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HOMEOWNERS RATEMAKING REVISITED (USE OF COMPUTER MODELS TO ESTIMATE CATASTROPHE LOSS COSTS)

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Abstract

Recent improvements in computer technology and easy access to large quantities of data have eliminated some traditional limitations on insurance ratemaking. The emergence of catastrophe simulation using computer modeling has helped actuaries develop new methods of measuring catastrophe risk and providing for it in insurance rates. This paper addresses these new methods and illustrates the features and benefits of computer modeling for catastrophe ratemaking. Hurricane loss costs as part of homeowners coverage are treated in the main body of the paper; modeling for other catastrophic perils is reviewed in the Appendix.

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1. WHY MODELING?

According to the CAS Principles of Ratemaking, a rate is "an estimate of the expected value of future costs, provides for all costs associated with the transfer of risk, and provides for the costs associated with an individual risk transfer."

Traditionally, ratemaking has been regarded as the art of extrapolating valid conclusions about the future from scientifically measured past experience. However, for lines of business with catastrophe potential, questions always arise as to how much past insurance experience is needed to represent possible future outcomes and how much weight should be assigned to each year's experience. For instance, if a 1954 hurricane was the last severe event in a given state, may one assume that the return period for an event of the same severity is 43 years? What if historical records show that more severe storms occurred in the 1930s, before the advent of homeowners coverage? If the same storm struck in 1997, would it affect the same properties? What level of damage would occur, given that the distribution of insureds has shifted to coastal communities and that the insured values at risk have trended at a pace that has exceeded inflation?

For these rare calamities, reliance on actual insured experience does not allow accurate measurement of future expected loss. Therefore, one must use a much longer experience period, especially for event frequency. Computer simulation of events to obtain current insured losses has replaced traditional methods based exclusively on reported loss experience. These new methods can now be used not only to measure expected losses, but also to develop risk loadings to compensate for the variance in outcomes, compared to lower-risk insurance products.

The need for catastrophe modeling to aid in reinsurance purchase decisions and in insurance ratemaking has existed for some time. However, computer limitations on the amount of data that could be manipulated to develop a catastrophe model rendered the concept impractical in the past. In recent years, computer capacity has improved dramatically, making catastrophe simulation feasible. Increased computer capability has also enabled scientists to expand their research and produce better simulations through a better understanding of catastrophic events.

2. WHAT TO MODEL

A state's most recent historical losses may not be indicative of its true catastrophe potential because what happens in a given year is only a sample of what could have happened. The goal is to build a model to simulate what could realistically occur, based on information relevant to that state and to all refined geographic areas within the state.

Building a computer model requires that the estimation process be separated between frequency and severity. For the frequency of hurricanes, there is a long history (more than 100 years) of recorded information to help gauge the relative likelihood of landfall in a given state. Even so, there may be a need to supplement that history with geologic information dating back several thousand years to measure the relative frequency of Category 5 hurricanes. Such investigations are now feasible. Scientists believe that they can determine the return periods of very severe events by examining tempestites—ocean floor and coastal lagoon samples, where catastrophic events have left telltale signs in the sand.

For severity of hurricanes, however, older storms over the past hundred years do not offer any useful insured loss information. Even for storms in the 1950s and 1960s, the extent of loss if that same storm occurred again would depend on *today's* insured values, deductibles and level of windstorm-resistant structures. However, a computer simulation model for the hurricane peril can take the characteristics of a storm and replicate the wind speeds over its course after landfall. The damage to buildings and contents and the resulting effect on insured values are based on the wind field created by the modeled storm. Validation of the model examines actual loss experience obtained from storms that have occurred over the recent past. This is an ongoing process as new catastrophes occur.

Because storm simulation by computer was the initial breakthrough, we start with it as the basis for modeling the severity component in estimating hurricane loss costs.

3. HOW TO MODEL FOR SEVERITY

The severity component of catastrophe modeling generally comprises three distinct modules requiring three separate skills:

- event simulation (science)
- damageability of insured properties (engineering)
- loss effect on exposures (insurance).

The event simulation module is designed to reproduce natural phenomena. For a hurricane model, wind physics is now understood well enough to predict wind speeds at every location over the course of a single storm. A model would use such key inputs as central pressure, radius of maximum wind, and forward speed of storm. For practical purposes, each risk can be viewed as being at the geographic centroid of the ZIP code in which it is located. This is generally the finest level of detail currently coded by insurers for their risks. However, greater availability of exposure information at the street level (especially for personal lines) will eventually allow models with even finer levels of detail.

The damageability module estimates the damage sustained by a given property exposed to the simulated event. The damage functions used in a catastrophe model are generally developed by engineers familiar with structural vulnerabilities who test the resistance of various materials to high wind speeds. (The results of these studies are also used to develop new materials and to implement new building codes to limit the damage from catastrophes.)

The insured loss effect module incorporates the results of the first two modules and adjusts for such factors as deductibles, coinsurance, insurance to value, and reinsurance. The loss effect is generally the only company-specific module because it includes all the factors that describe an insurer's in-force book of business. It is also the one used for risk analysis (probable maximum loss) for an individual insurer.

The severity component of catastrophe modeling is usually deterministic, calculating the impact of a predetermined event with known characteristics. The computer, in effect, simulates that event today, with the resulting losses to insured exposures. Of course, even for a particular set of parameters (e.g., wind speed or landfall), the actual distribution of losses will be stochastic. However, the use of a damage factor curve, with validation over a number of storms, can adequately represent the average loss results. This is especially true when a large number of events are simulated. Appendix A provides a detailed description of the process of developing and validating the severity component of a catastrophe model.

4. HOW TO MODEL FOR FREQUENCY

Deterministic catastrophe models were the first ones created, calibrated and validated. They helped to approximate probable maximum loss calculations for risk analysis, by postulating possible storms in different locations to estimate insured losses from adverse events. This deterministic method, however, is not appropriate for ratemaking, which needs to incorporate relative frequency or the probabilities of each type of storm.

To add a frequency component to the hurricane model, one must analyze long-term meteorological records of hurricanes by landfall area, supplemented with informed judgment obtained from professionals in the field of meteorology. One can obtain the historical data from National Oceanic and Atmospheric Administration (NOAA) publications. The past data are then fitted to derive probability distributions of the key input parameters, such as radius of maximum wind, forward speed and pressure differential at the eye of the storm. For example, an analysis of the radius of maximum winds of historical events in South Florida yields a conclusion that they are normally distributed ($N(\mu,\sigma)$), with parameters of 16.840 and 10.567 nautical miles.

Sampling techniques (Monte Carlo, stratified, or a combination of both) can randomly select the parameters from each distribution. Monte Carlo sampling generally assigns an equal probability to all sampled items from the entire population, which makes it easy to use and explain to a nonstatistical audience. One of its drawbacks, however, is a lack of precision in estimating unlikely events. This can be overcome by generating a very large sample size. However, in certain situations, the sample size may become enormous and create problems of efficiency, even with today's computers. An alternative is stratified random sampling.

