

ACTUARIAL MODEL FOR ESTIMATING INSURED HURRICANE LOSSES

Public Hurricane Loss Projection Model

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Table of Contents

1.	Introduction	p. 4
2.	Choice of parametric versus non-parametric method for estimating insured losses	p. 5
3.	Inputs	
3.1.	Input from the meteorological component	p. 6
3.2.	Input from the engineering component	p. 7
3.3.	Insurance data input	p. 8
3.4.	Treatment of missing observations	p. 9
3.5.	Replacement cost versus actual cash value	p. 9
3.6.	Policy modifications	p. 9
4.	Sources of uncertainty	p. 10
5.	The non-parametric algorithm for generating loss costs: Introduction and assumptions	p. 11
6.	Variable definitions	p. 11
7.	Modeling deductibles	
7.1.	Multiple types of losses, separate limits, and single deductible	p. 13
7.2.	Multiple types of losses, separate limits, and multiple residual deductible	p. 14
7.3.	Multiple types of losses, separate limits, and pro-rata allocation of deductibles	p. 15
8.	Algorithm for the Probabilistic Insurance Loss model (PILM)	p. 17
9.	Algorithm for the Scenario Insurance Loss model (SILM)	p. 23
10.	Use case for actuarial form A1: Loss estimates for thirty hypothetical hurricane events	p. 28
11.	Use case for actuarial form A2: Loss costs for hypothetical coverage by construction type for each zip code	p. 30
12.	Use case for actuarial form A4: Official hurricane set average annual zero deductible statewide loss costs	p. 31
13.	Use case for actuarial form A5: Current exposure based losses from modeled hurricane Andrew	p. 32
14.	Use case for actuarial form A6: Distribution of hurricanes by size of loss	p. 33
15.	Use case for actuarial form A7: Output ranges for loss costs by coverage type, construction type and deductibles	p. 35

16. Use case for statistical form S2: Probable maximum loss (PML) p. 38
17. Use case for statistical form S3: Comparisons of modeled versus actual historical hurricane losses p. 39
18. Use case for statistical form S4: Average annual zero deductible statewide loss costs- historical versus modeled p. 40

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1. Introduction

The traditional actuarial method in loss estimation is typically parametric and involves fitting some distribution to the number of claims (typically Poisson) and the amount of the losses. A variety of distributions are available for fitting losses (e.g. Lognormal, Weibull, Pareto, gamma, Burr, mixture of distributions), most with the preferred two parameters but a few with three parameters to be estimated. There are several techniques to estimate the parameters (percentile matching, method of moments, minimum distance, minimum chi-square, and maximum likelihood). The models are validated or accepted using both statistical and non-statistical criteria. If more than one model are acceptable then a ranking of the models is in order. Models can be ranked and selected by using, e.g., large maximum likelihood function value; small chi-square goodness of fit test statistics; small Kolmogorov-Smirnov test statistics; large p-value from chi-square goodness of fit test; minimum cdf, MSE or LAS etc¹. Though not necessary, ranking is often done by using the same method employed for estimating parameters.

Once the loss distribution has been selected and its parameters estimated and validated it is rather easy to use and a variety of hypotheses can be tested. For example, for purposes of prediction, hundreds or thousands of sample outcomes of losses can be generated for a given representative insured property. Next, policy modifications such as deductibles and limits can be applied to each outcome to generate a set of net of deductible losses, which are then averaged to generate expected loss. The losses can be aggregated. Exceedance probabilities curves can be generated to estimate the likelihood the portfolio of policies will suffer losses in excess of a given level. Alternatively, the Value at Risk (PML) can be estimated at a given exceedance probability.

¹ [See (Hogg and Klugman, *Loss Distribution*, 1984, particularly Ch. 4 and 5 and the appendix) and (Klugman, Panjer and Willmot, *Loss Models*, 1998)].

In the above traditional practice, only the insurance policy file and claims data are used. Typically, the losses are modeled directly and are not derivative of other variables. In our project, however, the catastrophe modeling process requires that in addition to the insurance data, output data from the physically based meteorology and engineering components must be utilized. The distribution of losses are driven by both the distribution for damage ratios generated by the engineering component and by the distribution of wind speeds generated by the meteorology component. The wind speeds and damage ratios are estimated through extensive simulations. The engineering group has produced non-parametric damage matrices rather than the traditional continuous vulnerability functions. Damage ratios are grouped and intervals (or classes) of various length are used. Furthermore, these set of damages probabilities for a group of damage intervals are produced for a whole range of wind speeds. No statistical distributions are fitted or tested. For a detailed description of the meteorological and engineering components and their methodology see the respective reports.

2. Choice of Parametric vs Non-Parametric Method for Estimating Insured Losses

The engineering component produces non-parametric estimates of damage probabilities for various intervals or classes of damage ratios for structures, appurtenant structure, contents and ALE. They do not fit any statistical distributions to the damage ratios. Thus, for the insured loss model a choice must be made to either fit a parametric statistical distribution for the damage intervals using some of the same standard techniques mentioned above but applied to grouped data, or to use a non-parametric technique presented as a broad algorithm.

The advantages and disadvantages of using parametric vs non-parametric techniques are well known. For our purpose the main advantage of the parametric technique would be computational efficiency. Once a statistical distribution has been fitted and its parameters estimated, it is relatively easy to estimate expected losses and formulas are available for estimating the mean and dispersion etc for many distributions in the presence of deductibles or limits (truncated data). Predictions can be made relatively easily if the distributions are stable. Computationally there are fewer steps involved. It

is also easier to test hypothesis or to investigate the effect of, e.g., changes in deductibles and limits on expected losses. The major disadvantage is that with limited data, we may never be sure if the right distribution has been fitted and the errors in the estimated parameters can be significant.

In non-parametric estimation empirical functions are fitted to the data. There is no worry whether a correct distribution has been fitted and uncertainties are likely to be lower. The disadvantage is that a complex algorithm may be required that involves many steps and long computational time. Hypothesis testing is also more complicated and stability may be a concern.

For various reasons we have decided to pursue the non-parametric option initially. Given the large computing power available, computational time is not a major concern. Thus, it may be prudent to develop a logical non-parametric and deterministic algorithm that should produce low uncertainties. The broad algorithm utilized to estimate insured losses is discussed below.

3. Inputs

3.1. Input from the Meteorological Component

Both the meteorology and engineering components provide outputs that constitute critical inputs into the insured loss model. The meteorology component provides, for each zip code, the associated probabilities for a common set of wind speeds. Thus, zip codes are essentially differentiated by their probability distribution of wind speeds. To satisfy the requirements of the engineering component, the probabilities are estimated for wind speed intervals of 5 mph, starting at 20 mph and going up to 250 mph. These are 3 second peak gust winds corrected for the terrain roughness.

The meteorology component uses up to 55,000 year simulations to generate stochastic set of tens of thousands of storms². The storms are hurricane events at landfall. Each simulated storm has an estimated track and a set of modeled wind fields at successive time intervals. The wind fields generate the open field 1 minute maximum sustained

² The number of years of simulation was determined statistically to minimize standard errors. The 55,000 year simulations produced a stochastic set of 42,262 hurricanes.

wind speeds for the storm at various locations (population weighted zip codes centroids) along its track. These 1 minute maximum sustained winds are then converted to 3 second peak gusts (V3) winds corrected for terrain roughness by using the gust wind model and the terrain roughness model. It should be noted the peak gust winds can be 30% to 35% higher than the more widely reported sustained winds. For each zip code centroid, an accounting is then made of all the simulated storms that pass through it. Based on the number of pass through storms and their peak wind speeds, a distribution of the wind speed is then generated for the zip code. Based on this distribution, probabilities are generated for each 5 mph interval of wind speeds, starting at 20 mph. These 5 mph bins constitute the column headings of the damage matrices generated by the engineering component.

