IAA Risk Book

Chapter 5 - Catastrophe Risk

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1. Executive Summary

Catastrophe risk has become an increasing focus for those involved in risk management largely due to recent major earthquakes and windstorms in various parts of the world. This chapter, after a brief introduction, discusses how the risk of such events is generally quantified and the issues associated with such quantification. Key observations/findings from the chapter include:

1. Catastrophes result in a sudden and mass destruction of property, lives, environment, and/or the economy.
2. Catastrophes can be natural or man-made (e.g., terrorism)
3. The frequency and severity of catastrophe losses have been increasing over past several decades primarily due to increasing concentrations of population and property in geographical areas prone to disasters.
4. Catastrophes impact society first, and insurers only to the extent that the damages are insured.
5. Due to their infrequent nature, analysis of past losses can't sufficiently measure catastrophe risk so many insurers use catastrophe models to estimate potential losses.
6. Catastrophe models are based on four primary components – event catalogs, intensity formulas, damage functions and a financial module.
7. Model uncertainty is unavoidable, and is impacted by both data issues (related to quality and availability) and political issues (influencing how events will unfold in times of stress). This is in addition to the uncertainty related to random events.
8. Model development and usage is evolving, including a trend towards open models (as opposed to closed proprietary models) and their use for scenario analysis.
9. Catastrophe models are part of the risk management process both in terms of pricing/underwriting and in terms of solvency/capital management.

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2. Introduction

Catastrophes refer to certain adverse events whose occurrence result in a sudden and mass destruction of property, lives, environment, and/or economy. Catastrophes can be caused by natural or man-made events. An adverse event will not rise to the level of a catastrophe or disaster if it occurs in an area without a vulnerable population. Catastrophe risk is highest where significant potential for adverse events coincides with population and building density.

According to the statistics published in the International Emergency Disasters Database[i], the frequency, duration and magnitude of disasters have increased since 1975 [ii]. Increasing population density and higher concentrations of property values in areas prone to disasters is leading to increased chances of mega-losses from natural and man-made events. According to a 2015 World Bank study of East Asia, in the decade 2000 to 2010, for urban areas with more than 100,000 people, population density increased from 5,400 to 5,800 per square kilometer[iii]. Coastal property values in the US have increased fourfold between 1988 and 2014 according to studies of population and property value growth[iv].

The risk arising from catastrophes can severely impact an individual insurer's solvency position if not properly managed. Effective catastrophe risk management requires a comprehensive approach to identifying, assessing, transferring, and mitigating the risk and large loss potential. This chapter provides an overview of the types of catastrophes faced by the global insurance industry and discusses how companies estimate and manage catastrophe risk. (While this chapter is written at a particular point in time, our understanding of catastrophes and the tools used to quantify and manage catastrophe risk continue to evolve.)

3. Causes and Risk Implications of Catastrophes

I. Causes of Catastrophes

Broadly, catastrophes can be categorized into two types—natural catastrophes and man-made catastrophes. A natural catastrophe is a major adverse impact from either weather or geological related events. Examples of weather related events include tropical cyclones[1], floods, tornadoes, hailstorms, wildfires, and blizzards. Geological events include earthquakes, tsunamis, volcanic eruptions, mudslides and avalanches. Natural catastrophes are relatively well understood by the scientific community but difficult to predict and impossible to prevent.

According to the most recent report by Intergovernmental Panel on Climate Change (IPCC), demographic changes are the main cause of increasing losses over the past few decades and not climate change. Catastrophe losses have grown and will likely continue to grow steadily over time, primarily due to increasing concentrations of people and property values in hazardous regions.

[1] This term is meant to include hurricanes, typhoons and cyclones – all the same phenomena but with different names based on where they occur.

Man-made catastrophes refer to incidental or deliberate human actions such as aviation accidents, act of terrorism, cyber-attacks, civil unrest, wars, nuclear power plant explosions, and oil/chemical spills. These events can cause great damages to property and lives because malicious man-made events often target large cities and high-profile landmarks such as international airports and civilian government facilities.