By dividing the entire population into smaller groups (or strata), stratified sampling allows a more accurate estimation of their distribution, considering homogeneity. These estimates can then be combined into a precise estimate of the overall population with a smaller sample size than with Monte Carlo sampling.[1] Another benefit of stratified random sampling is the ability to sample a larger number of events in each strata than their relative probability in the overall population. This makes the estimation of extremely unlikely events possible, such as a Category 5 hurricane in Maine. This is important because the potential damage associated with such an event, even though only remotely

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[1]Refer to Cochran [2, p. 87] for additional information on the benefits of stratified sampling.

conceivable, may be of significance for certain insurers for risk analysis or for ratemaking. When this approach is utilized, the relative probability of each sampled storm must be adjusted to reflect its overall probability in the distribution.

In conjunction with storm intensity distributions, one must also develop the storm path and landfall location for each modeled storm. The selected parameters are based on actual historical events over the last hundred years and on other available sources of information.

After selecting the storm intensity parameters and deriving their respective conditional probabilities, the results are combined. The probabilities are conditional because they refer to the likelihood of a hurricane of a certain size, once a hurricane makes landfall. By definition, the sum of the probabilities will add up to one. The end result is the probabilistic library, which comprises a large enough number of events (in excess of 5,000) to represent all likely scenarios, each with an associated probability. While there is no minimum set of events or sample size required, it is important that it be large enough to ensure that every ZIP code exposed to hurricane force winds will be subjected to a significant number of events. By using stratified sampling techniques, it will be typical for a given ZIP code to be affected by over 1,000 events, rendering the loss estimates fully credible.

5. BASIC OUTPUT OF MODEL

A probabilistic database is the key to calculating expected loss costs. Because the basic premise is that all possible events have been identified along with their probabilities, one can calculate expected loss costs directly for the base class risk in a geographic locale. Simply run the entire event library against a base class house at $100,000 of Coverage A at the centroid of each ZIP code. The resulting expected losses can be divided by the amount of insurance in thousands to produce an expected loss cost per $1,000 of insurance for each ZIP code.

The reason the ZIP code is used as the basic building block is that virtually all insurers are capturing this value. If insurers were geo-coding risks (i.e., by street address mapped to latitude and longitude), the model could also produce loss costs at that level of detail. However, the ultimate rating territories for hurricane are likely to include multiple ZIP codes, so the results can be initially produced by ZIP code.

To ensure that all coverages are handled appropriately in the simulation for a homeowners policy (HO-3), one would assign an additional 10% of the Coverage A (building) amount for Coverage B (appurtenant structures), 50% for Coverage C (contents), and 20% for Coverage D (additional living expense; i.e., loss of use).

Annual expected loss costs for a given ZIP code are obtained by multiplying the sum of the probability-weighted simulated results across all storms by an annual hurricane frequency. The average annual frequency of hurricanes making landfall in the U.S. has been approximately 1.3 for storms with central pressure under 982 millibars.

For a given line of business, the expected losses by ZIP code are then:

$$EL_{\mathrm{ZIP}} = F \times \sum_{\mathrm{storm}} (P_{\mathrm{storm}} \times E_{\mathrm{ZIP}} \times DF_{\mathrm{storm}}),$$

where

EL_{ZIP} = Expected losses for ZIP code for base class

F = Annual hurricane frequency

P_{storm} = Probability of storm

E_{ZIP} = Total exposure amount (Base class constant for all ZIP codes)

DF_{storm} = Damage factor for base class by ZIP code by storm.

These expected losses represent insured losses for a base class amount of insurance, construction type and deductible. These may be selected as frame building with a \$250 deductible, \$100,000 of Coverage A, \$10,000 of Coverage B, \$50,000 of Coverage C and \$20,000 of Coverage D. Because loss adjustment expenses for catastrophes are generally related to the overall level of losses, it is appropriate to include them in the expected losses as a percentage of total losses.

To convert this to a loss cost expressed as a rate per \$1,000 of Coverage A, divide by the exposure base times 1,000.

$$ELC_{\text{ZIP}} = \frac{EL_{\text{ZIP}}}{COVA_{\text{ZIP}}} \times 1{,}000,$$

where

ELC_{ZIP} = Expected loss cost for ZIP code

$COVA_{\text{ZIP}}$ = Base class Coverage A amount in ZIP code.

Independence from Company Experience

A major feature of this calculation is its independence from an individual company's actual loss experience and exposure distribution. Being independent of individual company data, it is, in fact, appropriate for each insurer.

What would happen if an insurer tried to use its own exposure distribution to estimate base class loss costs? First, it would have to run the model in complete class and ZIP code detail over its latest exposure distribution, which would produce expected losses in dollars for the insurer by ZIP code. However, dividing by the total exposures by ZIP code would only yield average loss costs by ZIP code. What if the insurer had a disproportionate number of high-risk exposures in that ZIP code? The insurer would have to divide by the average class relativity in each ZIP code to get the average base class loss cost.

Furthermore, the class relativities to divide out should, in theory, be the indicated class relativities, not the current relativities. Section 6 will deal with how to calculate indicated class relativities using a model. Doing all this using company exposures would then only produce the same answer as using the base class exposure method described above.

In traditional loss ratio methods of ratemaking, with actual loss experience determining loss costs, it is important to use the insurer's actual losses and exposures. However, in catastrophe ratemaking using computer modeling, large volumes of industry loss experience have been used over the last ten years to calibrate the average severity, and meteorologic data over a hundred years have been used to calibrate frequency.

Hence, the value of an individual insurer's actual loss experience is very limited. First, it may not be relevant to know that, for hurricane, a house was insured by Company A versus Company B. Second, an individual insurer may be such a small subset of the total industry loss experience that it has little credibility, especially if the insurer has less than a 5% market share. The example here is for such an insurer, for whom the hurricane model represents the best estimate of future expected costs.

Combining ZIP Codes Into Territories

The next step is to use the insurer's actual exposure distribution by ZIP code to get the base class loss costs for the territory structure it selects after reviewing the indicated hurricane loss costs by ZIP code. The use of geographic mapping is especially useful in this selection process because the ZIP codes can be grouped in ranges and then printed on color-coded maps to help visualize the boundaries of possible territories. For the early years of ratemaking via catastrophe models, broad groups of ZIP codes are likely, such as those with loss costs in ranges of $.25 per $1,000 of Coverage A. Once the ZIP code groupings are selected, the loss costs for the new territories can be calculated by the following formula:

$$ELC_{\text{terr}} = \frac{\sum_{\text{ZIP}} (ELC_{\text{ZIP}} \times COVA_{\text{ZIP}})}{\sum_{\text{ZIP}} COVA_{\text{ZIP}}},$$

where

$$ELC_{\text{terr}} = \text{Expected Loss Cost for territory, and}$$

$$COVA_{\text{ZIP}} = \text{Coverage A amount for territory.}$$

In Exhibit 1, the ZIP code loss costs per $1,000 of Coverage A for homeowners are averaged for a given territory structure to derive the territorial loss costs for hurricane coverage. It is likely that the more appropriate territory structure for hurricane will differ from regular homeowners territories. Because the latter evolved over time to respond to homogeneity considerations in setting rates for the perils of fire and theft, there is a need to create new territories to reflect differences in hurricane loss potential.