3.2. Input from the Engineering Component

The Engineering component produces damage matrices that are used as input in the insured loss model. Damage matrices are provided for building structure, contents, appurtenant structures and additional living expenses. A separate damage matrix is provided for each residential construction type. The structure types are: masonry, frame, mobile home, and unknown. But a particular construction type will have the same damage matrix across all the zip codes in a given region. Within each broad construction category, the damage matrices are specific to the roof types and number of stories. Since policy data do not provide this level of specificity, weighted matrices are used instead, where the weights are the proportion of different roof types in given region as determined by a survey of the building blocks.

The year of construction is used as a proxy for construction quality and to account for the building codes. The structure is designated as either weak, medium, or strong (standard) depending on the construction code under which it was built. For example, in South Florida structures built prior to 1994 are designated as medium while those built since 1994 are considered to be strong because of strengthened codes. Separate vulnerability matrices are estimated for the three quality of constructions in each region by assuming different requirements for rated shingles, thickness of plywood, type of nails and straps used, wall anchors, shutters etc.³ Furthermore, combined weighted matrices have also been estimated to be used for portfolio of policies that are

³ See the Report on the Vulnerability Matrices, volume 3.

aggregated at some level, or if year of construction is not available.

The cells of the matrix provide probabilities of damage outcomes for a given wind speed. The damages are specified in intervals or classes of ratios of 2% to 4%. The row represents a given interval of damage ratios and the column represent a given wind speed. In practice, the damage probabilities are assigned to the mid point of the interval of damage ratios. Thus, e.g., the first row represents the 0% to 2% interval and is evaluated at 1% ratio. The probabilities of all possible damage outcomes must add up to 1. Therefore, the sum of the cells in any given vector column (for a wind speed) add up to 100%.

It should be noted that both the damages and wind speeds are initially specified as a set of discrete points. If needed one can interpolate to get a rough continuous function by using either some standard smoothing techniques (e.g. by defining the jump of the distribution function and using it with a kernel function and optimal bandwidth to estimate a smooth pdf) or by specifying an empirical set of ranges or intervals where each interval has an associated probability. The latter method is used by the engineering component and its output is specified as a set of damage ratio intervals with associated probabilities.

3.3. Insurance Data Input

The third major data set utilized consist of the homeowner insurance policy and claim files provided by several property and casualty insurance companies operating in Florida as well as zip code level aggregate exposure data provided by the Florida Cat Fund. The *firm policy files* (exposure data) typically provide individual policy level data on the following:

- (a) policy identifier
- (b) the insured limits (or coverage) for structure, content, AP, and ALE
- (c) nature of coverage (replacement or actual value policy)
- (d) construction type
- (e) year built
- (f) policy period
- (g) zip code location
- (h) hurricane deductibles

The *firm claim files* typically provide individual policy level on the following:

- (a) policy identifier to ensure that losses are matched to corresponding exposure
- (b) zip code
- (c) loss paid for building structure
- (d) loss paid for appurtenant structures
- (e) loss paid for contents
- (f) loss paid for additional living expense
- (g) date of loss occurrence and/ or causing hurricane

The Florida Cat Fund file consist of only exposure data provided at some level of aggregation. It provides exposure data for structure, AP, content and ALE, grouped by construction type, deductible type (range), and by zip code. The number of policies in each group are also given.

3.4. Treatment of missing observations

If only the limits for structure are provided for a homeowner policy, the assumption is made that limits on appurtenant structures are 10%, content limits are 50%, and ALE limits are 20% of the limit on building structures. Inspection of available data indicate that these percentages are the most frequently represented in the policy file data.

3.5. Replacement Cost Versus Actual Cash Value

Actual cash value policies are assumed to insure up to 80% of the building value. The remainder is coinsurance. Therefore, to generate the effective value of the dwelling on these policies, the coverage amounts are multiplied by 1.25. The value for replacement cost policies are assumed to the equal actual coverage.

3.6. Policy Modifications

The following policy modification can be activated for purposes of sensitivity analysis, and can be justified by a limited survey of claim adjustment practices. The default is no activation. Loss costs can be produced both with and without the following policy modifications: If the % damage on a residential buildings reaches 50%, these damage are converted to 100% loss cost. Damages for AP, content and ALE exceeding 50% are also converted to 100% loss costs. The justification for these modifications is that once the residence becomes un-inhabitable or once it crosses a certain threshold, the structures are declared total loss.

4. Sources of Uncertainty

The actuarial model is essentially a fairly deterministic algorithm to calculate the expected insured loss costs for each individual insurance policies which are then aggregated in various ways to get the appropriate aggregate or mean loss costs. As currently designed there is no source of uncertainty in the actuarial component, except concerning the assumptions regarding the % at which damages convert to 100% loss and concerning the use of proxy for structure value. The modeling uncertainties carry over from the wind and vulnerability component. The model is predicated extensively on and constrained by the damage matrix and the methodology adopted by the engineering group. For example, since a non-parametric matrix is produced by the engineering component (based on proper engineering principles), the actuarial model is simply a non-parametric procedure to get expected losses net of deductible and constrained by the coverage limits. And since independent matrices were provided for structural, content and ALE damages (rather than the content and ALE damages being directly related to structural damages) the actuarial model is constrained to sum the three types of damages at the mean of the content and AP damage ratios (for a given wind speed) rather than at the content and AP damage intervals. Indeed, the model has been kept simple and does not introduce any separate distributional assumptions (as is typically the case in actuarial models) nor do we complicate it by including co-insurance or reinsurance or other policy modifications.

It is important to note that we do not model or predict the amount of the deductible or limits (they are given by the insurance data) but model how, for a given policy, the single deductible and the various limits are applied jointly to the combination of structure, appurtenant, content and ALE losses. Thus, the methodological errors in the actuarial model, if any, solely arise because of how the deductible and limits are applied.

All policies in a given zip code face the same distribution of wind speeds. Similarly, for all policies with the same construction type in a region, the same weighted matrix (e.g., weighted matrix of different roof types for masonry) is used as provided by the engineering group. Thus, the only reason two policies with the same construction type in the same zip code (and hence same region) produce different insured loss is because they have different property values (or coverage limit) or different deductibles. Two policies in the same zip code with the same construction type, same limits and same

deductibles will produce the same expected insured loss and the same set of discrete distribution of net of deductible loss across damage intervals and wind speeds. In sum, the source of variation in expected losses across properties is due to the zip code, construction type, coverage limits and deductibles.

5. The Non-Parametric Algorithm for Generating Loss Costs: Introduction and Assumptions

To generate expected loss first start with a given set of exposure, determine their zip codes and construction types and extract relevant meteorology, engineering and insurance data. The starting and the focal point for the computations is the damage matrix with its set of damage intervals and associated probabilities. Given a wind speed, for each of the mid point of the damage intervals the ground up loss is computed, deductibles and limits are applied, and the loss net of deductible is calculated. The net loss is multiplied by the probability in the corresponding cell to get the expected loss for the given damage ratio. The results are then averaged across the possible damages for a given wind speed, i.e. over all the cells in a given column. Next, the wind probability weighted loss is calculated to produce the expected loss for the property. The expected losses can be summed across all structures of the type in the zip code and also across zip codes to get expected aggregate loss.

To estimate the uncertainties associated with the estimates of expected loss, variances are also estimated. In practice to generate the variance of the expected loss we make the following assumptions:

- (1) Assume that the building types in each zip code are independent.
- (2) Assume that the damage caused by different wind speeds are independent
- (3) Assume that different policies within a zip code are independent
- (4) Assume that different zip codes are independent

6. Variable Definitions

X_n = Damage ratio for structure. It is the mid point of the damage ratio interval n .

V = \$ value of structure

$DM_n = \$$ damage for structure for interval n.	$DM = X * V$
$LM_S =$ Limit on structure loss	$LM_C =$ Limit on content loss
$LM_{AP} =$ Limit on appurtenant loss	$LM_{ALE} =$ Limit on ALE loss
$L_S =$ net of deductible structure loss costs	$L_C =$ net of deductible content loss costs
$L_{AP} =$ net of deductible appurtenant loss costs	$L_{ALE} =$ net of deductible ALE loss costs
$D_S =$ Deductible applied to structural loss	$D_C =$ Deductible applied to content loss
$D_{AP} =$ Deductible applied to AP loss	$D_{ALE} =$ Deductible applied to ALE loss

$p(X_n * w) =$ the probability of damage in the interval n, for a property type in zip code, conditional on the given wind speed w.