II. Risk Implications of Catastrophes

While there is wide variation from year to year, annual global catastrophe losses regularly exceed $100 billion and can top $400 billion in one year according to statistics published by Swiss Re and Munich Re. Total economic losses from a major event will typically include damaged infrastructure, lost jobs, disruption to services, and other costs not covered by insurance policies. Additionally, insurance policies in many countries exclude or limit coverage for certain types of perils that are considered "uninsurable" due to their very infrequent but severe nature and because of that the inability to credibly price the coverage. However, insurers will still be impacted by the indirect costs of uninsured risks resulting from infrastructure damage, disruptions to supply-chains, etc.2

There is wide variation between countries with respect to how catastrophe losses are funded. Governmental policies can influence how much of these losses are pre-funded through mechanisms such as insurance versus post-funded through taxation, borrowing, and international disaster assistance.

Insurance can be provided by governments or the private market. For example, in New Zealand and California, earthquake insurance is provided through both the private market and government-sponsored entities. In New Zealand, earthquake insurance for households is compulsory while in California it is not. Where coverage is voluntary, there is the concept of "take-up rates" that indicate the percentage of policyholders purchasing certain coverages. For example, the earthquake insurance take-up rates in California can range between 10 and 30 percent depending on the length of time since the last major event.

Private market insurance and risk-based pricing are generally thought to be the most efficient ways to fund catastrophe losses. Immediately after an event, insurers can begin to adjust and settle claims so policyholders can start rebuilding homes and businesses. It will typically take several months, and possibly years, for all of the claims to be identified and paid by the insurance industry depending on the size of the event leading to a relatively long payout pattern. Risk-based pricing also encourages mitigation activities that can help societies become more resilient to future events.

Since 1975 natural and man-made catastrophe losses have hit the insurance industry very hard and resulted in insolvencies of small and large insurersv. According to a 2013 A.M. Best's Special Reportvi, annual insured catastrophe losses ranged from 2% to 14% of US Property/Casualty (P/C) insurance companies' surplus during the period of 1969 – 2012 with two peaks—one in 1992 following Hurricane Andrew and the other in 2005 after

[2] Some also label pandemics as catastrophes. This paper instead focuses on those with a physical basis and not a biological basis. This paper also acknowledges emerging concerns with the risk of solar flares, but does not attempt to address that hazard at this time.

Hurricane Katrina. In the same report, it indicates that catastrophe losses are among the top four causes for P/C insurance sector's financial impairments, accounting for 7.1% of failures.

According to the A.M. Best report, between 1969 and 2012 a total of 53 US-based property/casualty Insurance companies became impaired as a result of catastrophe losses and 11 became insolvent from one event—Hurricane Andrew. While private insurance covers only a fraction of total global economic losses, private insurers collectively pay out between $50 and $100 billion each year based on current economic conditions.

4. Estimating Losses from Catastrophes

Catastrophes are infrequent events in specific geographical regions which means there is a paucity of data for loss estimation. Standard actuarial approaches using historical claims and loss data to project future losses are not appropriate for most types of catastrophes. Because of the sparse historical data any approach will be characterized by significant uncertainty, so it's prudent for insurance companies to use a variety of methods to identify the types of events that could result in large losses and to estimate the magnitude of those losses.

One method that can be used even if there is no data on past events is to add up total insured values in specific regions exposed to severe events and apply factors representing the percentages of total values that could be lost in one event or an aggregation of events over some time period—usually a year. Total insured values[3] obviously represent the upper bound of loss potential.

Scenario testing is another method used to estimate the losses from specific events. For example, Lloyd's of London has developed a set of Realistic Disaster Scenarios (RDS) and requires syndicates to report on their loss estimates from these scenarios each year. Many companies employ scenarios as part of their Enterprise Risk Management (ERM) framework.

Catastrophe models provide a robust structured approach for estimating a wide range of possible future scenario losses along with their associated probabilities. Because the catastrophe models provide full probability distributions, they are suitable for many types of actuarial analyses. Loss estimates produced from catastrophe models can be deterministic for a specific event (e.g., Hurricane Katrina, a magnitude 8.0 earthquake in San Francisco) or probabilistic from a catalog of hypothetical events.