6. ATTRIBUTES OF LOSS COSTS VIA COMPUTER MODELING

Credibility

Through computer simulation and stratified sampling, the individual ZIP codes are fully credible in the traditional sense because the inputs have theoretically accounted for all the useful information (from industry-validated damage factors to more than 100 years of storm frequency experience). One would not want to assign the complement of credibility to an insurer's actual results on a statewide basis over the past few years, because the recent insurer results add no useful new information and, in fact, could bias the answer because of too much randomness. The idea of the model is to substitute the random variation of low-frequency *actual* storms with the use of a reasonable set of *possible* storms, with their probabilities. (It is understood that even the past 100 years of hurricane history do not contain the set of all possible storms and their inherent likelihood.)

While theoretical full credibility can be assigned in refined cell detail from the computer simulation, this only means that random statistical variation can be resolved to minimize the process risk from a ratemaking standpoint. However, there is still parameter risk in the selection of the key variables because the event frequencies of the past 100 years may not be representative of the next 100 years. (This is especially true in earthquake simulation, where return periods may be in the hundreds or even thousands of years. Also, the understanding of the physics of shake intensity is still evolving among earthquake experts.)

Overcoming parameter risk is the goal of scientific research in the future. As geologic findings help measure the return periods of large hurricanes by region, better estimates of frequency will be developed. This is really no different from the basic ratemaking paradigm that the recent past history will repeat itself, and that the five-year experience period of loss ratio reviews is assumed to be predictive of the next few years. In the case of hurricane modeling, the pure premium method actually calculates the long-term frequencies separately from the more recent average severities, so the existence of parameter risk is highlighted, especially in the frequency calculation. Also, the answer to parameter risk is not to abandon modeling as a method, but to continually strive for better input parameters.

The pure premium method also allows the calculation of loss costs in refined detail directly, using the model's frequency and severity features. For traditional loss ratio ratemaking, the actual insured loss experience from the recent past is used, beginning with statewide totals. Each refinement of statewide data to territory or class carries with it a reduction in credibility because of much smaller experience volumes. This stems from the experience loss ratio method used to derive the result—actual insured experience that is a sample taken from what is expected to occur over time. In contrast, hurricane loss costs are derived from an estimated set of all possible events as constructed in the computer model.

Frequency of Review

Hurricane loss costs derived from modeling do not need frequent updates for two reasons. First, with more than 100 years of event characteristics shaping the model design, another year of actual results is unlikely to change the model parameters much. However, in the early years of model usage, the potential exists to update some of the damage factors. Also, when new class variables are developed, one can refine initial estimates with the loss experience of subsequent actual storms. For example, one could test new kinds of shutters and incorporate the results in the model. For estimating territory loss costs in the early years of model implementation, ZIP code distributions could change, as insureds and insurers react to high loss costs in certain coastal areas.

Second, once adequate rate levels are achieved, annual updates are not critical because the exposure base ($1,000 of Coverage A) is inflation sensitive. The accompanying premium trend can usually offset modest amounts of loss trend from partial losses. This makes for an easier validation of the damage factors using storm results over the past ten years. If there is any residual trend in hurricane loss costs, it may ultimately be difficult to measure directly, because of the relatively low frequency of hurricanes.

Risk Variations

Non-hurricane homeowners loss costs vary significantly by fire protection class, reflecting the large portion of the coverage represented by the fire peril. Yet, the hurricane peril is obviously independent of protection class.

Policy form relativities increase as additional perils are covered. In Forms 1 and 2, the perils are specified, while Form 3 gives essentially all-risk coverage on the building, but not on contents. Form 5 provides all-risk coverage on contents. Yet, the wind coverage is identical in all the homeowners policy forms. Hence, if the hurricane loss costs are a material portion of total homeowners costs, the policy form relativities would have to vary substantially by territory, if applied to an indivisible homeowners premium.

For construction class, a frame house can be almost as hurricane resistant as one made of brick or stone. For large hurricanes, the key is to protect the envelope of the building from penetration—i.e., the windows and the roof. Hence, the relative fire resistance of the construction is essentially irrelevant for the hurricane peril.

The hurricane peril ultimately needs a separate class plan because of different risk variation from the traditional covers. For example, new rating factors will likely emerge for shuttering and for roof type (e.g., gable versus hip roof). Local enforcement of building codes is another rating distinction that is implementable. Redoing all the traditional homeowners class relativities to meld with the new hurricane classes would be very cumbersome. Perhaps the traditional homeowners territories could be retained, with a separate set of territory definitions for the hurricane rate.

A possible class plan with sample surcharges and discounts is shown in Table 1.

TABLE 1

POSSIBLE HURRICANE RELATED SURCHARGES AND DISCOUNTS

Category	Criteria	Sample Factor
Hurricane Shutters	None	+0.20
	Add-On	−0.20
	Built-In	−0.40
Roof Type	Hip	−0.25
	Gable	+0.30
Location	Shielded by buildings	−0.20
	Subject to projectiles	+0.20
	Beach front or subject to surge	+0.10
Town Building Code	Not enforced	+0.15
	Enforced; not inspected	−0.10
	House inspected; within code	−0.25

Table 1 is just an illustration of possible risk variation. In reality, some of the criteria would interact. For example, a house with excellent shuttering protection would not be as susceptible to debris and projectiles penetrating the envelope of the building. Hence, the relativities may not be uniformly multiplicative or additive.

To calculate the indicated classification factors, one would run the model on a single house in each ZIP code, and vary the house based on different resistance characteristics. Next, using geographic mapping features, one would derive the relationships to the base class in ranges of relativities; e.g., .8 to .9, .9 to 1.0, 1.0 to 1.1. Because the ultimate selected relativities are usually expressed in a table used by the marketing force as well as by underwriters and regulators, one would select average relativities that form the dominant pattern from the map illustrations. If, within one state, the masonry house discount averaged 5%, but varied from 3% to 7% by territory, one could conceivably have several zones statewide for construction relativities. Alternatively, if the insurer printed all the rates by territory, instead of just the base class rates, then more flexibility could be allowed in the relativities.

7. FORM OF RATING

If the hurricane peril does not vary by class the same way non-hurricane perils do, should the hurricane rate be split out from the heretofore indivisible premium for homeowners? Should it have its own class plan? The answer to both questions is yes.

Basically, one can have the best of both worlds. The indivisible premium concept was originally introduced almost 50 years ago to simplify the review of loss experience and the rating of the homeowners policy. It also lowered the cost of the monoline coverages, because all the major perils were essentially compulsory.

With catastrophe modeling available today, virtually all of the advantages of the indivisible premium can be retained while still making the hurricane coverage mandatory. Ironically, it is the very difficulty of an overall loss experience review that suggests the unbundling of coverages for ratemaking—using the pure premium method for hurricane ratemaking and allowing a loss ratio approach for the other perils.

Computer modeling could also be used for other catastrophe perils within homeowners (e.g., tornado and winter storm), while the remaining non-catastrophe perils in homeowners would use the more traditional methods of ratemaking. Computer modeling of catastrophe perils actually makes ratemaking for the other perils much easier, because of results that fluctuate less. With loss costs supplied by modeling and with a separate rate for each catastrophe peril, the actual catastrophe losses only need to be removed from the experience period, and nothing need be loaded back to the normal homeowners losses. This means that catastrophe serial numbers ought to be retained for loss coding—to subtract catastrophe losses for the regular loss ratio ratemaking, to supply catastrophe losses to calibrate the models in the future, and, of course, to report to the reinsurers for recovery.

