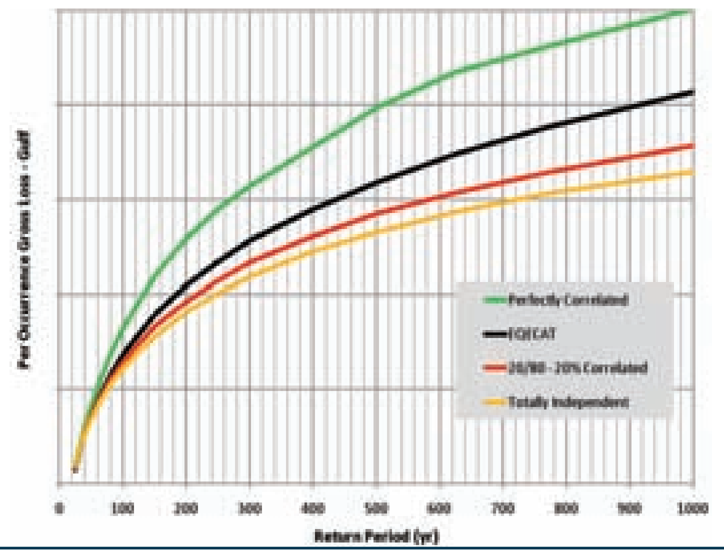

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BOARDROOM BRIEFING

DEALING WITH UNCERTAINTY IN CATASTROPHE RISK MANAGEMENT

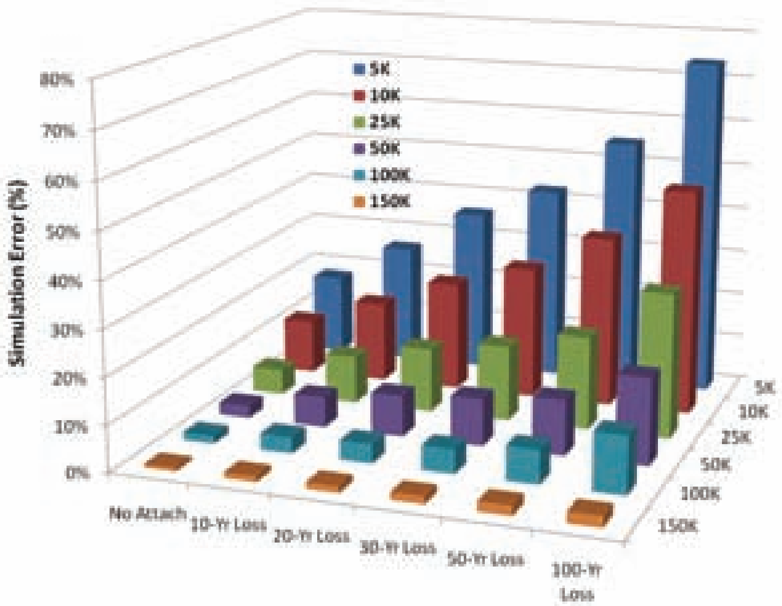
Assessing loss potential

1H catastrophe data

Hazard and vulnerability correlation

Hurricane stochastic storm track simulation

Next generation modelling



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Modelling analytics

Demystified and explained

NATURAL DISASTERS ranging from floods in Australia, to the Tohoku earthquake in Japan have already ensured that 2011 will be the most active year on record for insured catastrophe losses, regardless of what happens through the North Atlantic hurricane season.

In a world of increasing uncertainty one thing is sure – bigger and more frequently occurring catastrophes are set to test the mettle of modelling specialists in the extreme.

Over the past century, catastrophe modelling technology has progressed from little more than a collection of maps to the cutting edge applications we see today.

Today, risk managers must contend with a mind-boggling array of perils for which they must attempt to make the best possible preparations.

Therefore, the art and methodology of modelling has never been so sharply under focus from all angles.

Thankfully, this latest *Insurance Day* boardroom briefing provides a timely reminder that when using catastrophe models, it is imperative to understand their underlying assumptions to ensure that the models incorporate a robust handling of uncertainty.

The bottom line: the truest estimates of insured losses come from the most complete accounting of uncertainty. ■

Greg Dobie
Managing Editor
Insurance Day

WITH THANKS TO

Contributing editor - Mahmoud Khater, chief science and technology officer at catastrophe modelling firm EQECAT.