$C = f(X_n) = \$$ Mean damage for contents. The easiest method would be to assume that content damage are deterministically related to structure damage. Thus, the conditional probability of content damage, for a given mean structure damage, will be the same as the conditional probability of structural damage. The upper limit on content lost cost will be $C = LM_C$ if $C \exists LM_C$, and $L_C = 0$ for $L_C < 0$. The lower limit is zero, hence replace negative C by zero. The engineering component, however, produces a separate damage matrix for contents. Neither the content damage interval nor the mean content damage is specified for a given structural damage interval. In effect, though the content damage are related to structural damage indirectly through engineering relationships, they are essentially unrelated in terms of damage intervals or loss costs. Thus, to sum across the structural and content damage for a given interval of structural damage, we add the mid point structural damage, for a given damage interval and wind speed, to the mean content damage for the given wind speed. The wind speed is now the only common frame of reference for structural and content damage.

$AP = g(X_n) =$ Mean damage for appurtenant structures. Like contents, an effectively independent AP damage matrix has been provided. Thus, to sum across the structural, content, and AP damages for a given interval of structural damage, we add the mean AP damage for the given wind speed to the mid point of each of the structural damage intervals. $L_{AP} = LM_{AP}$ if $L_{AP} \exists LM_{AP}$, and $L_{AP} = 0$ for $L_{AP} < 0$.

ALE = h(X_n) = Mean loss for Additional Living Expenses. Like contents and AP, an effectively independent ALE damage matrix has been provided. Thus, to sum across the structural, content, and AP and ALE damages for a given interval of structural damage, we add the mean ALE damage for the given wind speed to the mid point of each of the structural damage intervals. $L_{ALE} = LM_{ALE}$ if $L_{ALE} \exists LM_{ALE}$, and $L_{ALE} = 0$ for $L_{ALE} < 0$.

7. Modeling Deductibles

A key problem in stipulating the equation for expected loss in the case of multiple types of losses is that for most policies the deductible applies jointly to structure, content, appurtenant and ALE loss, while the limits are separate. In the project the engineering team has developed damage matrices for structure and content, each with their own set of probabilities. In practice the common deductibles imply that multiple types of losses from a single event must be aggregated so that a multi-variate model is used. Ideally, for aggregation we need to have the joint probabilities of the losses. In practice such joint probabilities are hard to estimate and validate. Three alternative solutions are investigated. Depending on the solution chosen, their restrictions must be applied to the algorithm described in prior section.

7.1. Multiple Types of Losses, Separate Limits, and Single Deductible

From theory it is clear that content (C) damage, appurtenant (AP) damage and ALE all should be a non-negative function of structural damage. Thus an easy solution to the problem of probabilities may be to estimate the functional relationships, and then specify for each interval or class of structural damage, the corresponding non-random C, AP, and ALE damages. The conditional probabilities for C, AP, and ALE will then be the same as those for structural damage. The different losses can then be summed with the limits applied individually, the deductible subtracted and the net multiplied by a unique joint probability.

$$\text{Expected Loss} = \int_D^{L+D} (DM_n + C + AP + ALE - D) p(X_n * w) + \int_{L+D}^V LM_S p(X_n * w) \quad ? \exists 0$$

$$\text{Or} \quad \text{Expected Loss} = \int_0^{L+D} (DM_n + f(X_n) + g(X_n) + h(X_n) - D) p(X_n * w) dx + \int_{L+D}^{\infty} LM_S p(X_n * w) dx \geq 0$$

where, if $(DM_n + C + AP + ALE - D) \neq 0$ they are replaced by zero.

7.2. Multiple Types of Losses, Separate Limits and Multiple Residual Deductible

If the structures, contents, AP and ALE have separate probabilities and are not deterministically derived from structural loss then we need either separate deductibles for each type of loss or we should assume that deductibles are applied in some given priority order. Based on the relative ranking of coverage size, it is assumed the deductibles are first applied to structure, and next to contents, and next to AP and finally to ALE until they are exhausted.

$$\text{Expected Structure Loss} = E(L_S) = \int_{D_S}^{L+D_S} (DM_i - D_S) p_S(x_i * w) dx + \int_{L+D_S}^{\infty} LM_S p_S(x_i * w) dx$$

$$\text{Expected Content Loss} = E(L_C) = \int_{D_C}^{f(X_i)} p_C(x_i * w) dx + \int_{f(X_i)}^{\infty} LM_C p_C(x_i * w) dx$$

$$\text{Expected Appurtenant Loss} = E(L_{AP}) = \int_{D_{AP}}^{g(X_i)} p_{AP}(x_i * w) dx + \int_{g(X_i)}^{\infty} LM_{AP} p_{AP}(x_i * w) dx$$

$$\text{Expected ALE Loss} = E(L_{ALE}) = \int_{D_{ALE}}^{h(X_i)} p_{ALE}(x_i * w) dx + \int_{h(X_i)}^{\infty} LM_{ALE} p_{ALE}(x_i * w) dx$$

$$\text{Expected Loss} = E(L) = E(L_S) + E(L_C) + E(L_{AP}) + E(L_{ALE})$$

Where, either the deductibles $D_S, D_C, D_{AP}, D_{ALE}$ are allocated separately to the respective losses or are applied reductively in some rank order. In the latter case:

$$D_S = \{D_S \text{ if } D_S \neq D, \text{ and } D_S = D \text{ otherwise} \}$$

$$D_C = \{D_C \text{ if } D_C \neq D - D_S, \text{ and } D_C = D - D_S \text{ otherwise} \}$$

$$D_{AP} = \{D_{AP} \text{ if } D_{AP} \neq D - D_S - D_C, \text{ and } D_{AP} = D - D_S - D_C \text{ otherwise} \}$$

$$D_{ALE} = \{D_{ALE} \text{ if } D_{ALE} \neq D - D_S - D_C - D_{AP}, \text{ and } D_{ALE} = D - D_S - D_C - D_{AP} \}$$

otherwise }

Depending on the solution chosen, these conditions must be applied to the algorithm described in prior section.

7.3. Multiple Types of Losses, Separate Limits and Pro-rata Allocation of Deductible

In practice the insurance companies often allocate deductibles to structure, content, AP, and ALE on a pro-rata loss basis. Thus, if for example, structure and content damages before deductible are \$20,000 and \$6,000 respectively, and the deductible is \$3,000, then $(20,000/26,000)(3,000) = \$2,308$ is allocated to structure and $(6,000/26,000)(3,000) = \692 is allocated to contents. Although the FCHLPM does not have any specific method required for allocating deductibles in its standards, from its example it appears the commissions prefers this method of allocation. This means that the various damages have to be considered and deductibles applied simultaneously. The deductibles must be allocated among the different losses and the truncation applied to each loss separately on a pro-rata basis.

