Swiss Re

Natural catastrophes and reinsurance

Risk perception
Natural catastrophes

Natural catastrophes and reinsurance

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Storms: Moderate latitude winter storms ("extratropical cyclones") do not reach peak gust speeds as high as those of tropical storms. However, the *Lothar* and *Martin* storms in December 1999 showed the tremendous loss potential of some of the densely populated and highly insured European countries.

Foreword

Each year countless human lives are lost and considerable property damage is caused by natural catastrophes. Television images of such events evoke mixed reactions: we are at once saddened by the sight of human suffering, relieved that our worlds are still intact, and overwhelmed by the tremendous forces at work in nature.

Natural catastrophes remain unpredictable in spite of huge technical and scientific advances. Nevertheless, our understanding of the causes and effects of such extreme events has improved dramatically over the past few decades. This knowledge has flowed into hazard maps, construction standards and emergency planning and has helped us to be better prepared to tackle future scenarios.

One of the key responsibilities of re/insurers is to help in the risk mitigation process. The objective is to form a community of insureds whose premium payments will be sufficient to cover the cost of repairing the damage in the wake of a natural catastrophe. Demand for insurance against natural catastrophes such as earthquakes, windstorms and floods has steadily increased in the past, as has the willingness of re/insurers to cover such risks.

There is a tendency to underestimate risks relating to natural hazards when a catastrophic event has not occurred for a long time. Nowadays, insurers use mathematical models based on the most recent scientific data in order to make realistic risk assessments and avoid such inaccuracies. Swiss Re has a specialised department established to assess natural hazards, and it is also continuously engaged in trying to improve the effectiveness of such models.

As early as 1988, Swiss Re produced a publication entitled “Natural hazard and event loss”, detailing various aspects of natural hazard risk assessment. The fundamentals presented in that publication remain valid; however a complete revision was deemed necessary in view of the significant developments that have taken place since that time.

The ideas put forward in this publication are intended to stimulate debate and offer a snapshot of systems and methods that are continuously evolving.

Werner Schaad
Chief Underwriting Officer
Swiss Re

Floods: All activity ground to a halt at Dresden main station in August 2002. Heavy flooding led to serious disruption of the public transport system. Damage to the infrastructure was responsible for a considerable part of the event’s overall economic cost.

1 Natural hazards and event loss

Hurricane *Andrew* – a tropical cyclone that reached the highest level of the intensity scale – swept through the southeastern US in 1992 leaving a trail of destruction. The hurricane claimed 38 lives, thousands of buildings were destroyed, vehicles and ships were wiped out and electricity and telephone networks were down for days on end. With total losses of some USD 20 billion, hurricane *Andrew* was the most expensive natural catastrophe of all time for the insurance industry.[1]

The fierce storm threatened the very existence of individuals or companies that were not insured. Equally, many well-established insurance companies ran into financial difficulties and were hard-pressed to cover their clients' claims. Many insurers were caught completely off guard for a loss of this size and had not put aside the necessary reserves or purchased sufficient reinsurance cover to absorb such an event.

This example shows that the correct assessment of potential losses due to rare, yet possible catastrophes is enormously important for re/insurers, even if such catastrophes are seldom. However, even with today's technology, this remains a very challenging task.

Given the necessary experience, the probability of a loss caused by an extraordinary fire can be predicted with relative certainty. In the case of natural hazards such as earthquakes, storms or floods, however – where the loss potential is significantly higher as a result of the large number of policies triggered simultaneously – predicting extreme loss events becomes much more difficult. Major events of this type tend to have long return periods of decades or even centuries. This means that looking at loss patterns a few years into the past seldom gives a representative picture of the true risk exposure. When a long period has elapsed without losses, insurers frequently underestimate the extent of the damage such natural catastrophes can cause.

Event loss
An event loss is the sum of all individual losses resulting from a single occurrence. In property insurance, it is often defined as "all losses that can be attributed to one cause or chain of causes". Regarding natural catastrophes, "cause" or "chain of causes" need to be defined using scientific parameters. However, it is still very common to apply so-called "hours clauses" (all losses that are incurred within a certain period of time).