The first catastrophe models were developed in the late 1980s to assess the risk from hurricanes, earthquakes, and other natural hazards. The adoption of the models by the insurance industry accelerated after Hurricane Andrew in 1992 and the Northridge Earthquake in 1994. Models for man-made catastrophes, such as terrorism, were constructed after the World Trade Center disaster.

I. Key Components of Catastrophe Models

For all types of catastrophes and for all peril regions, the models have the same four primary components as shown in Figure 1 below.

[3] After adjustment for possible "replacement cost guarantees"

Figure 1. Catastrophe Model Components	
Model Component	Description
Event Catalog	Defines event parameters including frequency and physical severity by geographical region
Intensity Formulas	Estimates the intensity experienced at each location in the area affected by each event
Damage Functions	Estimates the damages to building, contents, and time element exposures (may also estimate casualties)
Financial Module	Applies insurance policy conditions and reinsurance terms to estimate insured losses

A. Event Catalog

The event catalog includes the important parameters defining the characteristics of each simulated event, such as location, severity, and size. For tropical cyclones the event catalog includes landfall point, peak wind speed, and radius of maximum winds while for earthquakes it includes epicenter, depth, and magnitude. For terrorist attacks, the event catalog could include location, type and size of bomb,.

For each event in the catalog, there is a rate of occurrence that is estimated using statistical analysis of historical information if there is enough data (tropical cyclones, other windstorms) or by scientific studies and expert opinion where there is less data (earthquakes, terrorist attacks). The catalogs typically include a large sample of events generated by Monte Carlo simulation or stratified sampling techniques.

The event catalog is extremely important because it defines the frequency and physical severity of events by geographic region. The reliability of the catalog varies considerably across peril regions depending on the quality and quantity of historical data and the scientific understanding of the hazard. For example, in California and Japan, there have been a number of significant earthquakes and the nature of the faulting is generally understood by scientists (although there are many unknowns with respect to the magnitudes and locations of future events). Even less is known about “intra-plate” regions, such as the central US and Australia.

B. Intensity Formulas

For each event in the catalog, the models estimate the intensity at each affected location using the event parameters discussed above, site information, and scientific formulas developed by the wider scientific community. While scientists have collected and analyzed intensity data from past events to develop these formulas, the amount and quality of the intensity data varies significantly across perils and regions.

For example, tropical cyclone intensity is defined by wind speed and scientists have developed well established formulas for hurricane wind speeds over water. When a storm makes landfall however, wind speeds start to dissipate because the hurricane loses its source of energy and due to frictional effects from the rougher terrain. Because there are relatively few reliable over land wind speed measurements for historical events, a degree of judgment goes into estimating hurricane intensity over land.

For earthquakes, intensity is defined by ground motion and is estimated using attenuation equations developed by scientists around the world. Because there is not an abundance of observed ground motion data for past events, historically, earthquake intensity has been inferred from the damage using the Modified Mercalli Intensity (MMI) scale.

A further complication with earthquakes is that the ground motion experienced at a location will be influenced by the nature of the rock and soil the energy waves pass through before getting to that location—these complexities cannot be reliably modeled. A simplifying approach of applying factors based on local soil conditions is typically used where detailed soil data is available. Secondary hazards such as liquefaction and fire following earthquakes might also be considered by the model.

While the likely frequency and severity of future man-made catastrophes is highly uncertain, there is a wealth of information on the impacts of terrorist attacks, particularly attacks using conventional types of weapons.

C. Damage Functions

The model damage functions estimate for different intensity levels the damages that will be experienced by different types of exposures. For property exposures, the damage functions will consider the building construction type, occupancy, and other characteristics depending on the peril.

The damage functions are expressed as the ratio of the repair costs (as a result of the damage) to the building replacement value. Because the nature of actual damage is "spotty", for any given wind speed and mean damage ratio, different properties will experience different levels of damage—potentially ranging from 0 to 100 percent.

This uncertainty is typically called "secondary uncertainty" and includes the uncertainty in the intensity and damage calculations. In the catastrophe modeling terminology, "primary uncertainty" refers to uncertainty with respect to the events themselves.