Thus, the overwhelming advantages of separate catastrophe rates are the simplification of the normal coverage rating and ratemaking, as well as the better class and territory rating of the catastrophe coverages.

This does mean an extra rating step for the catastrophe coverages, but there already are so many endorsements in homeowners that this should not be much of a burden. Furthermore, if hurricane loss costs are left in the indivisible premium, the homeowners classes will become much more complicated to rate. The class relativities will have to vary greatly by hurricane zone, and the actuarial calculation of relativity indications will also be much more complex.

Another simplification achieved through separate hurricane rating is the elimination of a complicated set of statewide indications including hurricane. Instead, the indications can be produced, and actual rates selected, separately. Ostensibly, this creates a problem in rate filings, where tradition has called for a combined statewide average *indicated* rate change as well as a *filed* rate level change. However, this is mere custom, and not strictly required by the rating laws—which usually call for *rates* to be filed, not *rate changes*. In other words, statutory requirements are for *rates* to be reasonable, not excessive, inadequate or unfairly discriminatory. Filed measures of *rate changes* have merely been a convenient way for regulators to monitor reasonableness.

This is not to suggest that a rate filing should repress the estimate of statewide rate change. However, given the different ways of calculating the appropriate rates (via a pure premium approach for catastrophes and a loss ratio method for other perils), the statewide indication does not as readily come out of the ratemaking method as, for example, it does for auto insurance. Hence, other reasonable ways of estimating changes will need to be developed, instead of directly from the ratemaking method. A sample indicated rate change calculation appears in Appendix C.

8. EXPENSE LOAD CONSIDERATIONS

If the hurricane peril is reinsured in a reasonable fashion, then the primary insurer ought to be able to pass those costs through to the policyholder. The reinsurance premium can be expressed as a function of the primary layer and added to the equation. Some portion of catastrophe treaty reinstatement premium should also be considered part of the reinsurance cost. If the reinsurance period does not coincide with the ratemaking period, then reasonable estimates of prospective reinsurance premiums might be considered.

The total expected hurricane loss costs need to be adjusted to exclude the reinsured portion by having the hurricane computer model simulate the reinsurance layer. This is done by running all probabilistic storms against the insurer's exposure base by ZIP code and line of business. Each storm's losses in the reinsurance layer are then allocated to line and ZIP code in proportion to total losses for that storm. Then each storm's probability is multiplied by the losses in the layer and accumulated. This produces the expected losses in the reinsurance layer.

$$L_{XS} = \text{MIN}\left(\text{MAX}\left(\left(\sum_{ZIP} E_{ZIP} \times DF_{storm}\right) - RET, 0\right), LIM\right), \tag{8.1}$$

where

L_{XS} = Total losses in layer for each storm,

RET = Reinsurance retention, and

LIM = Reinsurance layer size.

$$L_{XS,ZIP} = L_{TOT,ZIP} \times L_{XS} \div L_{TOT}, \tag{8.2}$$

where

$L_{XS,ZIP}$ = Excess losses by ZIP code for each storm,

L_{TOT} = Total ground-up losses for each storm, and

$L_{TOT,ZIP}$ = Ground-up losses by ZIP code for each storm.

$$EL_{XS,ZIP} = F \times \sum_{storm} P_{storm} \times L_{XS,ZIP}, \tag{8.3}$$

where

$EL_{XS,ZIP}$ = Expected losses in layer by Zip code,

F = Annual hurricane frequency, and

P_{storm} = Probability of storm.

The reinsurance premium can then be allocated to line of business and ZIP code in proportion to the expected excess losses in the reinsurance layer. Those premiums are then ratioed to the primary premium by line and ZIP code to get a factor to add to the indicated rate by line and ZIP code.

The remaining expected loss costs outside the reinsurance layer (above and below) would then be loaded for risk margin and expenses. The reinsurance pass-through would already have included the expenses and risk margin of the reinsurer.

9. RISK LOAD CONSIDERATIONS

Splitting the homeowners premium into a catastrophe and non-catastrophe component also allows for a separate calculation of a risk margin. As a result, the non-catastrophe component becomes easier to price, with less variability and a lower margin needed for profit. This makes it closer to a line of business like automobile physical damage in its target total rate of return and total target operating margin needed, which can be expressed as a percentage of premium.

Once a target margin is selected for the non-catastrophe component, the margin for the catastrophe piece can be calculated as a multiple of the non-catastrophe component, using some basic assumptions. One assumption is that profit should be proportional to the standard deviation of the losses. (Some actuarial theorists argue that risk load should be proportional to variance. It is important to note that these arguments apply to individual risks. The assumption that the required risk load for an entire portfolio is related to the standard deviation is not inconsistent with a variance-based risk margin for individual risks. In addition, the high correlation of losses exposed to the risk of a catastrophe, as well as the large contribution of parameter risk to the total risk load requirement, provides additional arguments in favor of a standard deviation basis for risk load.)

The calculation of the risk load should be performed on a basis net of reinsurance because the reinsurance premium is being built back into the rates separately. However, calculating the risk load both gross and net of reinsurance may be an important exercise for an insurer analyzing retention levels. By doing so, the insurer may be able to evaluate its reinsurance protection by considering the total risk load required.

In Table 2, a homeowners non-catastrophe pretax operating profit margin of 3% is assumed. At a 2.5 to 1 premium to surplus ratio, this is equivalent to about a 9.4% aftertax return on surplus

$(((2.5 \times 3 + 7) \times .65) = 9.4)$, assuming surplus can be invested at 7% pretax.

Next, assume that the total pure premium can be split into 80%/20% proportions for the non-catastrophe and catastrophe components, respectively. (This split is expected to be state-specific, since the hurricane loss cost in hurricane-prone states will represent a greater proportion of the total loss cost.) Based on direct homeowners industry data adjusted to eliminate catastrophes, the coefficient of variation of non-catastrophe loss ratios has been about 8% over the past 40 years. The corresponding coefficient of variation for hurricane losses, based on computer models, might be 350%, for example. This implies that the standard deviation of hurricane catastrophe losses would be 10.94 times the standard deviation of non-catastrophe losses.

If a 3% operating margin for non-catastrophe homeowners produces a \$2.40 operating profit on an \$80 pure premium, then the operating profit for the hurricane pure premium should be 10.94 times that, or \$26.25. Expressed as a percentage of the pure premium, this would result in a risk margin of 131% on top of the expected hurricane loss costs. (These operating margins would include investment income from policyholder-supplied funds, and therefore that quantity must be subtracted to derive an underwriting profit margin to be applied to loss costs.)

TABLE 2

CALCULATION OF THE HURRICANE RISK MARGIN AS A FUNCTION OF THE NON-CATASTROPHE RISK MARGIN

(1)	% of Loss (2)	Coefficient of Variation (3)	Standard Deviation (4) = (2) × (3)	Relativity (5)	Risk Margin (% of Mean) (6)	Dollar Return (7)
Non-Catastrophe	80%	0.08	0.064	1.00	3%	0.0240
Hurricane	20%	3.50	0.700	10.94	131%	0.2625

These calculations assume that all policies are issued for one-year terms. If the duration of policies changes to include multi-year policies, then the lower variance of actual results should ultimately result in a lower risk margin to be included in the rates.