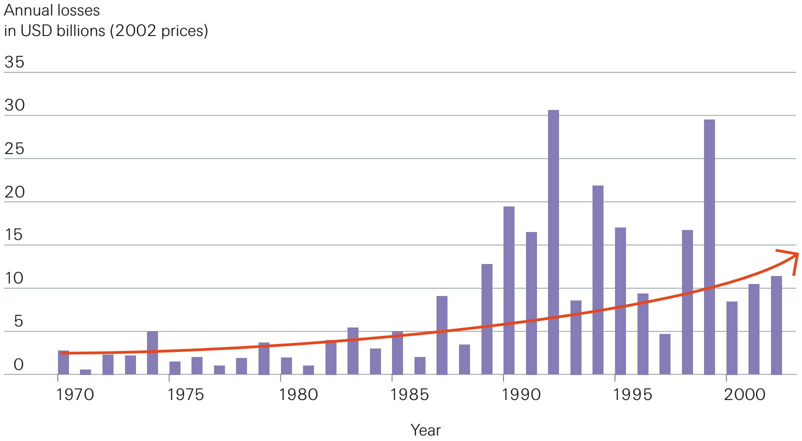
Return period
This term describes the average time within which the magnitude of an event is reached or exceeded. The return period is inversely proportional to the occurrence frequency, ie a return period of 100 years translates to an occurrence frequency of 1 in 100 years or 0.01 per year.

[1] *sigma* No. 1/2002: Natural catastrophes and man-made disasters in 2001, Swiss Re

Risk
Risk is generally defined as "a possible danger, the size of which is expressed using the formula: *loss potential x occurrence frequency*". In the insurance industry, the term "risk" also refers to insured objects or interests. In other words, in a portfolio of insured buildings, the buildings will often be referred to as "risks", or, in the case of event losses, as "affected risks" (ie damaged buildings).

The insurance industry is, therefore, well advised to use scientific models to predict the financial fallout of natural catastrophes (see text box "Are natural catastrophes on the rise?", page 9). This is the only way the industry can play its part in effectively mitigating the costs caused by such events. This publication describes how Swiss Re assesses the financial risk associated with natural catastrophes and how it uses this information to guide its business decisions in this sector.

Figure 1
Development of insured losses attributable to natural hazards over the past.
Source: Swiss Re sigma Catastrophe Database



Are natural catastrophes on the rise?

Water levels reached 150-year highs during the August 2002 floods in many areas in Central and Eastern Europe. Images of regional trains submerged in water at the main station in Dresden (Germany) were seen in the press throughout Europe, offering a stark reminder of the tremendous destructive power of natural catastrophes and of the vulnerability of our high tech world. Even before the water had receded from the flooded areas, intense discussions were underway as to whether an increase of natural catastrophes could be expected as a result of climate change.

Swiss Re examines global natural catastrophes in its *sigma* study on natural catastrophes and man-made disasters, published annually.[2] In spite of huge annual fluctuations, a clear trend emerges when reviewing events over the past 30 years. These indicate that insurance losses caused by natural catastrophes have risen dramatically (Figure 1). This increase is principally a result of higher population densities, a rise in insurance density in high-risk areas and the high vulnerability of some modern materials and technologies. Given that these trends have been constant, we assume that natural hazard losses will continue to rise. However, the fact that losses are on the increase should not necessarily lead us to conclude that the number and/or intensity of natural catastrophes per se has increased.

Insurance density
The term is generally used as a measure of the ratio between insured and existing insurable values.

Yet, a growing body of scientific research would seem to support the view that the frequency and intensity of certain natural catastrophes can be expected to rise beyond the normal cyclical fluctuations. Temperature measurements indicate that, overall, the earth's lower atmosphere has warmed up over the past hundred years. A large proportion of this temperature increase is, in all probability, attributable to human activities. In particular, greenhouse gas emissions such as carbon dioxide (CO_2), produced through the combustion of fossil fuels, are thought to be responsible for global warming. Due to the physical characteristics of the atmosphere, it is highly probable that a global temperature increase will lead to an intensification of the hydrological cycle. Global climate models predict increased and more frequent seasonal precipitation in various regions of the world.[3] The fear is that this might lead to more frequent and/or more extreme flood events. A general increase in temperature might also aggravate storm activity.