D. Financial Module

After the building, contents, and time element "ground up" losses are calculated, the secondary uncertainty distributions are used to estimate the insured losses accounting for policy terms and conditions. Policy terms include loss triggers, deductibles by coverage, aggregate deductibles, total and sub limits, coinsurance, attachment points, and applicable reinsurance terms. This model component is essentially the same across all peril regions (except for accounting for country and peril-specific policy conditions).

To construct the first three model components for a specific peril region, e.g. US hurricane, Turkey earthquake, data and information is collected from external entities such as government bodies and scientific organizations. The models are, for the most part, based on the same information collected, published, and maintained by the wider scientific community—model differences result from how the data is interpreted and analyzed to develop the many model assumptions.

II. Model Input

Exposure inventory is the key input in the catastrophe models. The most basic information is the replacement value for building, contents and time element coverages. Ideally, this information would be provided for each insured property by geo-coded location. In reality, the resolution and quality of the exposure data varies by peril region.

For US perils, most companies can provide this level of detail to the models along with other building characteristics such as construction, occupancy and year built. The more detailed the information on the structure and contents, the more reliable the model loss estimates will be. In other regions, the data may be total insured values (TIVs), aggregated by CRESTA (Catastrophe Risk Evaluation and Standardizing Target Accumulations) zone and line of business (residential, commercial, industrial). For example, in France, insurers typically collect data on the number of rooms rather than TIVs, and the data are aggregated by CRESTA zone.

Exposure data quality is an important issue in the quantification of catastrophe risk. Because most types of catastrophes impact localized areas, detailed knowledge of where exposures are located and the replacement values of those exposures are critical for credible loss estimates. For example, for properties exposed to storm surge flooding, it's important to know how far the properties are from the coast. In seismic regions, the risk depends heavily on how close the exposed properties are to active faults.

Regulators should inquire about the geographical resolution of the exposure data and whether it's exact latitude-longitude coordinates, postal code centroids, or aggregates by CRESTA Zones. They should also know how building, contents, and time element values are being determined. The nature and extent of other building characteristics contained in the exposure data files would be an indication of the emphasis placed on exposure data quality.

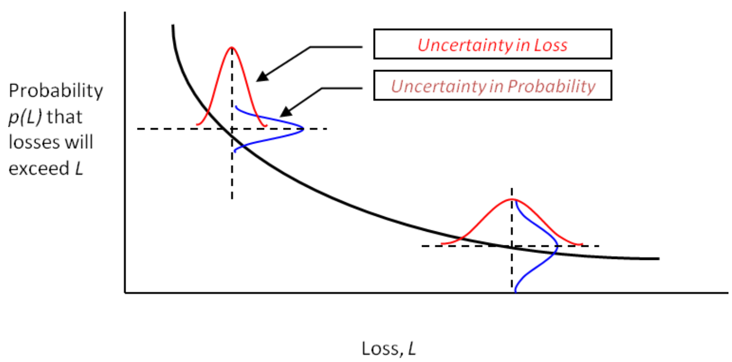
III. Model Output

The primary catastrophe model output is the exceedance probability (EP) curve that shows the probabilities of a portfolio of exposures exceeding losses of different amounts. The catastrophe models typically generate two types of EP curves—the annual occurrence distribution (OEP) and the annual aggregate distribution (AEP). The OEP gives the probabilities of losses from the maximum occurrence in a year, and the AEP gives the probabilities of total annual losses from multiple events in a year.

For very low frequency, high severity events, such as earthquakes, the curves will be very similar and typically converge in the tail. For more frequent events, such as tornado outbreaks, the AEP losses can be significantly higher than the OEP losses at all probability levels. The AEP losses will also be higher than the OEP losses for geographically diversified portfolios versus more concentrated books of business.

There are different techniques for estimating the AEP distribution. Generally, it is more challenging to estimate and less robust than the OEP distribution. Theoretically, average annual losses (AALs) should be calculated from the AEP.

Figure 2 – Illustrative Exceedance Probability (EP) Curve



Insurers and regulators have been relying on point estimates from this curve for risk management purposes. For example, in the US, insurers use the points on the curve where the estimated probabilities of loss exceedance are .01 and .004, popularly known as the 1 in 100 and 1 in 250 year losses, respectively. These points are also referred to as the 100 and 250 year Probable Maximum Losses (PMLs). In Europe, the .005 point estimate is used more heavily.