One can actually convert the risk margin to be a direct function of the ratio of CVs , as the risk margin incorporates the ratio of the dollar profit to the mean:

$$\text{Risk Margin}_{\text{CAT}} = \text{Risk Margin}_{\text{NON-CAT}} \times \text{CV}_{\text{CAT}} \div \text{CV}_{\text{NON-CAT}}.$$

10. DERIVING HURRICANE BASE RATES

Once the hurricane loss costs by ZIP code have been averaged to territory, expenses and profit margins must be included to derive base class rates. Exhibit 1 shows the derivation of a base class loss cost of \$1.545 for Territory B. Using the following values of expenses and profits:

Commission (C): 5% of Premium,

General Expenses (GE): 10% of Premium,

Taxes, Licenses and Fees (T): 3% of Premium,

Investment Income Offset (I): 3% of Premium, and

Profit and Contingencies (P): 131% of Losses,

the base class rate (BCR) for Territory B would be equal to:

$$\begin{aligned} BCR_{\text{terr}} &= \frac{ELC_{\text{terr}} \times (1 + P)}{(1 - C - GE - T + I)} \\ &= 1.545 \times \frac{2.31}{0.85} \\ &= 1.545 \times 2.718 \\ &= 4.199 \text{ per } \$1{,}000 \text{ of Coverage A.} \end{aligned}$$

If the insurer decides to pass through the cost of catastrophe reinsurance, then both the loss cost and the profit provision must be adjusted accordingly. Table 3 shows the total territory loss costs and those outside the catastrophe reinsurance layer (refer to Section 8 for more details):

TABLE 3

TERRITORY LOSS COSTS

	Expected Loss Cost	
Territory	Without Reinsurance	Excluding Reinsurance Layer
A	.401	.309
B	1.545	1.113
C	2.806	1.824
D	3.937	2.362
Statewide	2.464	1.646

From the allocation of the catastrophe treaty cost to ZIP code and line of business, one derives a cost of $2.015 per $1,000 of Coverage A for Territory B. Also, the required risk load for the losses retained by the company drops from 131% to 65%. Hence, the following rate calculation results:

$$BCR_{\text{terr}} = \frac{ELC_{\text{terr}} \times (1 + P) + R}{(1 - C - GE - T + I)}$$

$$= \frac{1.113 \times 1.65 + 2.015}{0.85}$$

$$= 4.531 \text{ per } \$1{,}000 \text{ of Coverage A,}$$

where R = Catastrophe reinsurance cost per $1,000 of Coverage A.

This indicates that the cost of the reinsurance treaty has a slightly higher embedded risk load than the overall indicated company risk load.

Another advantage of separating the hurricane rate from the heretofore indivisible premium is in the treatment of expenses. For example, a company may wish to implement a different commission structure for its hurricane coverage than for its non-hurricane coverage.

Since the hurricane coverage is intended to be part of the homeowners policy, fixed expenses that are part of the non-hurricane policy must not be double-counted. An easy way to achieve this is to include only variable expenses in the hurricane rates and to incorporate all fixed expenses in the non-hurricane rates.

Once the base class hurricane rates are calculated, they can be filed, along with the table of relativities for hurricane described above. As part of the filing, non-hurricane base rates (which are generally expressed as a dollar amount for the base class amount of insurance in each territory) will also be submitted. We have not demonstrated the calculation of non-hurricane rates in this paper because the topic has been covered extensively in other actuarial literature.

11. RATE FILING ISSUES

The approval of computer models as the source of expected catastrophe loss and risk margin can be a lengthy process because it changes the way regulators can verify the calculations. Under traditional filings, basic data are included with the filing, and the underlying source data are often part of statistical plan information that has been implicitly approved by the regulators in the past.

With catastrophe modeling, the frequency of events is often taken from published information tracking 100 or more years of event history. For the key simulation of a catastrophe event (e.g., hurricane or earthquake), the source is usually a scientific paper describing the ability of various equations to simulate the event. For the probabilistic model generating expected losses, often thousands of events are used, each with a specific probability derived from past distributions of input parameters.

Computer modeling presents a dimensionally different approach to the regulatory approval process. A separate evaluation of each independent modeler is necessary—to clear each model before an actual rate filing is made utilizing that model's calculation of expected loss costs. This pre-clearing process can take several months' time, depending on the level of due diligence needed and on the amount of rate level increase implied by the use of models to replace the old ratemaking system.

Once the independent modelers have been approved, the resulting set of indicated loss costs can provide a range of reasonable answers with which to evaluate specific company filings if the insurer has built its own model. If that company-specific model has loss costs within the pre-cleared range, that is usually *prima facie* evidence of the overall reasonableness of the company model. Even if the insurer model has some results outside the range, that should not necessarily disqualify the result. It merely places an additional burden on the insurer to prove the result is reasonable, based on its own assumptions and judgments.

The following steps can be considered in the regulatory approval process (the details of which are included in Appendix D):

- review general design of the model
- examine event simulation module
- test ability of module to simulate known past events
- check distributions of key input variables
- perform sensitivity checks on most important inputs
- verify damage and insurance relationship functions
- test output for hypothetical new events

- compare different modelers' results for loss costs
- conduct on-site due diligence and review of actual assumptions.

For independent modelers, and even for insurer-specific models, it is important to preserve trade secret information during the approval process and afterwards. The knowledge that research and development investments can be protected will encourage future innovations.

The on-site due diligence of regulators should keep the inner workings of the models confidential, as long as the examining process is documented by the regulator, much in the same way a financial examination of an insurance company keeps key information confidential.

Even after the approval of a model, the regulator can preserve the confidentiality of indicated loss costs by ZIP code by not publishing the ranges that it plans to use in reviewing other company filings. First, it is better policy not to disclose the high end of the range lest some insurers be tempted to file that answer rather than using a rigorous model. Second, publishing the rate may be tantamount to the regulator setting the rate instead of approving reasonable filed rates. Finally, the regulator would not be receiving the direct public attention on why the rates are so high in certain areas.

12. FINAL PERSPECTIVE

In summary, computer models are now capable of simulating catastrophic events and creating probabilistic models of reality that can be used to generate expected loss costs for catastrophe perils. These same models also provide a means of including the reinsurance premiums in the primary pricing process and can help quantify the needed risk load in relation to profit margins required for the non-catastrophe perils.

The same model can also be used for insurer or corporate risk analysis, including reinsurance purchase decisions, and for insurer marketing and underwriting strategies. These analyses are beyond the scope of this paper.

Use of computer models for ratemaking involves a different approach from the customary one, in that it is a pure premium method in contrast to the usual loss ratio method involving past insured loss experience. That carries advantages as well as challenges, because it attempts to deal with the true underlying probabilities of loss, not just with what appears in the last few years of actual insured loss experience—which is merely a sample of what could have occurred. The computer models attempt to simulate the entire spectrum of what could have occurred.

Thus, the models rely heavily on computer simulations and new technical methods made possible by the vast improvement in personal computer potential. This also requires a heavy investment in research and design as well as in resources to have the model evaluated and accepted by regulators and others.