[2] *sigma* No. 2/2003: Natural catastrophes and man-made disasters in 2002, Swiss Re
[3] IPCC (Intergovernmental Panel on Climate Change), Third Assessment Report, 2001

Forest/bush fires: Traditionally, insurers think of a typical fire loss as affecting a single building. However, in dry climates such as Australia or Colorado (as shown here), forest/bush fires may threaten entire towns and broad swaths of land, as the flames are fanned by strong winds and spread extremely rapidly.

2 Characteristics of natural hazard insurance

A re/insurer enters into a contractual obligation to assume the risk of future losses in return for a premium. If the re/insurer is to be able to meet its financial obligations in the event of a loss, it must be in a position to assess the risk – eg the relationship between loss potential and the occurrence frequency – as accurately as possible. There are two key parameters to be taken into consideration in any such assessment, irrespective of the risk insured:

- *Expected annual loss:*
  The re/insurer needs to estimate how high the expected annual loss of an insured object (individual risk) or an entire portfolio of insured objects will be. This figure plays a fundamental role in any premium calculation.

- *Extreme event losses:*
  The re/insurer needs to estimate how high event losses will be should an extraordinary catastrophe occur. This information can be used to prevent cash-flow problems: for example, to define the capital base required by the company, or determine the appropriate amount of reinsurance cover.

These two figures are calculated in various ways, depending on the type of peril insured. For example, there are major differences between a conventional risk – such as fire – and natural hazards, which require an altogether different analytical approach.

2.1 Occurrence frequency

The probability of an individual building suffering a fire loss is very low. In the case of an entire portfolio, however, fire losses occur relatively frequently, and they will be fairly consistent over a given unit of time (eg annually). Press and television reports occasionally give the impression that natural catastrophes also occur relatively often. Globally speaking, this may be true. However, the probability of an insurance portfolio being affected by a particular event – such as an earthquake – is extremely low. This means that after years or decades without losses there may suddenly be a year of an enormous event loss. So in contrast to fire losses, the natural hazard loss burden typically fluctuates radically (the smaller the region under consideration, the greater the fluctuations) from year to year.

In the case of fire insurance, several years' losses are compiled and analysed using statistical methods (*burning cost analysis* and *exposure rating*) in order to gauge expected losses in the future. In the case of natural hazards, however, loss data is frequently not representative and therefore not suitable for this purpose due to the aforementioned fluctuations (Figure 2). If rare and unpredictable natural catastrophes are to be factored into estimates in a meaningful way, the periods of time yielding statistical data must be extended using specialised scientific techniques.