For pro-rata deductible method to work optimally, the functional relationships between structure damage and others should be estimated, and for each interval or class of structural damage, the corresponding mean and variance of the C, AP, and ALE damages should be specified. The conditional probabilities for C, AP, and ALE will then be the same as those for structural damage. An independent content matrix is somewhat problematic and may create biases in estimates of net of deductible losses. For structures we are likely to have damage ratio ranges or intervals of 0 to 2%, 2% to 4%, 4% to 6% etc. For each of these intervals (and its mid points), ideally we may want to use the mean and variance of the corresponding damage ratios for contents, APS and ALE. In practice, since the damage matrix for different types of losses are not directly related, we need to use the mean of the content, or AP, or ALE damage vector conditional on wind speeds, since the wind speed is the only common frame of reference to the various types of damages.

$$\text{Expected Structure Loss} = E(L_s) = \sum_{D_s}^{L+D_s} (DM_i - D_s) p_S(x_i * w) + \sum_{L+C_s}^{L+C_s} LM_S p_S(x_i * w)$$

$$\text{Expected Content Loss} = E(L_C) = \sum_{c_s} 3 (f(X_i) - D_c) p_C (x_i * w) + 3 LM_C p_C (x_i * w)$$

Since AP and ALE losses are derived directly from structural they have the same probabilities as the structural losses.

$$\text{Expected Appurtenant Loss} = E(L_{AP}) = \sum_{c_s} 3 (g(X_i) - D_{AP}) p_S (x_i * w) + 3 LM_{AP} p_S (x_i * w)$$

$$\text{Expected ALE Loss} = E(L_{ALE}) = \sum_{c_s} 3 (h(X_i) - D_{ALE}) p_S (x_i * w) + 3 LM_{ALE} p_S (x_i * w)$$

$$\text{Expected Loss} = E(L) = E(L_S) + E(L_C) + E(L_{AP}) + E(L_{ALE})$$

Where, each of the losses net of deductible are ≥ 0 . And where the deductibles $D_S, D_C, D_{AP}, D_{ALE}$ are applied on a pro-rata basis to the respective damages as follows:

$$D_S = [DM_S / (DM_S + C + AP + ALE)] * D$$

$$D_C = [C / (DM_S + C + AP + ALE)] * D$$

$$D_{AP} = [AP / (DM_S + C + AP + ALE)] * D$$

$$D_{ALE} = [ALE / (DM_S + C + AP + ALE)] * D$$

The preferred method is the third one in which deductibles are applied on a pro-rata basis. For this method to work, ideally, the joint probabilities of the losses must be estimated and used. In practice such joint probabilities are hard to estimate and validate. Thus, the engineering component should ideally provide for each structural damage interval, and given a wind speed, the mean and variance of damage ratio for content, APS, ALE. If it is very difficult to derive or fit a functional relationship between a given structural damage and corresponding contents, AP, ALE for each interval and wind speed, or if the uncertainties are great, a less preferred alternative will be to use the mean C, AP, and ALE for the given wind speed alone to determine the allocation of deductible to various coverage. Such is the case in our model.

8. Algorithm for the Probabilistic Insurance Loss Model (PILM)

In this section we develop the algorithm for estimating expected loss costs summed over the expected structural, content, AP, and ALE costs. *Here, the exposure data by zip code is the only given observed data. The wind probabilities, and damage matrices are all modeled.* In practice to generate expected loss costs the method we adopt involves an algorithm with the following steps.

- (1) Start with a particular insurance company m or portfolio of policies m .
- (2) Next pick a residential policy exposure unit k from the insurance policy database.
- (3) Determine the zip code j of the policy.
- (4) Extract the distribution of wind speeds for the zip code j from the wind database.
- (5) Next determine the building type i for the selected policy.
- (6) Select the damage matrix for *structure* of type i . The structure types are: masonry, frame, mobile home, or unknown. The actual matrix selected will be a weighted matrix, where the weights are determined by the proportions of roof types in the region. For example, the matrix used for a masonry structure in Miami Dade county will be the weighted average of a masonry/hip roof matrix and masonry/gable roof matrix.

This matrix is provided by the Engineering team and consists of the simulated probabilities for various damage ratio intervals and wind speeds. The row represents a given interval n of damage ratios and the column represent a given wind speed w . Each cell represents the probability P_{nw} . Let X_{ij} be the vector of the mid points of the interval of damage ratios for structure type i in zip code j . It has N elements. Now rather than use the MDR (Mean Damage Ratio) of the whole matrix, the mid point of the damage ratio interval n , X_n , is used to represent an outcome, and the probability of this outcome for a given wind

speed is P_{nw} . In general, for structure i in zip code k , the mid point of damage intervals is X_{ijn} and its probability of outcome for a given wind speed is P_{ijnw} .

- (7) Select the damage matrix for *contents* for structure of type i . This matrix is provided by the Engineering team and consists of the simulated probabilities for various content damage ratio intervals and wind speeds. The row represents a given interval n of content damage ratios and the column represent a given wind speed w . The interpretation of the cells values etc is similar to the description given above for structure damage matrix. Although the content damage depend indirectly on structural damage, there is no stipulated functional relationship between the two matrices and their damage intervals.
- (8) Select the AP and ALE damage matrices. The Engineering team has generated independent matrices for AP and ALE based on indirect relationships between structural damage and both ALE and AP.
- (9) From the insurance policy file, get the policy limits LM_{ijk} , and its deductible D_{ijk} . Typically, property values are not reported. For replacement cost policy the value of the property, V_{ijk} , is set to equal the limit $V = LM_S$. For actual cash value policy (replacement cost minus depreciation) the value of the property is set to equal $V = 1.25 \times LM_S$, since typically, ACV policies are insured to 80% of the value.
- (10) Select a wind speed bin from the distribution. The bins are speed intervals of 5 mph starting at 50 mph. They are the column headings of the damage matrix. The wind speeds represent 3 second peak gust winds. The corresponding maximum 1 minute sustained wind speeds are typically 30 to 35% lower. The 1 minute maximum sustained wind speeds are converted to peak gust wind speeds by applying the gust factor model and the correction for terrain roughness

Apply the damage ratio vector X_{ij} to the property k (of type i in zip code j). For each damage interval n , calculate the \$ damage: $DM_{ijknw} = V_{ijk} * X_{ijnw}$. Thus, a $N \times 1$ \$ damage vector DM_{ijk} is generated for property k . This vector is associated with the chosen wind speed.

- (11) For the above selected wind speed, estimate the row vector of wind conditional

mean \$ content damages, where each element is the mean content damage for the given wind speed: $\text{mean } C_{ijkw} = LM_c * \text{mean } C_{ijnw}$ ratio.

(12) For the selected wind speed, estimate the row vector of wind conditional mean \$ AP damages, where each element is the mean AP damage for the given wind speed: $\text{mean } AP_{ijkw} = LM_{AP} * \text{mean } AP_{ijnw}$ ratio.

(13) For the selected wind speed, estimate the row vector of wind conditional mean \$ ALE damages, where each element is the mean ALE damage for the given wind speed: $\text{mean } ALE_{ijkw} = LM_{ALE} * \text{mean } ALE_{ijnw}$ ratio.

(14) Using the wind conditional mean \$ structural damage DM_{ijk} , and combine it with the wind conditional mean C, mean AP_{ijkw} and mean ALE_{ijkw} . Next, calculate the deductibles $D_S, D_C, D_{AP}, D_{ALE}$ on a pro-rata basis to the respective damages as follows:

$$D_S = [DM_S / (DM_S + C + AP + ALE)] * D$$

$$D_C = [C / (DM_S + C + AP + ALE)] * D$$

$$D_{AP} = [AP / (DM_S + C + AP + ALE)] * D$$

$$D_{ALE} = [ALE / (DM_S + C + AP + ALE)] * D$$

(15) Apply the pro-rata structure deductible D_{sijk} and limits LM_{ijk} to each of the cells of the \$ damage Matrix DM_{ijk} . Calculate the structure loss L_{sijkn} net of deductible, and truncate it on the upside by LM_{ijk} and on the downside by D_{sijk} . Thus, a vector L_{sijk} of insured losses is generated for property k. Its elements are L_{sijkn} . If L_{sijkn} is $\exists L_{mijk}$, then $L_{sijkn} = L_{mijk}$. If L_{sijkn} is $\# 0$, then let $L_{sijkn} = 0$.

(16) Repeat step (15) for C, AP, and ALE. Here, these variables are means conditional on the wind speed. Generate $L_c, L_{AP},$ and L_{ALE} .