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Assessing loss potential

ON THE AGENDA

- **Can uncertainty ever be eliminated from catastrophe risk modelling?**
- **What happens if you ignore or simplify uncertainty?**
- **What are the different types of uncertainties that need to be addressed in modelling?**

Fisher's Building, Christchurch: The 2010 quake which hit the city occurred on an unknown fault

FOR INSURERS AND REINSURERS assessing loss potential from natural hazards is risky business. That's why they look to catastrophe models to help them set rational expectations about risk and prepare for potential insured and financial losses before disaster strikes. Catastrophe models use the latest scientific and engineering knowledge, claims and exposure data, and advanced mathematics to help insurers and reinsurers understand risk correlation at the site, as well as at the policy and portfolio level, enabling them to quantify and manage risk effectively.

Insurers and reinsurers can gain access to such knowledge through catastrophe models, which are complex mathematical and probabilistic algorithms involving the simulation of tens of thousands of catastrophe events relevant to specific perils such as windstorms, earthquakes, and floods. Essentially, catastrophe models are an analytical framework for exploring, quantifying and managing the uncertainty associated with catastrophe risk.

An understanding of the importance of uncertainty in catastrophe risk modelling requires thinking about uncertainty in a new context. Rather than an admission of ignorance or a feeling of insecurity, uncertainty should be understood as the variability present in the world, especially when it comes to natural disasters.

While some uncertainty can be reduced, eliminating it may not be an achievable goal. In fact, the Holy Grail of catastrophe modelling is quantifying the best estimate for a particular risk, as well as the uncertainty reflecting the nature of that risk and the state-of-the-art quantification of the unknown.

Ignoring or simplifying uncertainty can result in severe underestimation of loss. This is particularly relevant to insurers and reinsurers concerned with the tail of a loss exceedance curve, which indicates the annual probability that a given loss will be exceeded for the location or portfolio in question.

TYPES OF UNCERTAINTY

In order to estimate the full spectrum of outcomes and exceedance probability, modellers address three types of uncertainty in their models:

ALEATORY (Randomness): This variability/uncertainty is irreducible due to the natural unpredictability of random processes, but nonetheless critical to analyse. With hurricanes, for example, we need to quantify the event frequency and the wind speed severity distributions, which affect the level of damages to structures in a considerable way. An inaccurate wind speed estimate can result in over- or underestimation of the damage.

EPISTEMIC (the scientific uncertainty in the modelling of a natural process): In modelling uncertainty, complicated scientific data is gained from natural perils that have occurred over time. However, individual researchers may vary in their assumptions and results; for example different research groups in the next generation earthquake attenuation (NGA) equations research project started with the same historical ground-shaking data and ended up developing different attenuation equations.

To account for these differences among alternative models, and, therefore, minimise some of the uncertainty, it is important to create checks and balances. Building a simulation framework with stochastic event sets and using multiple scientific models can deepen our understanding of risk.

ONTOLOGICAL: With elements of both aleatory and epistemic types of uncertainty, ontological uncertainty arises from an unknown process or mechanism.

Take, for example, quantifying hazards due to earthquakes. When faults are known, such as the numerous ones throughout California (*see picture, right*), slip rates can be measured and earthquake risk can be quantified.

However, this is not always the case, as demonstrated by the 2010 massive Darfield earthquake that hit the South Island of New Zealand, occurring on a fault that was unknown at the time. Often, even with limited historical data and no physical reason why there cannot be, say, an earthquake or a hurricane in a particular area, modellers need to simulate "all possible events" that may not be present in the limited recorded history.

> "Knowledge is an unending adventure at the edge of uncertainty"
>
> **Jacob Bronowski**
> British mathematician, biologist, historian of science, theatre author, poet and inventor.

PAST EVENTS

Past events are a rich source of data that inform risk modellers about a particular peril in a given region. Modellers then interpret this data from scientific consensus to build stochastic simulations they believe represent a robust set of possible events based on what has already occurred and is consistent with the physical phenomena.

Using these simulations the catastrophe model analyses exposure data sets that include details such as building characteristic, occupancy and insurance conditions that produce probabilistic output to inform risk decisions.