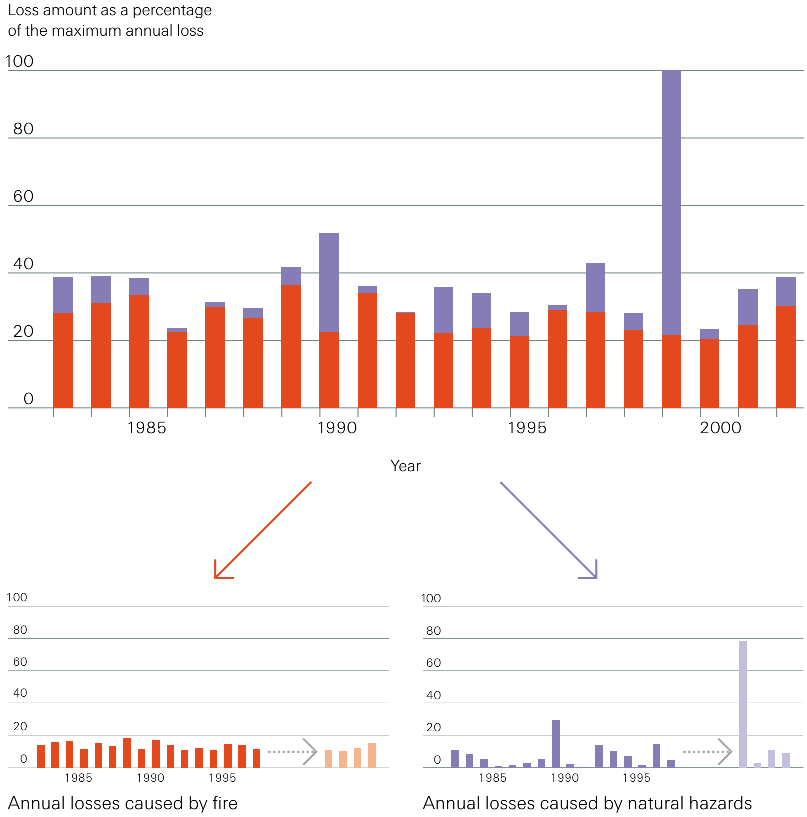


Figure 2
Generalised claims burden of Central European insurers between 1983 and 2002: The trend for fire losses is very consistent. Historical claims data offers reliable clues for the full spectrum of future annual losses. However, annual natural hazard losses fluctuate wildly and can have a dramatic impact on a re/insurer's annual financial results. This is clearly illustrated by losses in 1999, which were principally caused by the European winter storms *Lothar* and *Martin*. Even loss statistics that are tracked and indexed accurately over a fifteen-year period are not sufficient to assess natural hazard risks reliably.

Annual losses caused by:
- Fire
- Natural hazards

2.2 Event size

A fire will normally affect a single building, building complex or industrial facility. Structural fire prevention measures, fire-fighting efforts and the distance between the building and neighbouring buildings can limit the loss potential. A natural hazard, on the other hand, typically causes losses across broad geographical areas (ranging between 10 000 and 100 000 km^2) and involves numerous individual risks. In such cases, the re/insurer faces a "catastrophe accumulation". Individually, the losses can range from almost nothing to total losses. The sum of all of the losses – ie the event loss – can reach enormous proportions, even multiples of annual premium income. When event losses have not occurred for a long time, there is a tendency to underestimate the insurance premium rates needed to cover such eventualities. To ensure that consistently good business results are achieved as the number of insured objects increases (the so-called "law of large numbers"), it is imperative for the risks in a portfolio to be spread over a large number of separate geographical regions.

With sufficient experience, expertise and – where necessary – site inspections, it is possible to make an accurate assessment of the loss that might result from a major fire, as the size of a fire event usually remains within manageable limits. It is far more difficult, however, to estimate the accumulation loss in the case of natural hazards. Quantitative risk assessment of natural hazards therefore requires models that analyse large geographical areas and a large number of insured objects.

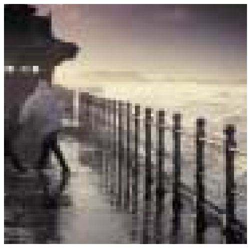
2.3 Location

In natural hazard insurance, the risk can vary enormously even over short distances. Attention should, therefore, be paid to the location factor as much as to the extreme fluctuation in the loss burden and the danger of catastrophe accumulation mentioned previously. In fire insurance, while market, sectoral and structural factors certainly play a role, the location of the building(s) is not of crucial importance: ultimately it is irrelevant for the insurer whether a warehouse is located in Florida or in California. It is quite different in regards to natural hazards, where location is a vital consideration. Whilst hurricanes represent a major threat in Florida during the summer months, the population of California – though spared this particular hazard – faces the risk of highly destructive earthquakes.

In light of these location-specific factors, a great deal of importance is attached to data on exposed values in natural hazard insurance. The recording of data on geographical location and other loss-relevant information related to the insured objects is known as "accumulation control". Accurate accumulation control is an essential precondition for arriving at a meaningful assessment of the financial risk involved in insuring natural hazards.

When assessing natural hazard risks, all of the special factors previously mentioned must be borne in mind (Figure 3). It is impossible to arrive at a reliable estimation of average and extreme loss burdens on the basis of a few years' data, or by conducting a site visit. Rather, specialised models need to be employed to achieve this end. The following chapter offers a more detailed look at these types of model developed by Swiss Re and attempts to explain how they work.