But it is worth the process, not only for the practical results in insurer ratemaking and planning, but also for the insights gained on these catastrophic events and the reduction in uncertainty for society in dealing with them.

Furthermore, the techniques developed in producing these computer models might ultimately be applied to other perils as well. After all, the essence of actuarial work is modeling reality to assess the present financial impact of future contingent events.

REFERENCES

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[3] Walters, Michael A., "Homeowners Insurance Ratemaking," *PCAS* LXI, 1974, pp. 15–61.

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EXHIBIT 1

SAMPLE INSURANCE COMPANY
STATE XYZ

Expected Hurricane Loss Cost
Per $1,000 of Homeowners Coverage A
Base Class: Frame
Base Deductible: $250

Zip Code Loss Costs

Base Territory	Zip Code	Exposure in Coverage A Amount	Expected Loss Cost
(1)	(2)	(3)	(4)
A	02001	3,227,000	0.351
	02002	12,495,000	0.342
	02003	8,113,000	0.421
	02004	9,204,000	0.482
B	02005	1,198,000	1.232
	02006	3,254,000	1.425
	02007	6,681,000	1.647
	02008	11,341,000	1.552
C	02009	7,295,000	2.565
	02010	6,400,000	2.752
	02011	8,508,000	2.832
	02012	9,212,000	3.011
D	02013	17,346,000	3.742
	02014	15,212,000	3.953
	02015	13,900,000	4.032
	02016	6,573,000	4.211
Total		139,959,000	2.464

Territory Loss Costs

Base Territory	Exposure in Coverage A Amount	Expected Loss Cost
(1)	(2)	(3)
A	33,039,000	0.401
B	22,474,000	1.545
C	31,415,000	2.806
D	53,031,000	3.937
Total	139,959,000	2.464

Notes:
In-force Coverage A amounts are as of June 30, 1995.
Expected Loss Costs are derived from probabilistic hurricane modeling.

EXHIBIT 2

SAMPLE INSURANCE COMPANY
STATE XYZ

Calculation of Statewide Rate Level Change
Homeowners

(1) Total premiums on current rate level		$4,544,326
(2) Current amount of insurance years (000's)		$872,589
(3) Current average rate per $1,000	(1)/(2)	$5.21
(4) Catastrophe factor from last approved filing		1.327
(5) Portion of rate from catastrophes	1 – [1/(4)]	24.6%
(6) Portion of catastrophe from hurricane (est.)		80.0%
(7) Portion of rate from hurricane	(5) × (6)	19.7%
(8) Current average hurricane rate per $1,000	(3) × (7)	$1.03
(9) Current average non-hurricane rate per $1,000	(3) – (8)	$4.18
(10) Indicated average non-hurricane rate per $1,000		$4.02
(11) Indicated average hurricane rate per $1,000		$4.53
(12) Indicated total rate per $1,000	(10) + (11)	$8.55
(13) Indicated rate level change—non-hurricane	(10)/(9) – 1	–3.8%
(14) Indicated rate level change—hurricane	(11)/(8) – 1	339.8%
(15) Indicated total rate level change	(12)/(3) – 1	64.1%
(16) Filed average non-hurricane rate per $1,000		$4.02
(17) Filed average hurricane rate per $1,000		$4.25
(18) Filed average total rate per $1,000	(16) + (17)	$8.27
(19) Filed average non-hurricane rate level change	(16)/(9) – 1	–3.8%
(20) Filed average hurricane rate change	(17)/(8) – 1	312.6%
(21) Filed average total rate change	(18)/(3) – 1	58.7%
Rate Change Status for Future On-Level Calculations		
(22) Approved average non-hurricane rate per $1,000		$4.02
(23) Approved average hurricane rate per $1,000		$3.75
(24) Approved average total rate per $1,000	(22) + (23)	$7.77
(25) Approved average total rate level change	(24)/(3) – 1	49.1%
(26) Premium level change for non-hurricane coverage	(22)/(3) – 1	–22.8%

APPENDIX A

How to Construct a Model

The severity component of a catastrophe model generally contains three modules built separately and later integrated. These modules are:

- event simulation (science)
- damageability of properties (engineering)
- loss effect on exposures (insurance).

Before it can be used for ratemaking purposes, a catastrophe model must undergo a high level of research and testing.

Science Module

As a first step, the modeler must incorporate the physics of the natural phenomena in a module (also called the event generator module) that simulates as closely as possible the actual event. Examples of input for a hurricane model include the radius of maximum winds, pressure differential at the eye of the storm (ambient pressure minus central pressure), forward speed, angle of incidence, landfall location and directional path. For an earthquake model, such factors as magnitude, location of the epicenter, soil conditions, liquefaction potential and distance from the fault rupture are used to estimate the shaking intensity of the ground at a given location.

The event generator module must be tested before its use to reproduce historical events and simulate hypothetical or probabilistic events. As a first step for a hurricane model, actual wind speed records for recent events should be compared to modeled results. Such organizations as the National Hurricane Center can provide records for the historical events.

Next, the hurricane model should be tested for reasonableness by predicting wind speeds for hypothetical events along the

Atlantic and Gulf coasts. Because one of the key drivers of a hurricane model is the roughness parameter, this testing will help evaluate the sensitivity of the model to this terrain factor and will allow necessary refinements to the initial assumptions.

The model's predictive accuracy is limited by the fact that data are not currently captured for some site-specific factors that affect an individual property (e.g., topographic peculiarities that influence wind speeds or liquefaction propensity at a given location for earthquakes). Therefore, one should not expect a model to exactly reproduce a single past event, but rather verify that it can adequately simulate hypothetical events with a given set of parameters. Over a range of input parameters, the model should generate intensity levels that are consistent and reasonable. Thus, actual future events with other site differences do not require major modifications to the model, but rather provide additional information to further refine it.

Engineering Module

Once the event generator has been developed, damageability functions are needed to estimate the damage to a property subject to an event of a given intensity. Input from various fields of the engineering profession, such as wind engineering and structural engineering, must be gathered to develop these functions. For damage by hurricane wind speeds, numerous studies have been performed that estimate these relationships. The functions should vary by line of business, region, construction, and coverage (building versus contents).

As was the case for the event generator module, accuracy of the damage functions is improved by analyzing actual past events. Actual loss experience of insurance companies should be compared to modeled losses in the most refined level of detail available. Whereas only aggregate loss amounts by catastrophe used to be collected by insurers, it is now generally possible to see loss data by line of business and county (or even ZIP code).

Next, on-site visits to the locations of catastrophes can help assess the damageability of exposed structures. While not imperative, these visits provide additional insight to the modeler, especially in identifying future classification distinctions.

The refinement of the damage functions is an ongoing process that is dependent on input generally provided by the engineering community. Engineering studies and loss mitigation reports are constantly being published, and their conclusions should be adapted and incorporated into the damage functions being used in the catastrophe model.

Insurance Module

Once the science and engineering modules have been developed, they must be integrated with the insurance module to determine the resulting insured loss from a given event. For risk analysis, Kozlowski and Mathewson [4] stress the importance of developing and maintaining a database of in-force exposures that captures the relevant factors that can be used in assessing the damage to a given risk. This database will not only include such factors as location, construction type, number of stories, age of building and coverage limits, but also replacement cost provisions, deductibles, co-insurance and reinsurance (both proportional and non-proportional).