Uncertainties cannot be eliminated in catastrophe modelling, therefore they need to be quantified and included in the modelling process in order to estimate the full spectrum of outcomes and exceedance probabilities.

Ignoring this can lead to underestimation of the loss exceedance curve, especially the quantification of the curve's "tail," where the high severity/low frequency events have a larger impact. ■

Quake damage to a residential building in Santa Monica, California.

First-half loss data

Loss activity up until the end of June topped the whole of last year's record catastrophe bill, Insurance Day reveals, with many of the weather-related events attributable at least in part to the La Nina climate phenomenon

FIRST-HALF insured catastrophe losses of $60bn are nearly five times the average of the past 10 years.

Total economic losses for the first half of the year are estimated by the world's largest reinsurer, Munich Re to total $265bn – already in excess of the costliest full-year on record.

Previously the costliest year to date was 2005, which Munich Re said saw economic losses of $220bn for the year as a whole.

The 2005 loss was largely driven by US hurricane activity, particularly the impact of hurricanes Katrina, Rita and Wilma.

Munich Re's estimates suggest Katrina will remain the costliest insured event in history – its figures count the March 11 Japanese quake as a $30bn event.

But Japan has surpassed Katrina in terms of economic losses – the reinsurer said it expects economic losses from the quake and tsunami to total $210bn. Katrina caused economic losses in the order of $125bn.

The first six months of 2011

	The first six months of 2011	The first six months of 2010	10-year average of the first six months in the period 2001-2010	30-year average of the first six months in the period 1981-2010
Number of events	355	480	390	310
Overall losses (US$ m)	265,000	97,200	47,400	36,400
Insured losses (US$ m)	60,000	26,900	12,100	8,200
Fatalities	19,380	230,300	52,900	42,700

Source: Munich Re

The five largest natural catastrophes in the first six months of 2011

Ranking by overall losses

Date	Country/Region	Event	Fatalities	Overall losses US$ m	Insured losses US$ m
11.3.2011	Japan	Earthquake, tsunami	15,500	210,000	~30,000
22.2.2011	New Zealand	Earthquake	181	20,000	>10,000
22-28.4.2011	USA	Severe storm/ tornadoes	350	7,500	5,050
Dec 2010/Jan 2011	Australia	Floods	35	7,300	2,550
20-25.5.2011	USA	Severe storm/ tornadoes	170	7,000	4,900

Source: Munich Re

The five largest natural catastrophes in the first six months of 2011

Ranking by insured losses

Date	Country/Region	Event	Fatalities	Overall losses US$ m	Insured losses US$ m
11.3.2011	Japan	Earthquake, tsunami	15,500	210,000	~30,000
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Dec 2010/Jan 2011	Australia	Floods	35	7,300	2,550

Source: Munich Re

Munich Re board member Torsten Jeworrek said it was very rare for such an extreme accumulation of natural hazards to take place during the first half of a year.

"We were not surprised by any of the events when viewed as single events, since they were within the range our risk models told us to expect. The accumulation of so many severe events of this type in such a short period is unusual, but is also considered in our scenario calculations," he said.

The five largest natural catastrophes in the first six months of 2011

Ranking by number of fatalities

Date	Country/Region	Event	Fatalities
11.3.2011	Japan	Earthquake, tsunami	15,500
12/16.1.2011	Brazil	Landslides/flash floods	1,350
22-28.4.2011	USA	Severe storm/tornadoes	350
1-28.6.2011	China	Floods	240
22.2.2011	New Zealand	Earthquake	181

Source: Munich Re

LA NINA INFLUENCE

Many of the weather-related events during the first-half are attributable at least in part to the La Nina climate phenomenon.

These include the series of tornadoes which caused havoc across much of the US during April and May – Munich Re said it expected insured losses from the two most serious tornado events – during the final week in April and third week in May – at $10bn, with the overall economic losses totalling $15bn.

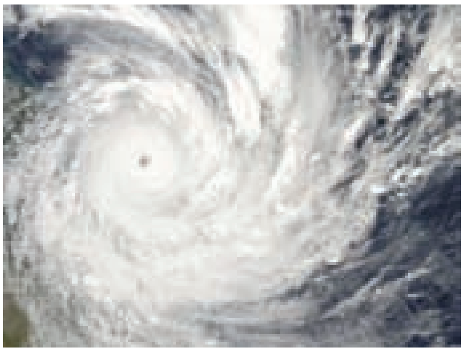
The number of tornadoes registered up until the end of June – approximately 1,600 is virtually at a record level – Munich Re said it was only marginally below 2008, the current record year. 2008 was also a La Nina year.