Figure 3
Summary of the most important differences between fire and natural hazard insurance and their consequences.



	Fire	Natural hazards
Differences		
Occurrence frequency	High	Low
Event size	Individual risk affected (individual building or complex of buildings)	Entire portfolios of risks affected
Location	Low importance	High importance
Consequences		
Pricing	Minor fluctuations in the loss burden; therefore, burning cost analysis and exposure rating are sufficient	Major fluctuations in the loss burden; therefore, scientific models are required
Loss potential from single event	Low to medium	Very high
Geographical distribution	Minimal impact on losses, no accumulation control required	Major impact on losses, accumulation control important

Earthquakes: People are often killed not by earthquakes per se but by falling buildings. And yet, there does not seem to be any logical pattern to the way buildings collapse in earthquake-prone regions. The mosque in the photograph, for example, remained completely unscathed, whilst neighbouring buildings were razed to the ground. Striking in the middle of the night, the earthquake in Izmit (Turkey) in 1999 claimed a greater number of victims than it would have done had it occurred during the day. More than 15 000 people perished. There are several ways to reduce the probability of building collapse, most notably by introducing and implementing appropriate construction standards.

3 Assessing the risk

3.1 Are natural catastrophes predictable?

Early in the morning of 15 January 1995, a violent earthquake rocked the Japanese port of Kobe. More than 5500 people lost their lives in the mountains of rubble and debris. Although the quake lasted only 14 seconds, the total economic loss incurred during this short period of time amounted to over USD 100 billion. Only a fraction of this was insured. Everybody knew that there was a risk of earthquake in the area around Kobe, and yet no one had any inkling of the impending catastrophe on that fateful morning. There were no warnings.

Despite an enormous amount of research, it has so far proved impossible to develop reliable methods for predicting earthquakes. Other natural hazards – eg windstorms or floods – can, at very best, only be predicted a few days before they strike. But if such events cannot be predicted, how are re/insurers able to estimate future losses?

The non-predictability, or randomness, of natural hazards is a fundamental prerequisite of insurability for these risk types. If it were possible to determine in advance who would or would not be affected by a loss event, it would no longer be possible to form a risk community for the purposes of insurance. Despite this randomness, which makes it impossible to predict an individual event, it is nevertheless possible to predict, on average, how many events will occur and how severe they will be, over a long time span (see text box "Natural catastrophes – game of dice?", page 16).

To conduct a statistical evaluation of this kind, the re/insurer needs a comprehensive catalogue of historical event data. This information allows it to establish the relationship between geographical distribution, occurrence frequency and intensity. This basic data is combined with scientific expertise to produce a general assessment of future hazard. Additional loss-relevant data must be factored in to assess the expected annual loss as well as extreme event losses. This procedure allows re/insurers to assess future losses without knowing precisely when the events will strike.

Natural catastrophes – game of dice?
Let us imagine a game of dice. And let us assume that the number six represents a natural catastrophe event. If we have unweighted dice, it is impossible to predict when the next six will be thrown. It is, however, possible to predict that out of 600 throws, it is highly probable that the number six will appear approximately 100 times. During this process one might expect several sixes to be thrown consecutively from time to time, and for there to be long periods where no sixes are thrown. Thus, as with natural catastrophes, the frequency with which "events" occur can fluctuate radically. The longer the period of time (ie the more times the dice are thrown), the greater the degree of accuracy with which one can predict the number of "events".

Even though the principle used to predict natural catastrophe hazard is similar to that described above, the process is considerably more complex. One important reason for this is that there is a great deal of uncertainty surrounding the frequency with which natural catastrophes occur, due to insufficient historical data. Also, the past, upon which all models are based, may not be at all representative of future developments. To complicate matters further, the occurrence probability of an event does not remain constant over time: in some cases it shifts as a result of natural fluctuations (climate cycles or forces at work in the earth's crust), and in others, it is permanently changing (climate change). This topic is discussed in further detail in the context of Turkey's earthquake hazard in Swiss Re's Focus Report entitled "Random occurrence or predictable disaster – New models in earthquake probability assessment".