(17) Next, to get the *expected insured loss for a given wind speed w*, multiply each element L_{ijkn} of the vector L_{ijk} by its corresponding probability P_{ijkwn} to compute L_{ijknw} , and then sum over the N intervals⁴. Steps 15 - 17 can be represented by:

⁴ Once the damage ratios are generated, the traditional actuarial theory says that:

Loss net of deductible = (Damage Ratio x Bldg Value) - Deductible

$$\text{Expected Structure Loss} = E(L_S) = \sum_{D_s}^{L+D_s} 3 (DM_i - D_s) p_S + 3 LM_S p_S$$

$$\text{Expected Content Loss} = E(L_C) = \sum_{D_c} 3(C - D_c) p_C + 3 LM_C p_C$$

$$\text{Expected Appurtenant Loss} = E(L_{AP}) = 3 (AP - D_{AP}) p_{AP} + 3 LM_{AP} p_{AP}$$

$$\text{Expected ALE Loss} = E(L_{ALE}) = 3 (ALE - D_{ALE}) p_{ALE} + 3 LM_{ALE} p_{ALE}$$

where $L_{ijkwn} = LM_{ijk}$ if $(DM_{ijn} - D_{sijk}) \exists L_{mijk}$, and if $(DM_{ijn} - D_{sijk}) \neq 0$, then let $DM_{ijn} - D_{sijk} = 0$, i.e. replace negative values of net of deductible loss with zero. The same applies to C, AP, and ALE.

(18) $\text{Expected Loss} = E(L) = E(L_S) + E(L_C) + E(L_{AP}) + E(L_{ALE})$

(19) Repeat step (10) through (18) for all the wind speeds to generate a row of *expected insured loss for all wind speeds*.

(20) Multiply the Expected Loss $E(L_{ijkw})$ for a given wind speed by the probability of the wind speed, p_w . Next sum over all wind speeds to get the property k *Expected Loss*:

$$\text{Property k Expected Loss } E(L_{ijk}) = \sum_w 3 [E(L_{ijkw}) * p_w]$$

(21) Steps (7) through (20) are repeated for all dwellings of type i in zip code j to generate $E(L_{ijk})$ for all properties $k = 1, \dots, K$.

(22) The expected losses are then summed to get the Expected Aggregate Loss for property type i in zip code j:

$$\text{Expected Aggregate Loss} = E(L_{ij}) = \sum_K 3 E(L_{ijk})$$

and Loss # Limit. If net loss is < 0 then replace it with zero.

Example

Bldg value = \$200,000. Limit = \$180,000. Deductible = \$3,000. J^{th} Damage ratio = 5%.

Loss net of deductible = $.05 \times 200,000 - 3,000 = \$7,000$. If the J^{th} Damage ratio = 1%, then loss net of deductible = 0. If the damage ratio is 95% then the loss net of deductible is = $\$180,000 - \$3,000 = \$177,000$.

- (23) **Variance** will now need to be computed empirically, since all the terms in the calculations for the expected losses are correlated. We compute the variance as follows:

The variance for all dwellings of type i in zip code j will be:

$$\sigma^2_{ij} = \{1/(k-1)\} \left\{ \sum_{k=1}^K E(L_{ijk})^2 - (1/k) \left(\sum_{k=1}^K E(L_{ijk}) \right)^2 \right\}$$

- (24) To get the Expected Loss (mean loss) for structure type i in zip code j, the E(AL) is calculated as the weighted average of the Expected Loss of all properties of type i. The weight is the relative value of the structure $V_{ijk} / \sum V_{ijk}$ (or relative exposure of the structure $LM_{ijk} / \sum LM_{ijk}$):

$$\text{Expected Loss for property type i in zip code j} = \sum_{k=1}^K (V_{ijk} / \sum V_{ijk}) L_{ijk}$$

- (25) To estimate the expected loss as a percentage of exposure for structure type i in zip code j, use:

$$\% E(L_{ij}) = \left\{ \sum_{k=1}^K L_{ijk} / \sum_{k=1}^K LM_{ijk} \right\}$$

- (26) Repeat steps (5) through (23) for all property types $i = 1, \dots, I$ to get the Expected Aggregate Loss and Expected loss for all property types in zip code j.

- (27) Sum the $E(AL_{ij})$ across all property types i to get the Expected Aggregate Loss for all exposure in zip code j:

$$E(AL_j) = \sum_{i=1}^I E(AL_{ij})$$

- (28) Sum σ^2_{ij} to get σ^2_j , the variance for all exposure in zip code j.

- (29) Pick another zip code and repeat steps (4) through (28) to generate $E(AL_j)$ for all zip codes. Sum across the zip codes $j=1, \dots, J$ to get the Expected Aggregate Loss for insurance company m.

$$E(AL_m) \text{ for company m} = \sum_{j=1}^J E(AL_j)$$

- (30) Sum σ_j^2 to get σ_m^2 , the variance for insurance company m.
- (31) Pick another company or another portfolio of policies m and repeat steps (1) through (30). Sum across the insurance companies or portfolios to get the Overall Expected Loss.

9. Algorithm for the Scenario Insurance Loss Model (SILM)

In this section we develop the algorithm for estimating expected loss costs for a given scenario. Typically the scenario refers to a particular hurricane with a given set of characteristics. *Hence, both the exposure data and the wind speeds by zip code are given observed data. The damage matrices, as before, are modeled.* The observed wind speeds used are the 3 second peak gust winds. These are converted from the reported 1 minute maximum sustained wind speeds (which are typically 30 to 35% lower) by applying the gust factor model and corrections for terrain roughness. Most of the steps in this algorithm are the same as in the prior section.

- (1) Start with a particular insurance company m or portfolio of policies m .
- (2) Next pick a residential policy exposure unit k from the insurance policy database.
- (3) Determine the zip code j of the policy.
- (4) Extract the distribution of wind speeds for the zip code j from the wind database.
- (5) Next determine the building type i for the selected policy.
- (6) Select the damage matrix for *structure* of type i . Select the damage matrix for *structure* of type i . The structure types are: masonry, frame, mobile home, or unknown. The actual matrix selected will be a weighted matrix, where the weights are determined by the proportions of roof types in the region. For example, the matrix used for a masonry structure in Miami Dade county will be the weighted average of a masonry/hip roof matrix and masonry/gable roof matrix.

This matrix is provided by the Engineering team and consists of the simulated probabilities for various damage ratio intervals and wind speeds. The row represents a given interval n of damage ratios and the column represent a given wind speed w . Note that in the **scenario analysis the observed wind speeds**

are used. Thus, only the column corresponding to the observed wind speed for the zip code is used. Let X_{ij} be the vector of the mid points of the interval of damage ratios for structure type i in zip code j . It has N elements. Now rather than use the MDR (Mean Damage Ratio) of the whole matrix, the mid point of the damage ratio interval n , X_n , is used to represent an outcome, and the probability of this outcome for a given observed wind speed is P_{nw} . In general, for structure i in zip code k , the mid point of damage intervals is X_{ijn} and its probability of outcome for a given observed wind speed is P_{ijnw} .

- (7) Select the damage matrix for *contents* for structure of type i . This matrix is provided by the Engineering team and consists of the simulated probabilities for various content damage ratio intervals and wind speeds. The row represents a given interval n of content damage ratios and the column represent a given wind speed w . The interpretation of the cells values etc is similar to the description given above for structure damage matrix. Although the content damage depend indirectly on structural damage, there is no stipulated functional relationship between the two matrices and their damage intervals.
- (8) Select the AP and ALE damage matrices. The Engineering team has generated independent matrices for AP and ALE based on indirect relationships between structural damage and both ALE and AP.
- (9) From the insurance policy file, get the policy limits LM_{ijk} , and its deductible D_{ijk} . Typically, property values are not reported. For replacement cost policy the value of the property, V_{ijk} , is set to equal the limit $V = LM_S$. For actual cash value policy (replacement cost minus depreciation) the value of the property is set to equal $V = 1.25 \times LM_S$, since typically, ACV policies are insured to 80% of the value.
- (10) Select the damage vector for the observed wind speed. The observed wind speeds represent 3 second peak gust winds. Apply the damage ratio vector X_{ij} to the property k (of type i in zip code j). For each damage interval n , calculate the \$ damage: $DM_{ijknw} = V_{ijk} * X_{ijnw}$. Thus, a $N \times 1$ \$ damage vector DM_{ijk} is generated for property k . This vector is associated with the observed wind speed.