Peter Hoppe, head of Munich Re's Geo Risks Research, said: "Overall, the accumulation is nothing unusual in La Nina years. The statistical increase in the number of tornadoes over the course of time is mainly the result of better documentation.

La Nina is also linked to the severe flooding in Queensland during the first quarter, which Munich Re estimates caused an insured event of $2.5bn out of a total economic loss of $7.5bn.

Queensland also saw cyclone Yasi make landfall on February 3. Although Yasi missed the major cities closest to its landfall location – Cairns and Townsville – economic losses totalled around $2bn. The Insurance Council of Australia has already confirmed insured losses from the event are in excess of $1bn.

"One factor that stood out was this year saw the highest sea temperatures ever measured off the coast of Austra lia, which are contributors to these weather extremes," Hoppe said. "Although this is linked to La Nina, temperatures were higher than the previous La Nina years." ■



Cyclone Yasi made landfall on February 3.

Damage correlation

ON THE AGENDA

- **How do we gain better knowledge of hazards, vulnerability and financial modelling?**
- **What are the essential factors when calculating the total loss distribution for a given event?**
- **In addition to multiple types of uncertainty, what other sources need to be taken into consideration?**

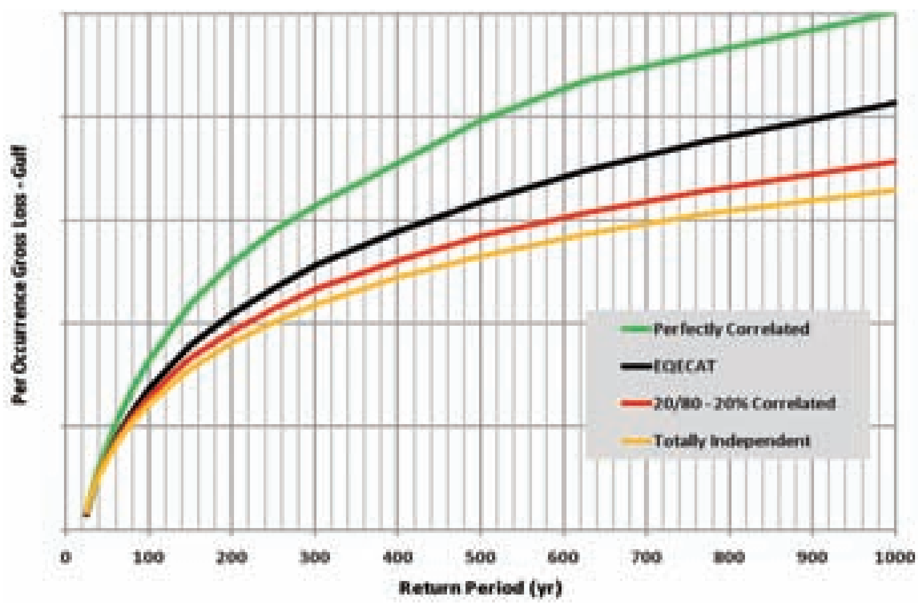
AN IMPORTANT ASPECT of the stochastic simulation in catastrophe models is the high degree of damage correlation within a geographical area.

Correlation in hazard and vulnerability is an essential part of calculating the total loss distribution for a given event and the loss exceedance probability.

It affects a model's performance, especially at the tail of the distribution. Important decisions related to pricing, capital, reinsurance purchasing, and risk of ruin are made by analysing the tail of the curve.

Therefore, failure to account for correlations can result in unpleasant surprises, including underestimating the risk of ruin.

For example, **Figure 1** *(right)* shows the effect of correlation on the loss exceedance curve. The highest and the lowest curves depict the perfect correlation (highest) and independent cases (lowest).



The exceedance curve labelled EQECAT is based on a complex correlation matrix developed from analysing billions of dollars of claims data.

The 20/80 labelling on the third curve in the figure is a common approximation used in the catastrophe modelling field.

It combines the perfect correlation and independent cases using assumed weights (in this plot 20% and 80%) in building the exceedance curve.