3.2 The fundamentals of modelling natural hazards

A model is nothing more than a simplified representation of reality. Natural hazard models use the virtual world of computers in an attempt to simulate natural catastrophe losses expected in reality. The risk that a natural hazards re/insurer exposes itself to depends on four basic sets of data, which must be fed into the loss model. They are:

- Hazard: Where, how often and with what intensity do events occur?
- Vulnerability: What is the extent of damage at a given event intensity?
- Value distribution: Where are the various types of insured objects located and how high is their value?
- Insurance conditions: What proportion of the loss is insured?

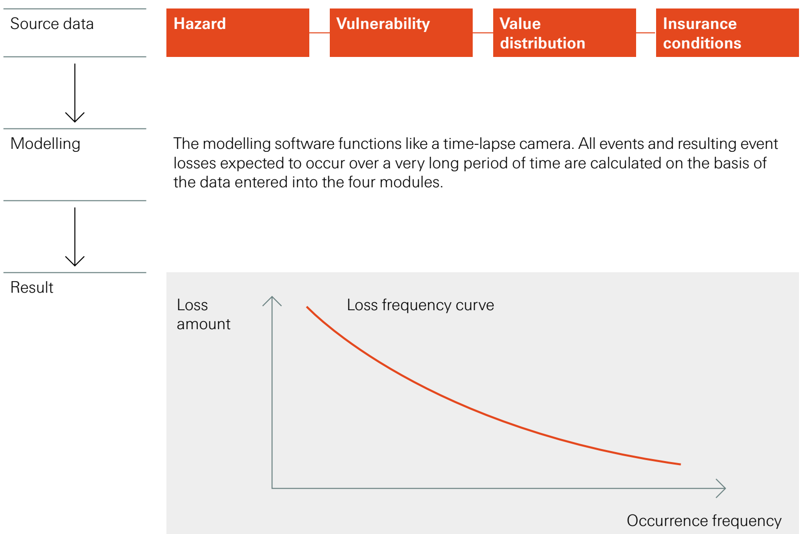
These four building blocks are quantified separately and are then combined in the process of estimating an event loss. This approach may generally be applied to all forms of natural hazard, whether earthquake, storm or flood or any other type of peril.

The simplest way to assess the loss potential of an insurance portfolio is to simulate an individual natural catastrophe scenario. This is known as “deterministic” or “scenario-based” modelling. Such models often refer back to major historical loss events, applying these to the insured values that exist now (“as-if analysis”). The disadvantage of this method is that, whilst it allows a single, extreme, individual event loss to be assessed, it fails to take account of all the other events that might occur. It is not possible to calculate an expected annual loss for a portfolio on the basis of a single event loss, and any prediction as to the occurrence frequency of the model scenario will remain very uncertain.

Today, in an attempt to avoid these problems, so-called “probabilistic” models are being used to assess hazards such as earthquakes, storms and – increasingly – floods. Rather than simply analysing one event, the computer is programmed to function as a sort of time-lapse film camera, simulating all the possible events that could unfold within a sufficiently long period of time (thousands or tens of thousands of years). This type of model produces a “representative” list of event losses (ie a list that accurately reflects the risk). From this list it is possible to understand the relationship between loss potential and occurrence frequency, and hence the cost of average and extreme loss burdens.

Swiss Re’s Cat Peril unit has developed models with which to conduct probabilistic analyses of its highest-risk earthquake, storm and flood hazards. By applying these models, risk associated with natural hazards can be estimated both for portfolios and for individual insured objects. The models are based on four modules, one for each of the fundamental building blocks of loss modelling: hazard, vulnerability, value distribution and insurance conditions (Figure 4). The following sections will examine each of these modules, and the ways in which they are combined, in more detail.

Figure 4
The Swiss Re approach to probabilistic natural hazard modelling using the four modules, and the resulting risk exposure, shown in the form of a loss frequency curve.



3.3 Modelling natural hazards – the four modules

3.3.1 Hazard module: Where, how often, how severe?

Exposure to natural hazard risks is expressed in terms of geographical distribution, occurrence frequency and intensity. Historical event catalogues and scientific research into the physical characteristics of natural phenomena are used to quantify these parameters.