The catastrophe models can generate the EP curves and the AALs at any level of resolution, bearing in mind that as the resolution increases, so does the uncertainty. Because the EP curve is a complete probability distribution, it is useful for many types of actuarial analyses, including pricing.

IV. Model Uncertainty

As Figure 2 illustrates there's significant uncertainty surrounding the EP curves. The EP curves are better thought of as "fuzzy areas" versus lines. Apart from the model uncertainty, there's uncertainty in the exposure data input, with respect to the claims handling practices of individual insurers, and due to other factors external to the model such as political pressures after a major event. In large loss events, there can also be material and labor supply shortages causing the costs of repair to be higher than the replacement values of properties pre-event. This is typically referred to as "demand surge".

Model uncertainty stems from lack of high quality data in sufficient quantities to credibly estimate all of the model assumptions. Catastrophe models are constructed from historical data on past events, and for peril regions where events are infrequent there will be less reliable data and higher uncertainty. Even in geographical areas with more recent events, there is typically not a comprehensive network of highly calibrated instrumentation required to collect high resolution data.

The source and relative reliability of the data underlying the scientific and engineering model components are illustrated in Table 1 below. Green shading indicates a relative abundance of data and red indicates the least—yellow is in between. (Note that even for the green shaded area there is generally significant uncertainty, given the difficulty of obtaining useful data for extreme return periods, such as 1-in-250 years, especially if the climate or other factors are changing over time.)

Table 1 – Data Supporting the Catastrophe Model Components

	Event catalogs	Intensity formulas	Damage functions
Tropical cyclones	In most regions of the world, based on historical data collected and maintained by government organizations, such as the National Hurricane Center and the Japan Meteorological Agency. The modeling companies rely on these databases and apply some expert judgment for assumptions on the characteristics of future events in regions where the historical data are sparse.	Based on established meteorological formulas developed over the past several decades by government organizations and the wider research community. Formulas are well-documented in the scientific literature. Expert judgment is applied for some aspects of hurricane intensity such as varying terrain impacts on overland winds. Land use data is maintained by and available through government agencies.	For a few regions, such as Florida and the Gulf states, historical loss and claims data has been made available to the modelers by insurance companies, and this data can be used to fine-tune the damage functions. However, because there are thousands of damage functions reflecting different occupancies, construction and building characteristics, most of the functions are based on expert judgment.

	Event catalogs	Intensity formulas	Damage functions
Earthquakes	Historical data on earthquakes is collected and maintained by government organizations such as the US Geological Survey and European-Mediterranean Seismological Centre. These organizations also sponsor research such as paleo seismicity studies to supplement the historical record. Catastrophe modelers use this data and other information, such as hazard maps and scientific reports, as the bases for the earthquake event catalogs.	New generation attenuation (NGA) equations have been developed by a global consortium of earthquake experts using data on significant earthquakes around the world, and these form the bases of the ground motion formulas in the catastrophe models. Generally, soil data is inferred from geological data except in major urban areas where more detailed studies have been conducted.	There is limited claims data available to the modelers for construction of the earthquake damage functions. The global earthquake community compiles information and periodically publishes studies of building and contents vulnerability to ground motion. Limited, full scale, shake table tests and sophisticated engineering analyses are available, but this model component is still heavily reliant on expert judgment.
Terrorist Attacks	There are many types of terrorist attacks and tens of thousands of potential targets for which there are little or no data for estimating the likelihood of future events. Given that terrorists want to intimidate by surprise, past data may not be a reliable guide for future events. The models rely heavily on the judgment of counterterrorism specialists from the FBI, CIA and other government bodies.	The shock waves and pressure impacts of various types of bomb blasts are well studied and understood even though the density and complexity of an urban setting can distort the resulting intensity pattern. The intensity footprints of chemical, biological, radiological, and nuclear (CBRN) attacks are much larger and more difficult to project reliably, but these impacts have been studied and tools have been developed to estimate the effects.	Because attacks using conventional weapons such as bomb blasts and aviation incidents are localized events, and the damage is often complete, the model damage functions are straightforward. Much more judgment goes into the construction of damage functions for chemical, biological, radiological, and nuclear (i.e., CBRN) incidents.