Integration of Modules

Table 4 presents a sample calculation of the loss estimate generated by the model for a sample hurricane after integrating the three modules.

The example assumes that there is one single-family dwelling in each ZIP code, each with a different deductible. Based on the parameters of the storm simulated, the event generator module calculates the average wind speed sustained by all structures within the ZIP code. In this case, the wind speeds decrease as the ZIP codes are further away from the coast.

TABLE 4

SAMPLE CALCULATION OF HURRICANE LOSSES

ZIP Code	Exposure Amount	Deductible	Windspeed (mph)	Corresponding Damage Factor	Gross Resulting Loss	Net Resulting Loss
2001	$180,000	$250	100	.15	$27,000	$26,750
2002	180,000	$500	90	.08	14,400	13,900
2003	180,000	2%	80	.05	9,000	5,400

The damageability module then predicts the damage sustained by each structure as a function of the windspeed. The damage factors generally vary based on factors such as construction type (e.g., frame versus wind-resistive), age of building and number of stories. The gross resulting loss is then calculated by multiplying the exposure amount by the damage factor. The estimate is then adjusted for insurance features, such as deductibles and reinsurance. In this example, the gross loss is reduced by the deductible to derive the net resulting loss.

How to Validate

The final task in developing a catastrophe model lies in validating the simulated results. While intermediate levels of calibration are performed for each module, the modeler must verify how they interact by completing an overall analysis of the results.

Because the model is designed to simulate reality, actual incurred loss experience is the obvious candidate to be used in testing modeled losses. Of course, all comparisons are dependent on the quality of the data captured from the loss records of insurers. As described above, the modeler should gain access to various sets of insured loss data and verify that all relevant factors are reflected in the model. These would include line of business, classification, coverage (e.g., building versus contents), and loss adjustment expense (LAE) as a percentage of loss.

One issue often raised when validating a catastrophe model is demand surge (or "price gouging"). Because this phenomenon is dependent on the time, size and location of the event, it should not be incorporated in the damage functions, except to the extent it is "expected." For example, most models underestimated the actual losses from Hurricane Andrew. If the models were adjusted to exactly reproduce Andrew's losses, they would effectively include a provision for factors specific to Andrew and not expected in the long run, such as:

- inflation in reconstruction costs due to the excess of demand over supply
- excess claim settlements that occurred because adjuster resources were overwhelmed by the volume of claims.

While these factors can be included separately in the reproduction of a single storm, they should not be part of the base model because they would inappropriately increase the expected level of future losses.

Another issue is storm surge from a hurricane. While a flood loss is not officially covered by a homeowners policy, some adjusters of losses on houses affected will construe coverage from wind damage prior to the house being flooded. This can be handled with a small additional factor on those locales in low areas most susceptible to surge. However, from a ratemaking and rate filing standpoint, it is difficult to support much of an increase from a coverage that does not officially apply to homeowners.

APPENDIX B

HOW OTHER PERILS ARE MODELED

Earthquake

The library of historical earthquake events producing significant insured losses is scant compared to that of historical hurricane events. Hence, the precision level of computerized earthquake models will not reach that of hurricane models. Nevertheless, numerous models have been developed and a great amount of research done to define the various factors and relationships.

In the science module, the model begins with simulating the magnitude of an earthquake, generally expressed as a unit on the Richter scale. This implies a rupture length on a fault. Using other factors, such as distance to the rupture, soil conditions and the liquefaction potential of the areas affected, the model estimates the shaking intensity for each ZIP code. For the engineering module, resulting shaking intensities are usually converted to the Modified Mercalli Intensity (MMI) scale, because most models use the ATC-13 damage functions as a starting point. These functions were developed by a group of 13 engineers and scientists commissioned by the Applied Technology Council (ATC) in 1982 to estimate the damage to California properties from earthquake.

The insurance module for an earthquake model is generally similar to a hurricane model. However, the use of percentage deductibles (which is not common on a standard homeowners policy) and separate coverage deductibles present a new twist. Hence, the model must have the capability of handling various deductible combinations. For instance, some earthquake policies apply a building deductible different from the contents deductible and the additional living expense deductible. The deductible credit applies separately for each coverage.

The insured loss data available to validate an earthquake model are more limited than for hurricanes. Also limiting is the fact that earthquakes are not all similar. For instance, most major faults in California have been of the strike-slip type. These faults generally run in a north-south direction, with energy being released when western blocks of crust move north past the eastern block. This causes ground displacements that are mostly horizontal.

Yet the 1994 Northridge quake was a "blind" thrust-fault earthquake. In this type of event, sections of rock overriding others at an angle are displaced. The movements are generally upward and sideways, which creates strong shaking that is generally more damaging. In the case of Northridge, the fault did not reach the surface. Hence the term "blind" fault.

These two types of earthquakes are by their nature very different, and the event generator module will vary to reflect the different types of shaking intensities.

Once the deterministic earthquake model has been developed, a probabilistic version must be generated. For earthquake modeling, a set of known faults is generally used as a starting point in building the library of events. Events of various strengths and locations are simulated for each fault. A probability is then assigned to each event in the library. These probabilities are generally expressed in a return time format such as 1 in 400 years. They can be obtained from geological sources, such as the United States Geological Survey.

The Northridge event highlighted the fact that serious damage could be caused by earthquakes not located on known fault systems. This has implications for earthquake ratemaking because the frequency of these events is very much unknown at this time, and inclusion of this type of event could increase the expected loss costs substantially. However, the modeler needs to take care that the long-run frequency of earthquakes remains reasonable.

Tornado and Hail

The actual loss experience of tornadoes and hailstorms is more readily available than for any other type of natural catastrophe. Given that there are roughly 1,000 tornadoes in the U.S. each year, the traditional way of developing a tornado catastrophe loading in states with exposure to these perils has been to smooth the actual loss experience over a number of years. However, this methodology does not capture the essence of why catastrophe modeling is the preferred approach, which is to estimate the loss potential of a company given its current distribution of exposures. Also implicit in any modeling approach is the simulation of events that have not occurred much in some areas but are reasonably foreseeable given the historical database of events.

Tornadoes and hailstorms are typically generated by inland storms when moist, warm air masses collide with cooler, drier air masses. Such conditions are often present in the southcentral United States (e.g., northern Texas and Oklahoma) and the plains states (e.g., Iowa and Kansas) where the Gulf of Mexico provides a continuous source of warm, moist air, and the Rocky Mountains create a source of cooler drier air as weather systems move over them. Tornadoes do, however, occur in all 50 states.

An inland storm capable of generating tornadoes may create dozens of individual funnels over a widely dispersed area. A single funnel will produce damage over the portion of its track making contact with the earth. The length of that ground contact track can range from a few hundred feet to a hundred miles. The width of the track funnel can range from ten feet to a mile. In order to model the loss effects of a single funnel, it is therefore necessary to consider the small scale (nine-digit ZIP code) location of exposures relative to the funnel path.

Because tornadoes and hailstorms are more sudden and unpredictable than hurricanes, most historical information has been the result of human observation. Current tornado databases generally consist of date and time, initial observed location, path width, path length and storm intensity for each event. Tornado intensity is generally measured on the basis of the Fujita scale, which translates an expected degree of damage to a range of windspeeds. For example, a tornado with a Fujita-scale intensity of F2 will be expected to tear roofs from frame houses. Engineering studies indicate that damage of this intensity can be generated by windspeeds between 113 and 157 miles per hour.