- (11) For the observed wind speed, estimate the row vector of wind conditional mean \$ content damages, where each element is the mean content damage for the given wind speed: $\text{mean } C_{ijkw} = LM_C * \text{mean } C_{ijnw}$ ratio.
- (12) For the observed wind speed, estimate the row vector of wind conditional mean \$ AP damages, where each element is the mean AP damage for the given wind speed: $\text{mean } AP_{ijkw} = LM_{AP} * \text{mean } AP_{ijnw}$ ratio.
- (13) For the observed wind speed, estimate the row vector of wind conditional mean \$ ALE damages, where each element is the mean ALE damage for the given wind speed: $\text{mean } ALE_{ijkw} = LM_{ALE} * \text{mean } ALE_{ijnw}$ ratio.
- (14) Using the wind conditional mean \$ structural damage DM_{ijk} , and combining it with the wind conditional mean C, mean AP_{ijkw} and mean ALE_{ijkw} : calculate the deductibles $D_S, D_C, D_{AP}, D_{ALE}$ on a pro-rata basis to the respective damages as follows:
- $$D_S = [DM_S / (DM_S + C + AP + ALE)] * D$$
- $$D_C = [C / (DM_S + C + AP + ALE)] * D$$
- $$D_{AP} = [AP / (DM_S + C + AP + ALE)] * D$$
- $$D_{ALE} = [ALE / (DM_S + C + AP + ALE)] * D$$
- (15) Apply the pro-rata structure deductible D_{sijk} and limits LM_{ijk} to each of the cells of the \$ damage Matrix DM_{ijk} . Calculate the structure loss L_{sijkn} net of deductible, and truncate it on the upside by LM_{ijk} and on the downside by D_{sijk} . Thus, a vector L_{sijk} of insured losses is generated for property k. Its elements are L_{sijkn} . If L_{sijkn} is $\exists L_{mijk}$, then $L_{sijkn} = L_{mijk}$. If L_{sijkn} is $\# 0$, then let $L_{sijkn} = 0$.
- (16) Repeat step (15) for C, AP, and ALE. Here, these variables are means conditional on the wind speed. Generate $L_C, L_{AP},$ and L_{ALE} .
- (17) Next, to get the *expected insured loss for the observed wind speed w*, multiply each element L_{ijkn} of the vector L_{ijk} by its corresponding probability P_{ijkwn} to

compute L_{ijkwn} , and then sum over the N intervals. Steps 15 - 17 can be represented by:

$$\text{Expected Structure Loss} = E(L_s) = \int_0^{L+D_s} 3 (DM_i - D_s) p_s + 3 LM_s p_s$$

$$\text{Expected Content Loss} = E(L_C) = \int_0^{D_s} 3(C - D_c) p_C + 3 LM_C p_C$$

$$\text{Expected Appurtenant Loss} = E(L_{AP}) = \int_0^{D_s} 3 (AP - D_{AP}) p_{AP} + 3 LM_{AP} p_{AP}$$

$$\text{Expected ALE Loss} = E(L_{ALE}) = \int_0^{D_s} 3 (ALE - D_{ALE}) p_{ALE} + 3 LM_{ALE} p_{ALE}$$

where $L_{ijkwn} = LM_{ijk}$ if $(DM_{ijn} - D_{sijk}) \geq LM_{ijk}$, and if $(DM_{ijn} - D_{sijk}) < 0$, then let $DM_{ijn} - D_{sijk} = 0$, i.e replace negative values of net of deductible loss with zero. The same applies to C, AP, and ALE.

(18) Expected Loss = $E(L_{ijk}) = E(L_s) + E(L_C) + E(L_{AP}) + E(L_{ALE})$ for property k

(19) Steps (7) through (18) are repeated for all dwellings of type i in zip code j to generate $E(L_{ijk})$ for all properties $k = 1, \dots, K$.

(20) The expected losses are then summed to get the Expected Aggregate Loss for property type i in zip code j:

$$\text{Expected Aggregate Loss} = E(L_{ij}) = \sum_{k=1}^K E(L_{ijk})$$

(21) **Variance** will now need to be computed empirically, since all the terms in the calculations for the expected losses are correlated. We compute the variance as follows:

The variance for all dwellings of type i in zip code j will be:

$$\sigma_{ij}^2 = \left\{ \frac{1}{(k-1)} \sum_{k=1}^K E(L_{ijk})^2 - \left(\frac{1}{k} \sum_{k=1}^K E(L_{ijk}) \right)^2 \right\}$$

(22) To get the Expected Loss (mean loss) for structure type i in zip code j, the $E(AL)$ is calculated as the weighted average of the Expected Loss of all properties of type i. The weight is the relative value of the structure $V_{ijk} / \sum_{k=1}^K V_{ijk}$

(or relative exposure of the structure $LM_{ijk} / \sum_{k=1}^3 LM_{ijk}$):

$$\text{Expected Loss for property type } i \text{ in zip code } j = \sum_{k=1}^3 (v_{ijk} / \sum_{k=1}^3 v_{ijk}) L_{ijk}$$

- (23) To estimate the expected loss as a percentage of exposure for structure type i in zip code j , use:

$$\% E(L_{ij}) = \left\{ \frac{\sum_{k=1}^3 L_{ijk}}{\sum_{k=1}^3 LM_{ijk}} \right\}$$

- (24) Repeat steps (5) through (21) for all property types $i = 1, \dots, I$ to get the Expected Aggregate Loss and Expected loss for all property types in zip code j .

- (25) Sum the $E(AL_{ij})$ across all property types i to get the Expected Aggregate Loss for all exposure in zip code j :

$$E(AL_j) = \sum_{i=1}^I E(AL_{ij})$$

- (26) Sum σ^2_{ij} to get σ^2_j , the variance for all exposure in zip code j .

- (27) Pick another zip code and repeat steps (4) through (26) to generate $E(AL_j)$ for all zip codes. Sum across the zip codes $j=1, \dots, J$ to get the Expected Aggregate Loss for insurance company m .

$$E(AL_m) \text{ for company } m = \sum_{j=1}^J E(AL_j)$$

- (28) Sum σ^2_j to get σ^2_m , the variance for insurance company m .

- (29) Pick another insurance company m and repeat steps (1) through (28). Sum across the insurance companies to get the Overall Expected Loss.

10. Use Case for Actuarial Form A1: Loss Estimates for Thirty Hypothetical Hurricane Events

Thirty hypothetical events have been specified by the Commission consisting of five hurricanes, one for each hurricane category 1-5, at six different landfall locations; Jacksonville, Ft. Pierce, Miami, Ft. Myers, Tampa/St. Petersburg, and Panama City. A description of the events and the tracks of all storms are specified in the file named “*FormA1Input04.xls*”.

More specifically, for the thirty events, data are provided on central pressure, radius of maximum winds, forward speed, landfall location, direction at landfall, and radius of hurricane force winds. The hurricane are assume to continue through the state in the direction specified until they exit the state. The use case identifies all the zip codes over which the each hurricane passes. Data on exposure, for the zip codes, by coverage type and construction type are extracted from the Cat Fund aggregate exposure data file. The damage matrices for these zip codes and construction types are selected. The losses are then estimated using the Scenario Insurance Loss Model (SILM) for the exposure in the zip codes.

Because the meteorological data is given, the wind field model and wind probability components are not activated. *This test, therefore, is essentially a test of the upstream vulnerability and actuarial components.*

The form requires the following output to be generated:

- (a) maximum estimated one-minute sustained 10-meter wind speed over land associated with the events. Modeled estimated one-minute average wind speeds should be consistent with central pressure inputs.
- (b) projected loss by coverage type. Projected losses are requested in total and by coverage type for the thirty hypothetical events.