Because of the paucity of data underlying the model components for many peril regions, model assumptions rely in large part on expert opinion and judgment. Model variability and volatility frequently arise from differing scientific opinions and perspectives.

The complexity and the infrequent nature of the natural hazards being represented by catastrophe models implies that the models will always contain a significant amount of uncertainty. This uncertainty is both aleatory (inherent process uncertainty) and epistemic (introduced by the incomplete knowledge of the process parameters and/or the proper model structure4). In theory, aleatory uncertainty is impossible to reduce due to the stochastic nature of the process and in a well designed model it is suitably represented by the probabilistic distribution of loss from a single model.

Estimation of epistemic uncertainty requires use of multiple models built using different parameterizations of the natural hazard process. Many insurance companies are moving towards the use of multiple catastrophe models (or multiple representations of the same catastrophe model enabled by newer, open loss models) to better manage the model risk arising from epistemic uncertainty. Various approaches have been devised to combine (blend) the output from these models to derive a more robust view of risk.

The models do not anticipate all sources of loss from an event and parameter risk cannot be accurately quantified. Typically they do not, but if the models do produce confidence bands around the EP curves, these will not be all-inclusive or robust. They may reflect process risk and/or the uncertainty around the losses for individual events.

V. Model Usage

While the models are useful tools to quantify the nature and uncertainty of catastrophe risk, it is important to recognize that they are often constrained in their ability to fully capture all the varied aspects of the hazard and its consequences - they reflect the model developer's inherent assumptions and scientific judgment. The onus is on the model user to determine if the model is fit for purpose; to use only credible models and adapt them to their specific business with appropriate settings.

If the model representation is fairly adequate but with certain gaps, then, to the extent possible, the model user may apply appropriate adjustments to the model output. If model adjustments are not possible due to the nature of the gap or the lack of transparency/flexibility in the model, the model gaps may need to be documented and accounted for separately. In some instances, addressing the gaps may necessitate significant amount of model development in itself because non-modeled gaps can be fairly material.

For instance, tsunami losses are not explicitly modeled in the earthquake models for many regions, nor are losses from inland floods triggered by tropical cyclones. In a similar vein, the model may not represent certain exposures, such as out-buildings in residential

[4] For example, studies of some past hurricanes and floods have identified the level of soil saturation from previous rains as a factor in the extent of the hazard intensity or damage. This generally is not modeled currently (perhaps due to practical difficulties in doing so).

exposures, contingent business insurance in commercial exposure, and potential loss to infrastructure assets.

There may also be residual market pools or other societal mechanisms to provide insurance policies to otherwise uninsured risks. To the extent these mechanisms are funded by assessments on the insurance industry, they may lead to otherwise non-modeled exposures. Of course, such gaps are model dependent and models continue to evolve to address some of these gaps. The model user may use underwriting insight, industry, and internal claims experience to calibrate and supplement the models.

The closed proprietary nature of the traditional catastrophe models makes it difficult to assess whether the portfolio risk is driven by the hazard (frequency, physical severity, and intensity of the events) or vulnerability component of the model. Often, decision makers are interested in such underlying detail to devise optimal risk management strategies. There are various other risk measures that allow risk managers to assess the risk in more intuitive ways.

One such approach is to track the portfolio risk for certain events, such as the Realistic Disaster Scenarios developed by Lloyds as discussed earlier. Many companies might complement probabilistic risk measures derived from the model EP curves with the development of their own internal catalogue of disaster scenarios to monitor accumulations and manage risk appetite. The uncertainty surrounding catastrophe risk, and its low frequency high severity nature, necessitates multiple approaches to estimating losses to help inform and arm decision makers.

VI. The Future Evolution of Catastrophe Models

Catastrophe models have made significant strides since the late 1980s and they will continue to evolve as actual events occur, scientific discoveries are incorporated, technology advances and new data is analyzed as well as when there is expansion to cover more perils and exposed regions. However, the models will never be complete or accurate so the onus will remain on the model user to fully understand, validate, and refine the model assumptions as appropriate.

