression, and aggregation testing presented in the testing document
- Use testing software in documenting and analyzing all components – Done
  - Developed MATLAB, C, C++, Fortran, and Java code for testing

CI-5 Verification (2/3)

- Unit testing – Done
  - Presented in the testing document
- Regression testing – Done
  - Presented in the testing document
- Aggregation testing – Done
  - Presented in the testing document
- Use testing software to assist in documenting and analyzing databases and data files – Done
  - Data integrity and consistency are maintained by PostgreSQL database system
  - Issue query (PL/SQL) to check data in the database
  - Using Excel, Access, and PostgreSQL to manually check data files

CI-5 Verification (3/3)

- Perform and document integrity, consistency, and correctness checks on databases and data files – Done
  - Presented in the testing document
- State whether the model produces the same loss costs and probable maximum loss levels with same input and parameters. – It does.
- Provide an overview of the component testing procedures – Three-stage verification
- Describe verification approaches used for externally acquired data, software, and models – Done
  - Presented in the primary document

CI-6 Model Maintenance and Revision (1/3)

- Maintain a clearly written policy for model review, maintenance, and revision – Done
  - Policy specified in the primary document
- Assign new model version identification if model revision causes a change in loss cost or probable maximum loss level – Done
  - Presented in the primary document

CI-6 Model Maintenance and Revision (2/3)

- Use tracking software to identify and describe all errors and modifications to code, data, and documentation – Done
  - Apache Subversion (SVN)
- List of all model versions since this year's initial submission – Done
  - Presented in the primary document

CI-6 Model Maintenance and Revision (3/3)

- Identify procedures used to review and maintain code, data, and documentation
  - For each component, document
    - Installation date
    - Program specification
    - Personnel involved
    - Current version number
    - Date of changes
  - Use of SVN for version control
  - Use of access control mechanisms for file access

CI-7 Security (1/2)

- Secure access to individual computers – Done
  - Servers: in a secure server room
  - Computers: in the lab with key card control
- Anti-virus software installation – Done
- Secure access to documentation, software, and data in the event of a catastrophe – Done
  - Copies/backups kept in different locations
  - Resources secured and safeguarded by designated personnel

CI-7 Security (2/2)

- Methods to ensure the security and integrity of the code, data, and documentation
  - Electronic measures
    - Different authorization levels
    - Network security
    - Regular backups
    - Confidential data saved in the system with access control
    - Setup of a development environment separate from the production environment for model modification and testing
  - Physical measures
    - Copies of backup tapes placed in a secure and hurricane protected building
    - Servers protected in a secure room with restricted access
    - Documents and workstations in lab with key card access control

Florida Public Hurricane Loss Model
Version 6.2

Actuarial Standards

Standard A-1
Modeling Input Data

A. *When used in the modeling process or for verification purposes, adjustments, edits, inclusions, or deletions to insurance company input data used by the modeling organization shall be based upon accepted actuarial, underwriting, and statistical procedures.*

- Input data received from insurance companies are reviewed via a combination of editing programs and human intervention. The editing programs search for missing or invalid entries and inconsistencies among attributes (e.g. zip code and county mismatch). Edits identified are reviewed by the model operator.

- Records missing key information such as policy form, insured value or deductible are dropped.

- The most commonly missing or inconsistent values are secondary attributes such as roof cover, roof to wall connection, deck attachment, etc. When the majority of this information is missing, all values are treated as "unknown" and the model is run using weighted vulnerability matrices. If a substantial portion of the values are reported and valid, any missing or inconsistent attributes are methodically populated using rules based on survey statistics.

These adjustments to the inputs are reasonable and acceptable from an actuarial stand-point.

(continued on next slide)

Standard A-1
Modeling Input Data

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

All changes to the input data are documented in the model output report.

(end of Standard A-1)

Standard A-2
Event Definition

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

Modeled loss costs and PML levels include damages from:

- Hurricanes with landfall in Florida
- Hurricanes with landfall in neighboring states, but producing open terrain winds of 30 mph or greater in at least one Florida zip code.
- Non-landfalling hurricanes producing open terrain winds of 30 mph or greater in at least one Florida zip code.

(continued on next slide)

Standard A-2
Event Definition

B. *Time element loss costs shall reflect losses due to infrastructure damage by a hurricane.*

Time element losses are calculated as a function of interior damage to the structure.

The functions do not explicitly consider claims arising from indirect loss, but Personal Residential functions were validated against claim data that would have been impacted by both direct and indirect loss.

Commercial Residential functions are judgmental due to lack of claim data for validation.

(end of Standard A-2)

Standard A-3 Coverages

A. *The methods used in the development of building loss costs shall be actuarially sound.*

The model estimates building damages by storm using a set of matrices for Personal Residential, and a set of curves for Low Rise Commercial Residential. For Mid-High Rise Commercial Residential the model sums expected damages per story.

Resulting damages are adjusted for policy limits, deductibles and demand surge and aggregated across all storms to determine loss costs.

(continued on next slide)

Standard A-3 Coverages

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

The Personal Residential vulnerability matrix for appurtenant structures assumes a distribution of three types of structures: slightly, moderately and highly vulnerable and was validated against claim data.

For Commercial Residential clubhouses and administration buildings are modeled as additional buildings. Other structures use the Personal Residential matrix.

(continued on next slide)

Standard A-3 Coverages

C. *The methods used in the development of contents loss costs shall be actuarially sound.*

The damage functions for contents are based on engineering judgment regarding internal damage.

For Personal Residential exposures these empirical functions were validated against claim data for Andrew, Charley and Frances.

Commercial Residential functions are primarily judgmental due to lack of claim data for validation.