The procedure for A1 consists of the following steps:

1. Run the wind field model for each of the 30 hypothetical storms tracks. and their given tracks run the wind fields at successive time intervals using a

combination of the inland decay, storm track and intensity, and wind field models.

2. Determine the set of zip codes over which each the 30 hurricane pass.
3. The maximum wind speed anywhere in the storm for open terrain exposure (OTWS1) is the required output for field 10. This should be entered for each of the 30 storms.
4. For each storm the wind field model output file contains the mean OT wind Speed and direction. These data are then sent to the wind speed correction (WSC) algorithm and the wind speeds are corrected to the maximum 1 min wind speed for the actual terrain (V1mph) and the peak 3 s gust (V3) for the actual terrain.
5. Run the Scenario Insurance Loss Model (SILM), using (a) the zip code level Cat Fund exposure data (file 02fhcfwts.xls) by construction type and by type of coverage, (b) the peak 3 second gust (V3) generated in step 4, (c) the appropriate damage matrices for the zip code region by construction type.
6. For each of the 30 hypothetical storms, generate the following output from the SILM model: projected total losses for structures, contents, AP, and ALE, and the total losses across all coverage types. The losses for are aggregated across all affected zip codes and across construction types.

11. Use Case For Actuarial Form A2: Loss Costs for Hypothetical Coverage by Construction Type For Each Zip Code

This use case requires the model to provide the expected annual loss costs by construction type and coverage for each ZIP Code in the sample data set named “*FormA2Input04.xls*.” There are 1,479 ZIP Codes and three construction types; therefore, the completed file should have 4,437 records in total. The exposure for each zip code is set at: \$100,000 for structure, \$50,000 for contents, \$10,000 for appurtenant structure, and \$20,000 for additional living expenses. The deductible is set at 1%.

The use case tests the Probabilistic Insurance Loss Model (PILM) for all the zip codes. The exposure and the deductible are held constant across the zip codes. *So the purpose of this form is to determine how the loss costs vary across zip codes because of the meteorological and vulnerability functions.*

The procedure for A2 consists of the following steps:

1. Get the wind probability distribution for each zip code generated by the 55,000 year simulation run of the meteorology model. These runs generate a stochastic set of 42,262 simulated storms. Based on the number of years and the number of storms, for various wind speed intervals, that pass through a given zip code, the probability distribution of wind speeds is generated for that given zip code. These distributions are for the terrain corrected 3 sec peak gust winds.
2. Run the Probabilistic Insurance Loss Model (PILM), using (a) the exposure data (file *FormA2Input04.xls*) by construction type and by type of coverage, (b) the modeled terrain corrected peak 3 second gust (V3) generated by the meteorological components for all zip codes in step 1, (c) the probabilities for the wind speeds generated by the meteorological use case, (d) appropriate damage matrices for all the zip code region by construction type.
3. For each zip code, and for each construction type, using the PILM, produce the projected loss costs for structure, AP, contents, and ALE.

12. Use Case For Actuarial Form A4: Official Hurricane Set Average Annual Zero Deductible Statewide Loss Costs

Requires the model to produce the monetary contribution to the average annual personal residential zero deductible statewide loss costs from each specific hurricane in the 2004 Official Hurricane Set. There are 73 hurricane in the official set and they occur between 1901-2003.

The procedure for A4 consists of the following steps:

1. Using HURDAT data set determine the actual track of all 73 Florida hurricanes of the past century.
2. Run the wind field model for each of the base set hurricane storm tracks.
3. For each storm the wind field model output file contains the mean OT wind Speed and direction. These data are then sent to the wind speed correction (WSC) algorithm and the wind speeds are corrected to the maximum 1 min wind speed for the actual terrain (V1mph) and the peak 3 s gust (V3) for the actual terrain. The peak winds are generated for all affected zip code centroids. These wind speeds will be used in the scenario based ILM.
4. Run each historical storm through the Scenario Insurance Loss Model (SILM), using (a) the zip code level Florida Cat Fund exposure data (file *hlpm2002.xls*) grouped by construction type and by type of coverage, (b) zero deductible, (c) the terrain corrected peak 3 second gust (V3) generated in step 3 for all the affected zip codes along the historical track, (d) the appropriate damage matrices for all the zip code region by construction type.
5. Using the SILM produce the contribution of each storm to the zero deductible statewide loss costs. First estimate the total projected losses for each historical storm track, summed across all construction types, all coverage types, and all affected zip codes. Next divide the losses by 104 (years) to get the monetary contribution to the average annual residential zero deductible statewide loss costs from each hurricane in the Official Hurricane Set.

13. Use Case For Actuarial Form A5: Current Exposure Based Losses From Modeled Hurricane Andrew

Requires the model to produce the losses from Hurricane Andrew track for the 2002 Cat Fund exposure data. Requires that the projected loss and percentage of losses be generated for each zip code from Hurricane Andrew track. The winds underlying the loss costs calculations must be produced by the modeled wind fields rather than the published wind field for Hurricane Andrew.

The procedure for A5 consists of the following steps:

1. From the HURDAT data set extract the actual track, central pressure, R-Max, translational speed etc. for Hurricane Andrew.
2. Run the wind field model for the given track, CP, R-Max etc.
3. The wind field model will produce the mean OT wind Speed and direction. These data are then sent to the wind speed correction (WSC) algorithm and the wind speeds are corrected to the maximum 1 min wind speed for the actual terrain (V1mph) and the peak 3 s gust (V3) for the actual terrain. The peak winds are generated for all zip code centroids affected by hurricane Andrew. These wind speeds will be used in the scenario based ILM.
4. Run the modeled hurricane Andrew through the Scenario Insurance Loss Model (SILM), using (a) the zip code level Florida Cat Fund exposure data (file *02 fhcfwts.xls*) aggregated by construction type and by type of coverage, (b) zero deductible, (c) the terrain corrected peak 3 second gust (V3) generated in step 3 for all the affected zip codes along the hurricane Andrew track, (d) the appropriate damage matrices for the southern Florida region for all the construction types.
5. Using the SILM produce the contribution of each zip code to the zero deductible aggregate losses. These are the projected losses and % of total losses for each affected zip code, summed across all construction types, and all coverage types.

14. Use Case For Actuarial Form A6: Distribution of Hurricanes by Size of Loss

Requires the model to provide the distribution of hurricane by size of losses. More specifically, requires the model generate, for successive loss ranges, the following: total loss, average loss, number of simulated hurricanes, expected annual hurricane losses, and return time in years. For the Expected Annual Hurricane Losses column, provide personal residential, zero deductible statewide loss costs based on the 2002 Florida Hurricane Catastrophe Fund's (FHCF) aggregate exposure data.

The procedure for A6 consists of the following steps:

1. Determine the optimal number of years of simulation for the meteorological component. This is done through procedures outlined in statistical standard S4.
2. Run the meteorological simulations for the optimal number of years. For our model it is around 55,000 years. The 55,000 year run generated a stochastic set of 42,262 simulated storms. Extract the track and maximum sustained wind speed information for each of the tens of thousands of simulated storms. Convert the sustained wind speeds into terrain corrected 3 sec peak gust wind speeds.
3. For each of the 42,262 simulated storms in the stochastic set, run the Scenario Insurance Loss Model (SILM), using (a) the zip code level 2002 Florida Hurricane Catastrophe Fund's (FHCF) aggregate exposure data by construction type and by type of coverage, (b) zero deductible, (c) the modeled terrain corrected peak 3 second gust (V3) winds generated by the meteorological components for all the zip codes affected by a given simulated storm, (d) the appropriate damage matrices for all the affected zip code region for masonry and frame construction type.
4. The SILM should produce for each simulated storm, the aggregate personal residential (frame and masonry construction) zero deductible state wide loss. This is done for all the thousands of simulated storms.