Tornadoes do not behave like hurricanes. The spinning funnel-shaped updraft of a mature tornado is the most damaging windstorm produced by nature. The damage relationships at a given windspeed for a tornado are quite different from those of a hurricane. The results of engineering and damage studies specific to tornadoes must be collected to develop a representative model.

The development of a hail model resembles that of a tornado model. However, difficulties lie in the definition of what is considered a hailstorm and which hailstorms are already included in a tornado database. The interpretation of the data present in the databases therefore has a significant impact on the overall frequency assumptions used in both models.

The validation of a tornado and/or a hail model against actual loss experience is dependent on the availability of loss data and on how much differentiation between the two perils is possible. (If this cannot be obtained, the modeler may have to calibrate the models on a combined basis. As a result, this would make the development and justification of territorial loss costs for all severe local storm perils easier.)

Winter Storm

Winter storm and freeze activity has been quite severe over the last few years. As a result, the need for better risk measurement and expected loss calculations has increased. Also, some of the same characteristics as hurricanes prompt the use of a catastrophe model to simulate winter storm losses—changes in exposure and longer return periods than in an individual insurer's data base.

However, contrary to the other catastrophe perils, winter storms do not have a specific unit of measure that describes the intensity of a given event, and individual temperature is not the only factor that can describe these events. For example, wide temperature swings and absolute highs and lows over consecutive days have been identified as some of the factors that affect the intensity and duration of these events.

The damage functions associated with winter storms are also very different from those of the other perils. Because little of the damage is structural, damage functions are less severe than those of hurricanes, for example.

Similar to a hurricane model, the creation of a probabilistic database requires simulation of multiple events. While the parameters are different, each event is defined by a location (or landfall), size, intensity and duration.

Because individual winter storms have not been as surplus threatening as hurricanes or earthquakes, the motivation to develop computer models has not been as high for risk analysis and development of PMLs. However, for ratemaking, this peril is equally as compelling as hurricane toward the use of computer modeling. Not only does it yield better expected loss estimates, but it allows the exclusion of past catastrophes from the normal homeowners ratemaking database for better stability in rate level indications.

APPENDIX C

ESTIMATING STATEWIDE RATE LEVEL CHANGES FOR HOMEOWNERS USING HURRICANE-MODELED LOSS COSTS

In the initial year of implementing hurricane ratemaking using a model, it may be necessary to split the current homeowners rates into the estimated portion due to hurricane and non-hurricane. (See Exhibit 2 for the calculations.) The next year's rate level review for non-hurricane can then use the non-hurricane rate as the basis for review using a traditional loss ratio method. However, until the actual written premiums can be coded into hurricane and non-hurricane, the on-level premium calculations will need to consider the separation of the rate into the two components. This can be done by treating the separation of the premium as a premium level reduction. In the example on Exhibit 2, the premium reduction statewide is 22.8% for non-hurricane coverage versus the heretofore total coverage. Thus, future experience reviews containing unbundled premiums must separate out the non-hurricane portion with this factor. When all the premiums are recorded separately for non-hurricane and hurricane, this on-level method is not necessary.

The accuracy of the split may not be critical to the outcome of the rate review, especially if the credibility of the insurer's experience is high. If credibility is 100%, then it matters little what the current rate level is, because the loss experience will completely determine the indicated premium level. Of course, the amount of the quoted rate level change may vary, but the indicated rates are the key to any filing, unless the amount of the change is very large, in which case there may be some regulatory objections to the size of the change.

For the hurricane coverage, the actual premium change is irrelevant to the calculation of next year's indicated rates because the model produces those on a pure premium basis. However, there may be a continuing need to use the average rates charged to keep the regulator informed of the size of the changes for the current customer base.

APPENDIX D

METHODS TO REVIEW CATASTROPHE MODELS IN REGULATORY PROCESS

1. **Review general design of model**
   - Examine the credentials of the modeler.
   - What is the scientific basis for the key event simulation?
   - What is the engineering support for the damage factors produced by each event severity?
   - Are the insurance limitation features reasonable; e.g., deductibles, coinsurance and reinsurance calculations?
2. **Examine event simulation module**
   - What are the credentials of the scientists who specified it?
   - Has their work been published and/or peer reviewed?
   - What special insights are they offering on the particular event to be simulated?
3. **Test event generator's ability to simulate known past events**
   - Use published information from some critical events, such as Hurricanes Andrew and Hugo, the Loma Prieta earthquake (1989) or even the 1906 San Francisco earthquake.
   - Input some key parameters, such as central pressure, landfall, speed and radius of maximum wind, and examine the output wind field at various locations compared to published information on wind speeds. This can be done for any event, even if no current estimates of insured losses are available, as a test of the event simulation accuracy.
4. **Conduct sensitivity checks**
   - Use a few sample events.
   - Promulgate a sample exposure base statewide (e.g., 25 risks).

- Vary the parameters one at a time, or perhaps a few in pairs.
- Observe changes in output (insured losses) for incremental changes in input.
- The goal is a rough measurement of the effect of changing inputs (e.g., central pressure, radius of maximum winds, forward speed).

5. **Check key input distributions**

   Compare the distributions of key input values among the different modelers, to see if there is any disparity in the key drivers of results. For hurricanes, a possible approach could be to look at the:

   - Distributions of central pressure at ten millibar intervals: 900–909, 910–919, etc.,
   - Distributions of radius of maximum winds in five nautical mile ranges, and forward speeds in five knot ranges, and
   - Probabilities of landfall for all storms affecting the state (direct hit and nearby landfalls).

6. **Verify damage and insurance relationship functions**

   - Examine the credentials of the engineers.
   - Has the analysis been published and/or peer reviewed?
   - Analyze the damage curves (functions of increasing damage for increasing event intensity) separately for types of exposure, class and coverage.
   - Review the insurance module for effects by deductible and reinsurance or coinsurance.
   - Review the validation of the two components (damage and insurance effects) via multiple events over the past few years for multiple insurers; each event does not have to be replicated, but the components should average out over all events and all insurers.

7. **Test output for hypothetical new events**
    - Select some new events defined by key parameters.
    - Use a sample database of exposures by ZIP code.
    - Compare results for different modelers and ask outside experts for their opinions on the reasonableness of these results.
8. **Compare indicated loss costs for different modelers**
    - Select sample ZIP codes throughout the state.
    - Have modelers run all events with probabilities for those ZIP codes.
    - Use several base classes and coverages:
        - homeowners, $100,000 frame house, $250 deductible,
        - tenants, $30,000 contents, masonry, $250 deductible,
        - businessowners, $200,000, masonry, $1,000 deductible.
    - Compare modelers' loss costs per $1,000 of coverage by ZIP code.
    - Ask outliers to explain large differences from average.
9. **Conduct on-site due diligence and review of key assumptions**
    - View a live running of the model, with actual input data.
    - Review input data sources—published and non-published:
        - all key input parameters,
        - frequency of events by location,
        - key damage factors and sources.
    - Review output, including color-coded maps showing ranges of expected loss costs.