An objective of catastrophe modelling is to reduce the second (systemic) and third (ontological) types of uncertainties by gaining better knowledge of hazards, vulnerability and financial modelling.

SOURCES OF UNCERTAINTY

In addition to multiple types of uncertainty, there are numerous sources that must also be taken into consideration, such as uncertainty in:

- time (frequency of occurrence)
- space (event location, such as where a hurricane makes landfall or where an earthquake occurs)
- event intensity (its strength, magnitude, or severity index, etc.)
- spatial distribution of the hazard (the overall footprint of the event, for example, soil failure in an earthquake, tornadoes in a hurricane, a tsunami's wave height, speed, etc.)

Beyond the hazard or peril itself, modellers also need to quantify the following uncertainties when calculating final loss estimates:

- defence systems
- building response (requiring understanding of building type and design, whether there was deferred maintenance or there were hidden defects)
- post-event mitigation (for example, fire suppression, waterproofing, offsite utilities.)

Non-modelled losses such as Hurricane Katrina's levee failure and flooding in 2005, and the unanticipated scale of the tsunami following the March 2011 Tohoku earthquake (further complicated by the ensuing nuclear plant damage and surrounding contamination) are prime examples of important uncertainties that affect losses. These non-modelled losses also have a significant impact on post-event loss amplification and restoration time.

Models only reflect what they are built to model. As is evident, understanding both what is and is not included are equally important in interpreting results.

RISK REPRESENTATION

Completeness of the stochastic event set is based on accounting for all credible events that could occur. Consistently incorporating uncertainty into site hazard estimations and vulnerability functions provides the truest representation of risk.

Along these lines, integrating site correlation into the tail risk calculation offers the best account of observed "clusters" of damage, which greatly influence extreme outcomes. ■

Hurricane stochastic storm track simulation

ON THE AGENDA

- **What parameters should be included in the event set generation?**
- **What factors can result in a significant underestimation of losses?**
- **Why does complete accounting of uncertainty result in the truest estimate of insured losses?**

WHEN BUILDING a stochastic storm track set, all potential hurricanes are taken into consideration. This event set must be comprehensive with no gaps, and no bias in the event spacing, otherwise the existence of such deficiencies would underestimate the wind speed, and, therefore, the losses.

This is of a particular importance to insurers and reinsurers with high value commercial and industrial books of business which, by their nature, are geographically sparse.

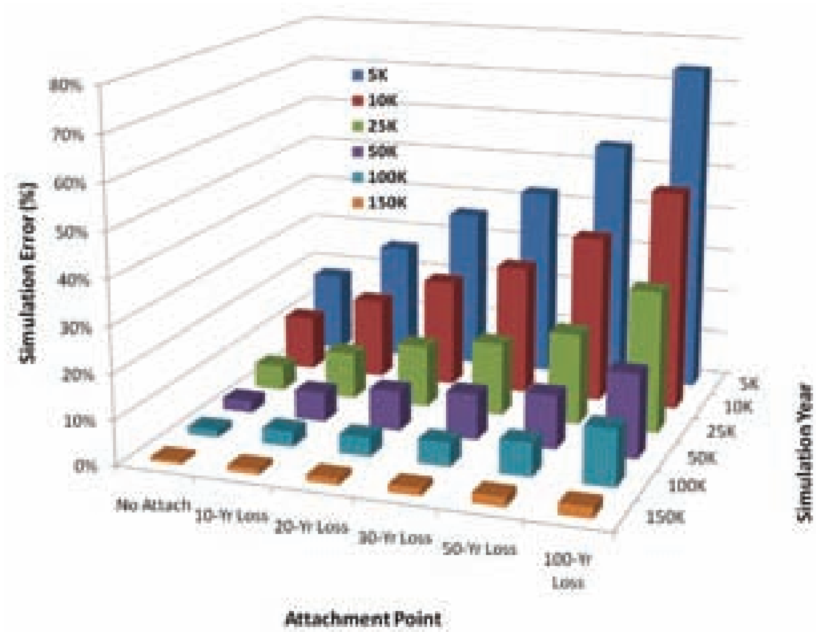
If no sufficient historical data exists, using numerical analysis and climate models along with a large number of simulated years, helps reduce the incidence of gaps.