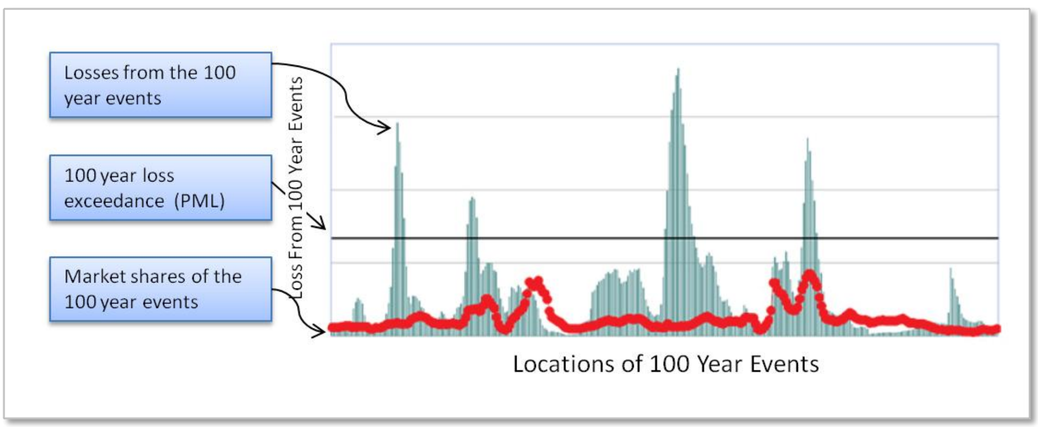
Because catastrophe model development requires scientific, engineering and computer programming expertise not usually found within insurance companies, most insurers have been licensing catastrophe models from third party vendors. The proprietary nature of the third party models makes it difficult for insurers to ascertain which assumptions are driving the model loss estimates. Model updates add to the volatility of loss estimates, and it's very challenging and time consuming for insurers to determine what's causing the changes.

Open Models - The future evolution will be to more open models that allow for a greater ownership of risk as well as better appreciation of the inherent uncertainty in catastrophe risk. Open models are transparent enabling insurers to more fully understand the model assumptions and how different scientific opinions impact their losses. Open models enable users to test their portfolio losses against different sets of assumptions to clearly evaluate model sensitivities and key drivers of their loss estimates.

New Risk Metrics - Future evolution will also be in the area of facilitating new and intuitive risk metrics that give decision makers more insight into their large loss potential. While the EP curve metrics are informative, they do not provide decision-makers with all of the risk information they need, and they can be misleading. For example, the 100 year PML can be misinterpreted as the 100 year "event" loss which can give a false sense of security. The largest losses incurred from the 100 year events will likely be much greater than the 100 year PML from the model-generated EP curve.

The new Characteristic Event (CE) approach in which the probabilities are based on the hazard versus the loss provides additional and more intuitive information for risk management purposes. It gives decision makers their losses from the 100 year (and other return period) events—information many may have thought they already had. The chart below shows the loss estimates for the 100 year event at different locations for a hypothetical company. The 100 year PML is the point on the EP curve that represents a one percent chance the company will have a greater loss; the 100 year CEs show how much greater and where the larger losses are likely to be.

Figure 3 – Example Characteristic Event (CE) Chart



The CEs help a company identify potential solvency-impairing exposure concentrations—information not provided by the EP curve metrics. The CEs are operational metrics that can be used to monitor and manage risk over time.

5. Catastrophe Risk Management

The first step in effective catastrophe risk management is to recognize the uncertainty inherent in estimating catastrophe losses and to utilize multiple approaches and risk metrics to gain as much insight as possible into large loss potential. Then insurers can determine if they're overly exposed to specific events and decide how to underwrite and price the risk and how much to transfer to the reinsurance and financial markets.

I. Underwriting and Pricing

For many insurance coverages, underwriting rules and rates (prices) are based on the "expected losses", also called the average annual losses (AALs) to an insurance policy. A proportion of the standard deviation around the expected losses can also be applied.