5. Classify the simulated storms by the size of state wide losses they produce. Assign the storm losses to their respective loss range. The ranges are in bins of \$500 million up to \$5,000 mil and bins of \$1000 mil thereafter (0 to \$500 mil, \$501 to 1000 mil,, 4501 to 5000, 5001 to 6000 etc. all the way to the maximum).
6. For each loss range sum across the corresponding assigned storms to get the total loss for the range.
7. Divide the total loss for each loss range by the number of hurricanes in the range to generate the average loss for the range.
8. Divide the total loss for each loss range by the number of simulated years to generate the expected annual hurricane loss for that range.
9. Estimate the return time associated with the average loss within the ranges on a cumulative basis. This is based on the probability of exceedance. The return time is the reciprocal of the probability of the loss equaling or exceeding the average loss for the range. Specifically, the return year for a given loss range is the reciprocal of the ratio of (number of years with losses > than the mean of the range)/(number of simulated years or 55,000).

15. Use Case for Actuarial Form A7: Output Ranges for Loss Costs for Counties by Coverage Type and Construction Type and Deductibles

Requires the model provide loss costs per \$1000 for each county in the state of Florida. Within each county, loss costs should be shown separately per \$1,000 of exposure for personal residential, tenants, and mobile home; for each major deductible option; and by construction type. This use case uses all the components of the model and is therefore a joint tests of the meteorological, vulnerability, and actuarial models.

For each of these categories using ZIP Code population centroids, the output range should show the highest loss cost, the lowest loss cost, and the weighted average loss cost based on the 2002 Florida Hurricane Catastrophe Fund (FHCF) aggregate exposure data provided in the file named "*hlpm2002.exe*". Use file named "*02FHCFWts.xls*" for determining the weighted average loss costs. Include the statewide range of loss costs (i.e., low, high, and weighted average). For each of the loss costs provided, identify what that loss cost represents by line of business, deductible option, construction type, and coverages included, i.e., structure, contents, appurtenant structures, or additional living expenses as specified.

The procedure for A7 consists of the following steps:

1. Get the wind probability distribution for each zip code generated by the 55,000 year simulation run of the meteorology model. These runs will generate a stochastic set of tens of thousands of simulated storms. Based on the number of years and the number of storms, for various wind speed intervals, that pass through a given zip code, the probability distribution of wind speeds is generated for that given zip code. These distributions are for the terrain corrected 3 sec peak gust winds.
2. Run the Probabilistic Insurance Loss Model (PILM), using (a) the hypothetical exposure data provided in the ROA for various coverage, ale , and using the weights derived from zip code level Cat Fund exposure data (files *hlpm2002.exe*) by policy group (combination of construction type, deductible

option and line of business) and by type of coverage, (b) the modeled terrain corrected peak 3 second gust (V3) wind data generated by the meteorological components for all zip codes in step 1, (c) the probabilities for the wind speeds generated by the meteorological use case in step 1, (d) the appropriate damage matrices for the zip code region by construction type.

3. For each policy group in each of the zip codes (each combination of construction type, deductible option, line of business in the zip code), using the PILM, produce the projected expected losses for structure, AP, contents, and ALE.
4. For each policy group (combination) in each zip code, and for each coverage type, estimate the loss costs per \$1,000 = (expected losses/amount of coverage)*1,000. Report the results for each policy form, for each construction type and each deductible type at the county level of aggregation.
5. For each given policy group (combination), select and report the highest and lowest zip code level expected loss costs per \$1,000 among all the zip codes in the county.
6. Next using the weights determined by the relative Cat Fund zip code level aggregate exposure data (file *02fhcfwts.xls*) by construction type and by type of coverage, estimate the weighted average county lost costs. The weights are the percentage of county wide exposure in each zip codes. Repeat this for various types of deductibles.
7. For each county, using the PILM, produce the projected expected losses for structure, AP, contents, and ALE for the range of deductibles and construction type.
8. For the variety of deductibles and construction type, and line of business, calculate the county wide loss costs per \$1,000 = (expected losses/amount of coverage)*1,000. Report these loss costs.
9. Repeat steps 6 to 8 using the same amount exposure for all policies (instead of

the Cat Fund county wide aggregate exposure data (file *02fhcfwts.xls*). Use the *hlpm2002.exe* data to estimate the exposure weights to produce the weighted average loss costs for each counties.

16. Use Case for Statistical Form S2: Probable Maximum Loss (PML)

The purpose of this use case is to provide the PML distribution of annual losses for a set of hypothetical policy data. The hypothetical data is provided in the input file “*FormA1Input06.xls*.”

The procedure for S2 consists of the following steps

1. For each of the 42,262 hurricane in the 55,000 year run simulated stochastic set, estimate the aggregate losses for the hypothetical exposure data.
2. The 42,262 hurricane occur in about 35,000 years. Sum the losses across the multiple hurricanes occurring in any given year. This generates a set of annual losses.
3. Rank the annual losses from high to low.
4. Choose a set of return time (e.g., 5, 10, 50, 100, 250, 500, 1000, 5000, 10000 years). The probability of exceedance for any given return time is the reciprocal of the return year. Therefore, probability of exceedance for 50 year return time is $1/50 = 2\%$.
5. The rank (position from the top) of the loss for a given return time is = (# of simulated years/ return time). Thus, the position of the 100 year return time will be $55,000/100 = 550$. The losses corresponding to this position will be the total annual loss for 100 year return time.
6. Repeat step 5 for all selected return time.
7. Based on the 55,000 years of losses calculate the mean, median, standard deviation and inter-quartile range of losses

17. Use Case for Statistical Form S3: Comparisons of Modeled versus Actual Historical Losses

The purpose of this use case is to validate the modeled losses against actual historical losses for different insurance company policy portfolios and for different hurricanes.

The procedure for S3 consists of the following steps

1. From the HURDAT data set extract the actual track, central pressure, R-Max, translational speed etc. for selected historical hurricanes.
2. Run the wind field model for the given track, CP, R-Max etc.
3. The wind field model will produce the mean OT wind Speed and direction. These data are then sent to the wind speed correction (WSC) algorithm and the wind speeds are corrected to the maximum 1 min wind speed for the actual terrain (V1mph) and the peak 3 s gust (V3) for the actual terrain. The peak winds are generated for all zip code centroids affected by hurricane Andrew. These wind speeds will be used in the scenario based ILM.
4. Run the modeled hurricane through the Scenario Insurance Loss Model (SILM), using (a) each of the policies in the portfolio of company policy exposure data of the affected zip codes at the time of the hurricane, (b) actual policy deductibles, (c) the terrain corrected peak 3 second gust (V3) generated in step 3 for all the affected zip codes along the hurricane Andrew track, (d) the appropriate damage matrices for all the construction types.
5. Using the SILM produce the aggregate modeled losses and loss/exposure ratio, by coverage type and by construction type for each hurricane/company.
6. Compile the actual aggregate losses for each event and compare with the modeled losses.

18. Use Case for Statistical Form S4: Average Annual Zero Deductible Statewide Loss Costs-Historical versus Modeled

The purpose of this use case is to provide the average annual zero deductible statewide loss costs using the 2002 personal residential Cat Fund exposure data provided in the input file “*hlp2002.exe*.” The Cat Fund aggregate exposure data is applied to wind fields and track data for the list of historical hurricanes in the Base Hurricane Storm Set.

The procedure for S4 consists of the following steps

1. Run the Cat Fund exposure data through the SILM using the historical wind field and track data for each of the historical storm in the base set (1900-2005). Use the appropriate vulnerability matrices for the zip code level exposure data grouped by construction type, and policy type. Set the deductible for each group equal to zero. Estimate the aggregate loss generated by each historical hurricane using the current exposure data.
2. Sum the losses across all the historical hurricanes. Divide the sum by the number of years in the base set. This provides the average annual zero deductible statewide loss costs for historical hurricanes.
3. Run the Cat Fund exposure data through the PILM using the modeled wind field and wind probabilities and appropriate vulnerability matrices. Set the deductibles for each policy group equal to zero. The PILM will produce the average annual zero deductible statewide modeled loss costs.