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Validation of a probabilistic model for hurricane insurance loss projections in Florida

J.-P. Pinelli [a,*], K.R. Gurley [b], C.S. Subramanian [a], S.S. Hamid [c], G.L. Pita [a]

[a] Florida Tech, Melbourne, Florida, USA
[b] University of Florida, Gainesville, Florida, USA
[c] Florida International University, Miami, Florida, USA

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ABSTRACT

The Florida Public Hurricane Loss Model is one of the first public models accessible for scrutiny to the scientific community, incorporating state of the art techniques in hurricane and vulnerability modeling. The model was developed for Florida, and is applicable to other hurricane-prone regions where construction practice is similar. The 2004 hurricane season produced substantial losses in Florida, and provided the means to validate and calibrate this model against actual claim data. This paper presents the predicted losses for several insurance portfolios corresponding to hurricanes Andrew, Charley, and Frances. The predictions are validated against the actual claim data. Physical damage predictions for external building components are also compared to observed damage. The analyses show that the predictive capabilities of the model were substantially improved after the calibration against the 2004 data. The methodology also shows that the predictive capabilities of the model could be enhanced if insurance companies report more detailed information about the structures they insure and the types of damage they suffer. This model can be a powerful tool for the study of risk reduction strategies.

1. Introduction

In the United States, the 2004 hurricane season resulted in insured losses of over $20.5 billion, of which Florida accounted for 85%. In 2005, hurricanes Katrina, Rita, and Wilma produced losses in excess of $30 billion along the Gulf Coast and in Florida. The need to predict hurricane-induced losses for $1.9 trillion worth of existing structures exposed to such potential hurricane devastation in the state of Florida has prompted the Florida Department of Financial Services to charge a group of researchers to develop the Florida Public Hurricane Loss Model (FPHLM).

The project called for the efforts of several functional teams: A meteorological team developed a hurricane wind model (see [1]); an engineering team developed the building vulnerability and exposure model [2,3]; an actuarial team translated the damage into insurance loss; and a computer team integrated the different components into a user-friendly and stable computer platform [4].

Although several good commercial models already exist in the market, their proprietary nature prompts concern by the public [5]. This is the first public model specifically designed to predict residential losses which is accessible for scrutiny to the scientific community and the public. The aim of the FPHLM is to provide transparent unbiased prediction of the existing risk that will strengthen the consensus between the industry, government regulators, and the public for the definition of reasonable insurance policy premiums and the influence of mitigation measures. In particular, the credibility of a risk model depends on its ability to accurately predict actual events for which there is recorded data. Version 1.5 of the FPHLM model was initially validated and calibrated against insurance claim data predominantly from the 1992 hurricane Andrew that struck southern Florida. The intense 2004 hurricane season yielded significant additional data that provided a validation opportunity, resulting in the new version 2.6. This paper focuses on the recent validation and calibration of the engineering component of the FPHLM during the transition from version 1.5 to 2.6.

2. Engineering component of the FPHLPM

The engineering component of the FPHLM has been described in detail in [2,3]. It consists of three stages, as shown in Fig. 1. The first stage simulates the physical wind damage to the exterior components of a single family residential structure. This includes openings (doors, windows), roof cover, roof sheathing, walls, and roof to wall connections. The result of this stage is a statistical

* Corresponding author. Tel.: +1 321 674 8085; fax: +1 321 674 7565.
E-mail address: pinelli@fit.edu (J.-P. Pinelli).

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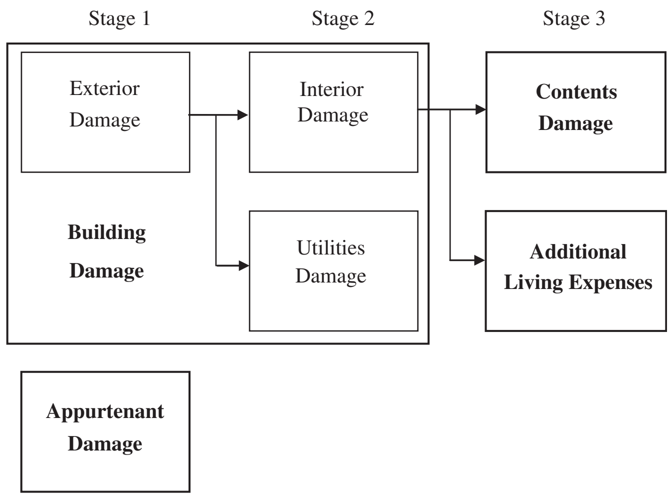

Fig. 1. Components of the vulnerability model.