To properly account for uncertainty in a simulation, the full spectrum of events must be considered. An insufficient number of simulated events or years can cause errors. Simply put, the more comprehensive the event set, the greater the credibility of the model.

Parameters included in the event set generation are:

- azimuth (storm direction at landfall)
- translational speed
- rate of change of translational speed
- maximum wind speed by Saffir-Simpson Intensity Scale (SSI)
- rate of change of intensification or decay by SSI
- radius to maximum wind
- storm size (profile factor)
- curvature of storm tracks
- probability of dying by SSI

Site-specific parameters, in other words, additional factors affecting wind speed at a particular site, need to be included in the stochastic process and uncertainty calculation in order to estimate damage at a particular location.



All such parameters, including gust factor, friction factor and filling rate are treated as random variables, and full distributions are developed for each variable. The gust factor, for example, should not be modelled as a point estimate, but the full ranges need to be considered.

Accounting for uncertainty in the performance of buildings is essential in the probabilistic simulation of a catastrophe model, especially when you recognise that no two buildings exposed to the same hazard will sustain the same level of damage, due to variances in materials, construction practice, adherence to building codes, etc.

The non-linearity of the loss calculation highlights the importance of accounting for the full uncertainty in vulnerability and hazard in the loss calculation. Accounting for only partial uncertainty in hazard or vulnerability could result in a significant underestimation of the losses. This is of a particular importance to insurers and reinsurers with high attachment points, where the loss underestimation could be very significant at the tail of the exceedance curve.

SIMULATION ERRORS

Figure 2 *(above)* highlights the simulation errors that can result from using inadequate number of simulated years in the creation of the loss exceedance curves.

It illustrates that the error in the expected annual loss of a given layer for a market portfolio is significantly higher in the case of using 5k simulated years compared to a more comprehensive 150k simulated years.

The figure also demonstrates that the higher the layer of interest's attachment point, the higher the error, and that the more comprehensive simulation with 150k years produces stable results and minimises the simulation error. ■

Third generation correlation Q&A

EQECAT president Bill Keogh (BK) explains to Greg Dobie (GD) why catastrophe modelling's "dirty secret", correlation is becoming increasingly important and outlines how assessing this phenomenon will continue to evolve in the future

GD: Why is correlation important and what does it mean today in the context of modelling?

BK: First, let's begin with a good example of misunderstanding correlation, the most obvious being what happened with the financial crisis in 2008.

Many people thought: "I have got a home, investments in stocks and bonds, I've got some assets like gold and silver, artwork and so on. My portfolio is so diversified that I will never have to truly worry about everything".

Then, of course, along came the financial crisis and they discovered that way out on the tail of the distribution all of these things were correlated.

The lesson from that is it is very important to understand the tail of the distribution correlation can be very high.

GD: Can you give us an example of a simple modelling challenge?

BK: Say, you have a single building which is subject to windstorm risk. It has a certain structure and it has building contents.

To model that you say: "what is the peak gust wind speed that is going to hit that building?" You have a variety of speeds that can hit it, then you have the building's response to damage, which could be anything from 10% damaged to 100%.

This is a modelling fundamental. You've got hazard and vulnerability and people understand those components.

Ultimately, there is a limit to what will happen there, because the building can only be 100% damaged. At some point the peak gust wind speed becomes irrelevant because after it is 100% damaged, you really don't care anymore.

> "To the extent that one uses a simplistic assumption related to correlation, there can be a tendency to underestimate risk in the tail"
>
> **Bill Keogh**
> President, EQECAT

You think of the limitations of just looking at hazard and vulnerability and that brings about the question of correlation.

Correlation is the tendency for things to either behave or not behave in the same way.

If they tend to behave the same way they are correlated, if they tend to behave differently they are uncorrelated.

We need to think of that as a distribution, not as a fixed relationship. There is a mean relationship and then a distribution for correlation.

GD: What other factors need to be considered?

BK: Some of the things that come into play with correlation are the distance of structures from one another, the occupancy of the building and then the building response (which is related to the characteristics of the building, the building's height, construction and other characteristics, such as whether it has a steel frame, for example).

Those three factors are the main drivers of correlation. What we do is we take all of these things into account and we base all of that on billions of dollars of claims data that we have from certain loss events where we have seen what the distance has been between buildings and how they have responded.