(continued on next slide)

Standard A-3
Coverages

D. *The methods used in the development of time element coverage loss costs shall be actuarially sound.*

Time element losses are calculated as a function of interior damage to the structure.

Commercial Residential functions are judgmental due to lack of claim data for validation.

(end of Standard A-3)

Standard A-4

Modeled Loss Cost and Probable Maximum Loss Considerations

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

These items are not included in loss costs or PML's.

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

There is no provision for economic inflation in loss costs or PML's.

(continued on next slide)

Standard A-4
Modeled Loss Cost and Probable Maximum Loss Considerations

C. *Loss cost projections and probable maximum loss levels shall not include any provision for direct hurricane storm surge losses.*

There is no provision for storm surge in loss costs or PML's.

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

Losses can be calculated at the geocode level whenever street address or latitude-longitude is provided for the exposures.

(continued on next slide)

Standard A-4
Modeled Loss Cost and Probable Maximum Loss Considerations

E. *Demand surge shall be included in the model's calculation of loss costs and probable maximum loss levels using relevant data.*

Demand surge factors are applied to the losses from each storm in the stochastic set before calculating loss costs and PML levels.

(continued on next slide)

Standard A-4

Modeled Loss Cost and Probable Maximum Loss Considerations

F. *The methods, data, and assumptions used in the estimation of demand surge shall be actuarially sound.*

Model assumes demand surge is a function of:

- Coverage
- Region
- A storm's statewide damages (before DS).

(continued on next slide)

Standard A-4
Modeled Loss Cost and Probable Maximum Loss Considerations

Data used in the development of demand surge functions:

- Marshall Swift construction cost indices for FL zip codes
- Miami-Ft. Lauderdale Consumer Price Index for Household Furnishings & Operations
- Actual hurricane losses of insurance companies from Frances, Charley and Andrew.

(continued on next slide)

Standard A-4
Modeled Loss Cost and Probable Maximum Loss Considerations

<u>General Approach</u>

Method used to estimate DS involves examining the gap between forecasted post-storm indices and actual post-storm indices.

(end of Standard A-4)

Standard A-5
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 distributions used are:

- Distribution of damage ratios by wind speed as determined by the engineers.
- Distribution of modeled losses by coverage prior to the application of the deductible.

No other distributional assumptions are involved in applying deductibles and policy limits to modeled losses.

(continued on next slide)

Standard A-5
Policy Conditions

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

Modeled loss costs decrease as the deductible increases, all other factors held constant.

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

If there are multiple hurricanes in a year in the stochastic set, the wind deductibles are applied to the first hurricane, and any remaining amount is applied to the second hurricane. If none remains, the general peril deductible is applied.

(end of Standard A-5)

Standard A-6
Loss Output

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

PML for a given return period =

((1 – 1 / return period) x 100) th quantile of the ordered set of annual losses produced by the simulation.

For example, the PML for a return period of 100 years is the 99^{th} quantile.

(continued on next slide)

Standard A-6
Loss Output

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

Loss costs are similar for similar risks.

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

The model produces positive, non-zero loss costs for all valid zip codes.

(continued on next slide)

Standard A-6 Loss Output

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

The model produces loss costs that decrease as the quality of construction increases. See Form A-6, Construction and Policy Type sections.

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

The model produces loss costs that react appropriately to hazard mitigation. See Form A-6, Building Strength section.

(continued on next slide)

Standard A-6
Loss Output

F. *Loss costs cannot increase as the quality of building codes and enforcement increases, all other factors held constant.*

Loss costs vary appropriately with the quality and enforcement of building codes. See Form A-6, Building Code /Enforcement (Year Built) section.

G. *Loss costs shall decrease as deductibles increase, all other factors held constant.*

Loss costs vary appropriately by size of deductible. See From A-6, Deductible section.

(continued on next slide)

Standard A-6
Loss Output

H. *The relationship of loss costs for individual coverages, (e.g., structures and appurtenant structures, contents, and time element) shall be consistent with the coverages provided.*

Validation testing demonstrated that the relationship between loss costs and coverage are reasonable and consistent with the coverage provided. Also, see Form A-6, Coverage section.

(continued on next slide)

Standard A-6
Loss Output

I. *Output ranges shall be logical and any deviations supported.*

Output ranges generated by the model are logical as detailed below .
Anomalies at the county level in Form A-4 can be resolved at the zip code level.

J. *All other factors held constant, output ranges produced by the model shall reflect lower loss costs for:*

A. masonry construction versus frame construction,

Output ranges produced by the model reflect lower loss costs for masonry versus frame construction.

(continued on next slide)

Standard A-6
Loss Output

B. personal residential risk exposure versus mobile home risk exposure,

Output ranges produced by the model reflect lower loss costs for site-built versus mobile home exposure.

C. inland counties versus coastal counties, and

Output ranges produced by the model reflect lower loss costs for inland counties versus coastal counties.

D. northern counties versus southern counties.

Output ranges produced by the model reflect lower loss costs for northern counties versus southern counties.

(continued on next slide)

Standard A-6
Loss Output

K. *For loss cost and probable maximum loss level estimates derived from or validated with historical insured hurricane losses, the assumptions in the derivations concerning (1) construction characteristics, (2) policy provisions, (3) coinsurance, (4) contractual provisions, and (5) relevant underwriting practices underlying those losses, as well as any actuarial modifications, shall be appropriate based on the type of risk being modeled.*

For each storm the model estimates damages to an insured property based on the characteristics of the property and engineering judgment as to the strength of that particular combination of characteristics.

The estimated damages are adjusted for the effects of deductibles, policy limits and demand surge to determine the expected insured loss.

There are no additional adjustments applied to modeled losses.

(end of Standard A-6)