prediction of the physical damage that occurs to these components over a range of wind speeds. The second stage of the engineering model predicts the interior and utilities damage based on the exterior damage. This includes damage due to water penetration (through broken windows and lost roof sheathing), damage to interior systems (electrical, plumbing, and mechanical) and fixtures (fixed cabinets, carpeting, partitions, doors). The third stage predicts the damage to contents and the additional living expenses (ALE) based on the interior damage. The program also computes the damage to appurtenant structures (pool, deck, unattached garage). This three-stage modeling process is conducted for a series of different structural models that represent different ages and types of construction [3], including masonry homes, timber frame homes, and manufactured homes. The model explicitly accounts for the different common construction practices by defining weak, medium, and strong versions of any given structural type. Different regional construction practices in Florida are also considered. For example, there are weak, medium, and strong versions of the model that represents single story-wood frame-gable roof construction in North Florida, and separate models for other regions, wall types, and roof types common to Florida.

The combined results of the engineering model (stages one, two, and three) produce a set of probabilities of various levels of overall damage ratio (DR) (expressed as a % of replacement cost (RC)) for a series of prescribed peak 3-s gust wind speeds from mild (22 m/s) to severe (112 m/s). The probability that each of these wind speeds represents the peak gust occurring on an annual basis (by zip code) is provided by the meteorological team [1]. The meteorological team base their estimates on state of the art climate models that combine historical information with the latest science on tropical cyclones. These models are constantly updated to take into account the latest advances in the field, including possible effects, if any, of global warning. Thus, together, the meteorological and engineering teams produce the information necessary to estimate the annual probability of various levels of wind damage as a function of zip code and construction type. This information is represented by vulnerability matrices. A total of 168 matrices are created for every combination of structural type, region, subregion, and roof cover type (tile vs. shingle).

The cells of a vulnerability matrix for a particular structural type represent the probability of a given DR occurring at a given wind speed. The columns of the matrix represent the different wind speeds from 22 to 112 m/s in 2.25 m/s increments. These are 3-s gust wind speeds at a 10 m height. The rows of the matrix correspond to DRs in 2% increments up to 20%, and then in 4% increments up to 100%. Each column of numbers in the matrix is a discretization of the probability distribution function (pdf) of the damage for a particular wind speed interval. Table 1 shows the first five columns and 12 rows of a typical vulnerability matrix.

Each column of the vulnerability matrix is a pdf of the damage conditional to a particular wind speed interval. The mean value of damage for a given wind speed can be plotted over a range of wind speeds to produce a vulnerability curve. A set of vulnerability curves is shown in Fig. 2. These are the vulnerability curves for weak, medium, and strong models of masonry wall homes in Central Florida.

Fig. 3 shows the contribution of the different components of building damage to its vulnerability at different wind speeds (in m/s). It can be seen that the interior damage and the utility damage (light upper portion of the plot) are one of the largest contributors to the vulnerability. Both of these are due mainly to water penetration, especially at lower wind speeds. Since the next largest portion of the vulnerability corresponds to roof cover and sheathing damage, this illustrates how important it is to preserve the envelope of the house, and hence its interior, as the best strategy for mitigation.

3. Hurricane data

The meteorology module of the FPHLM has three main components: the wind model developed by the meteorological team; the roughness data used to convert open terrain wind speeds predicted by the wind model into actual terrain wind speeds used by the engineering module; and postal zip code population centroid data used to define the locations at which mean losses are computed. The conversion of wind speeds from open terrain to actual terrain is also dependant on the fetch parameter, which is the distance upstream of any wind direction used to average the roughness. The first step in the validation process was to verify the accuracy of the wind speed predictions of the meteorology module for different hurricanes. Wind speed data were obtained from the Hurricane Research Division (HRD) of the National Oceanographic and Atmospheric Administration. HRD scientists (one of them the leader of the FPHLPM meteorology team) analyze the wind speed data available at landfall from a variety of sources, and then project the peak sustained winds along the observed track of the surface circulation center at 1 min intervals using the HRD inland decay model. The results are wind swaths of sustained surface wind speeds at the 10 m level (33 ft) for open terrain exposure over land and for marine exposure over water. This information is published online [6]. For the purpose of this study, the wind speeds from NOAA wind swaths were transformed into actual terrain wind speeds at postal zip code centroids using terrain correction coefficients. The results of the comparisons between HRD winds and FPHLM winds from version 2.6 are presented below. All the wind speeds are 3 s gusts at 10 m height for actual terrain exposure, and for every location they represent the maximum value for the entire duration of the storm. If the wind model had a perfect prediction capability, all the points would lie on the 45° line that bisects each plot.

3.1. Hurricane Andrew

Andrew made landfall in August 1992, south of Miami. This hurricane, one of the most destructive hurricanes to ever hit Florida, has been extensively studied, and it has been recently reclassified from a category 4 to a category 5 hurricane at landfall. Fig. 4 shows a comparison between the resulting HRD wind speeds (horizontal axis) and the wind speeds from the FPHLM