Catalogues of historical event data on the various natural hazards form the foundation of the hazard module. The further back a historical data series reaches, and the more complete it is, the more likely it is to provide a reliable reflection of the real risk exposure. Unfortunately, dependable – and quantitatively comparable – information on natural catastrophes often goes back barely 100 years. It would be entirely possible for no extreme event to have occurred during this period, or for such an event to have struck a sparsely populated area when it could just as easily have struck a nearby city.

If a re/insurer is to arrive at a realistic assessment of the risk, a representative selection of all possible events has to be simulated in the hazard module. As the range of historical events we have at our disposal is insufficient, the assessment needs to be reinforced by scientific research on the genesis and dynamics of natural hazards. On the basis of the known historical events, thousands of additional hypothetical events are generated by varying particular parameters, (eg geographical location, intensity, etc). Whilst these artificially generated events never actually took place historically, there is – from a scientific point of view – no reason why they should not occur at some point in the future. The characteristics of all of these simulated events – the so-called "event set" – must resemble those of historical precedent, unless there are convincing scientific reasons speaking against this. The hazard module event set typically comprises tens or hundreds of thousands of events, which represent a model time frame of several thousands or several tens of thousands of years.

The task of constructing a reliable event set represents a major scientific challenge (see text box "Event set for tropical cyclones in the North Atlantic", page 19). However, this method offers several advantages over previous models where a hazard was defined on a regional basis:

- The probability that geographically distant areas will be affected by the same event can be modelled more accurately ("hazard correlation").
- The occurrence frequency of events of a given intensity can be clearly defined.
- Annual loss amounts can be estimated more reliably.
- Variable factors of exposure, such as "El Niño" conditions in the Pacific, can be taken into account.
- It is easier to calculate loss estimates more quickly following an event.

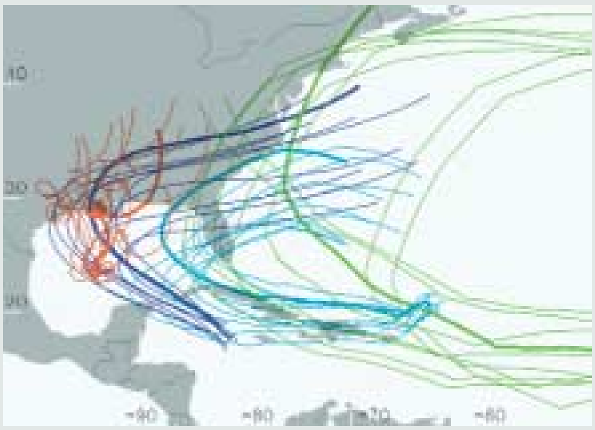
Tropical cyclones
Tropical cyclones are variously called hurricanes (North Atlantic/Caribbean), typhoons (Northwest Pacific) or cyclones (Indian Ocean, South Pacific).

Event set for tropical cyclones in the North Atlantic
To produce the probabilistic Swiss Re event set, cyclone activity covering a period of 50 000 years is simulated on the basis of statistical data and the dynamic development of tropical cyclones that have occurred in the North Atlantic over the past hundred years. Cyclones are generated that have never occurred in reality but could in the future.

The first step in generating the event set is to vary and store the paths of the historical cyclones using a *directed random walk* – a mathematical simulation process based on random numbers (*Monte Carlo* process). Both statistical and physical factors are taken into account to determine the build-up of atmospheric pressure and the subsequent intensification and decay of the cyclones. The life cycle of the cyclone as well as meteorological data on all historical cyclones are considered here. This step defines the storm paths and the pressure developments of the probabilistic cyclones. The next step involves simulating the surface windspeeds, which are crucial in determining the extent of the damage incurred. The strength of these wind fields is calculated by applying differential equations to meteorological data. Detailed surface and topographical information is also taken into account. Making allowance for the total life span of the cyclones ensures that the hazard correlation between different regions (ie the frequency with which a cyclone that strikes Cuba will also strike Florida) is simulated accurately. A so-called *annual occurrence* set is produced by randomly distributing the probabilistic event set across virtual model years.