We look at similar occupancies and how they have responded as a class and we look at certain kinds of building and how they have responded as a class.

GD: How are insurers dealing with correlation at present? What information are they relying on?

BK: They are certainly relying on their catastrophe models to represent correlation. However, the question is: are their catastrophe models representing it in a robust way or are they representing it in a simplistic way?

To the extent that one uses a simplistic assumption related to correlation, there can be a tendency to underestimate risk in the tail.

When we talk about the tail in this context, the tail is best explained as being the really low probability event at the end of the distribution which is highly unlikely, but could have a very high impact.

That part of the distribution is where insurance companies make decisions about risk of ruin. This obviously impacts pricing and reinsurance-purchasing decisions and the tail is especially sensitive to assumptions related to correlation.

GD: What problems arise from making simplified assumptions?

BK: The most simple approach to correlation involves simplifying assumptions.

The beauty of that is that it is very easy to implement from a modelling point

CORRELATION CASE STUDIES

A CLOSER examination of the damage caused by **Hurricane Ike** after its subsequent storm surge, revealed that any structure or building, which was not on stilts "basically disappeared". Conversely, those structures which were on stilts were left standing, with many of them suffering very little damage.

Hurricane Andrew, Florida

"This is an example of correlation in an occupancy class, but a different building response based on different building characteristics," says EQECAT president, Bill Keogh.

"Then there is the distance factor and this would be very highly correlated if the buildings were near to each other."

Another example, Keogh cites is the impact of **Hurricane Andrew** on Florida homesteads in 1992.

"In this case you had an unusual situation where there was certainly a lot of damage, but there were also many instances where you would have very similar structures, which were very close together, which had very different losses," Keogh explains.

"For example, two houses on the same street had incurred a total 100% damage loss and 50% damage loss, respectively, despite having very similar structures.

"This is about distributions of correlation. In this case you would say, it is not completely correlated because you had a very different loss from a very similar occupancy and building type."

of view, for example, taking loss results out of the model and being able to do things post-processing, combining portfolios, that kind of thing.

What the simplified assumption does not take advantage of is all the claims data and information we have which informs us about correlation. That is the first generation of correlation.

The second generation of correlation is actually what we are doing today. The way we deal with these three elements – the distance between structures, the occupancy and the building response for correlation.

We actually build a correlation matrix, which has all of these factors involved for each peril region we model.

Correlation related to distance, occupancy and building response will be different for US quake, US hurricane and European windstorm because they are different phenomena. You would intuitively understand they are going to be different.

> "In 2012 we will have the ability to aggregate portfolios on the fly outside of the model"
>
> **Bill Keogh**
> President, EQECAT

We take everything that we know about each of these peril regions and have what I would call, a bespoke correlation matrix for that peril region, which is very robust.

It is based on data from the claims and we can say: "this is how we are going to construct this correlation matrix because this is what we have seen and experienced". It is certainly defencible.

GD: How many years worth of data is involved in this?

BK: It is based on data that we have from relatively recent events. It was only around 20 years ago, that people started, in a meaningful way, to collect claims and exposure data.

The important thing is they don't need to be insured loss events to be relevant.

If you think of a lot of the quakes that happen around the world, we are certainly getting data from those.

The one drawback of the second generation, which we currently have, is that it does complicate things because the correlation matrix that we have is not portable.

GD: In what context?

BK: In the context of, to the extent that you want to do things outside of the model, then you want to bring this large complex correlation matrix with you.

Recognising our clients' needs to do much more work with the output outside of the models brings us to the third generation correlation.

We are working on that right now. What we will do, and what we have with our new model, which was released in June, and will receive a further enhancement in 2012, is the ability to have this robust treatment of correlation but it will be very easy to use and implement outside of the model.

What we are doing is taking this very strong advantage we currently have with a robust correlation, and all that it implies for the tail of the distribution, and making it much more easy to use and to implement so that our clients can get a lot more utility out of the model. This will obviously link with all EQECAT models and products.

In 2012 we will have the ability to aggregate portfolios on the fly outside of the model.

It is a mathematical challenge that we have taken on and we are very excited about it because the ability to be able to do this in a robust way, but also making it easy to use, is what makes it revolutionary. ■

For the latest loss updates from the North Atlantic hurricane season visit **www.insuranceday.com**.

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