For example, in the US, actuaries often use model-generated AALs by postal code to develop hurricane catastrophe loads for homeowners rating territories. The California Earthquake Authority (CEA) uses model-generated AALs to determine earthquake rates by territory. While it is less common outside the US to utilize the models for ratemaking, some global companies use AALs by location and policy to underwrite and price individual accounts. At this high resolution, however, and for specific types of risks, the traditional model output has the least credibility and is highly volatile.

Because of the nature of catastrophes and the skewed, thick-tailed loss distributions, insurers have moved from using expected losses and standard deviation metrics to catastrophe pricing approaches that factor in the capital consumed by different peril regions and even specific contracts. This is typically called "marginal impact" pricing because it's based on the additional capital required to write the new policy, line of business, etc. Rather using the PML, a VaR measure, insurers are moving to metrics capturing more of the EP curve such as TVaR, or "tail-value-at risk" for their marginal impact decisions.

Apart from pricing considerations, it is also common for underwriters to manage the catastrophe risk in high hazard and accumulation zones by offering restrictive policy terms and conditions such as, sublimits, exclusions and higher deductibles, or by focusing on those building types/locations that are less susceptible to catastrophe losses5. Risk metrics, such as CEs, enable companies to see where they have exposure concentrations that need to be reduced.

II. Enterprise Risk Management and Transfer

For solvency and risk transfer purposes, insurance companies, rating agencies and regulators in the US, have come to rely most heavily on the .01 and .004 loss exceedance probabilities—the so called 100 and 250 year "probable maximum losses" (PMLs), respectively. These numbers are used to set capital requirements, determine how much reinsurance to buy, and for formal risk tolerance statements, but there's a growing awareness of the danger in relying on point estimates from the EP curves.

To reduce the over-reliance on one point of an EP curve, companies are leveraging other more robust tail risk measures, such as Conditional Tail Exceedance (CTE, also known, as TVaR) or an Excess Annual Average Loss (XSAAL). The CTE or TVaR, represent the loss amount conditional on the loss exceeding a certain threshold (perhaps, at a certain exceedance probability) and XSAAL represents the (unconditional) average value of loss exceeding a certain threshold. Unlike the PML, both of these measures take into account the thickness of the tail, are not overly dependent on one point on the distribution, and they

[5] For example, analyses of recent hurricanes and floods in the US have shown that it is possible in some cases to prevent or minimize susceptibility to damage through the use of certain building practices.

have attractive coherent properties (such as, subadditivity), which make them attractive to risk aggregators and portfolio managers. (As a caution, however, such values are based on the most uncertain and hence least reliably estimable sections of the loss exceedance curve.)

Risk transfer is a key exposure accumulation management strategy for insurers in their quest to limit net aggregate risk to their balance sheet or earnings. Due to the high demand and supplier interest, over the years, many different risk transfer approaches have evolved. Risks can be transferred at various levels, at a single location or account or at a business unit or a corporate aggregate portfolio. The risk can be assumed by reinsurers, retro-cessionaries and institutional investors6. The modes of risk transfer might include indemnity based or parametric/index based cessions or a hybrid of both.

The underwriting and pricing of risk transfer options fully leverages catastrophe model outputs, which are used to assess the expected loss in the contract, the marginal capital impact and the relative cost of that capital, in addition to corporate risk appetite considerations. Some firms may also use risk transfer to mitigate inherent model risk.

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[6] See Chapter 6 - Non-Proportional Insurance for more details.

[i] The International Emergency Disasters Database http://datahub.io/dataset/emdat

[ii] 2013 Global Assessment Report on International Disasters Reduction http://www.preventionweb.net/english/hyogo/gar/2013/en/gar-pdf/GAR2013_EN.pdf

[iii] East Asia's Changing Landscape: Measuring a Decade of Spatial Growth, World Bank 2015

[iv] "Coastal Exposure and Community Protection: Hurricane Andrew's Legacy", Insurance Institute for Property Loss Reduction and Insurance Research Council, April 1995 and "The Coastline at Risk: 2013 Update to the Estimated Value of US Coastal Properties", AIR Worldwide Report, 2013

[v] Swiss Re 2000, Mills et al. 2001

[vi] A.M. Best's Impairment Review June 24, 2013 http://www.reuters.com/article/2013/06/25/nj-am-best-idUSnBw256092a+100+BSW20130625