Comparing the simulated and the historical climate data (eg frequency of various wind speeds) can test the validity of the artificially generated event set. When producing an annual occurrence set, it must be ensured that the distribution of probabilistic cyclones into Saffir-Simpson Intensity Scale categories and the cyclones' landfall characteristics correspond to historical records and/or the laws of physics. The validated event set – based on the latest scientific research – gives a reliable picture of exposure to cyclones in the Caribbean/North American region.

Figure 5
Historical "mother" (bold) and derived probabilistic "daughter" cyclones in the North Atlantic.



The intensity of each potential event in the hazard module must be known to be able to create a loss model. The intensity of a natural catastrophe depends on many factors and can be defined in different ways, depending on the approach taken. The aim of modelling natural hazards is to be able to assess the future loss burden; it therefore makes sense to choose an intensity measure that describes the characteristics of an event in a given location accurately and that correlates as closely as possible with the damage incurred.

Modified Mercalli Intensity scale (MMI) and Richter Magnitude
The force of an earthquake is often given in Richter Magnitude. This is a measure of the energy released by the quake. MMI, on the other hand, is a measure of the damage caused. Thus, an earthquake will have several MMIs which decrease the further one moves from the epicentre, but will only have one Magnitude.

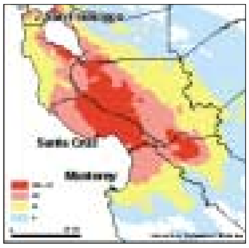
In probabilistic models, various parameters are taken into account when describing the intensity of events. In the case of earthquakes, for example, Modified Mercalli Intensity (MMI) scale or peak ground acceleration are used; in the case of windstorms, peak gust speed and sustained windspeed are taken into account; and in the case of floods, high-water levels, flow speed, amount of deposits and the duration of the flood are key measures of intensity. Historical data has shown that there is a close correlation between these intensity parameters and loss levels.

The intensity of an event generally decreases the further one gets from the "centre". With earthquakes, numerous factors such as the magnitude, the depth of the focus and the subsoil are considered when calculating the intensity of probabilistic events on the surface. The geographical extension of the various intensity classes across the earth's surface is known as the event "footprint" (Figure 6). It enables one to define – in the hazard module – the expected intensity of each probabilistic event in any given location.

Global hazard maps of natural perils may be regarded as highly concentrated illustrations of representative event sets. In addition to an interactive atlas of global hazard maps, Swiss Re offers clients and other interested parties a wide range of information on "CatNet" (*www.swissre.com*), including data on historical events and analyses of various insurance markets.

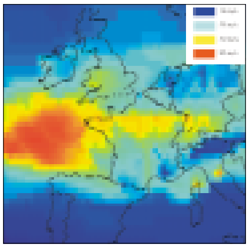
Figure 6
Illustrations of footprints resulting from earthquake, windstorm and flood, respectively. In the hazard module, such footprints are available for each probabilistic event and form the basis of the calculations in the subsequent modules.

Earthquake



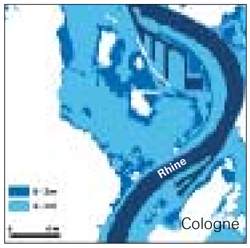
Footprint of the 1989 *Loma Prieta* earthquake in in California/US (MMI Scale)
Source: USGS

Windstorm



Footprint of the 1999 European winter storm *Lothar* (peak gusts)
Source: Swiss Re model

Flood



Footprint of a hypothetical Rhine flood in the area of Cologne/Germany
Source: Rhine Atlas, International Commission for the Protection of the Rhine (ICPR), 2001

3.3.2 Vulnerability module: How extensive will the damage be?

Each time a natural catastrophe strikes, it becomes clear that the amount of damage caused can vary enormously even in cases where the event intensity remains the same. The extent to which a building is affected may depend largely on its type of construction, age or height. Equally, when it comes to the contents of a building, the loss amount can vary considerably depending on whether the event strikes a china shop, an electrical supplier or a garden centre.

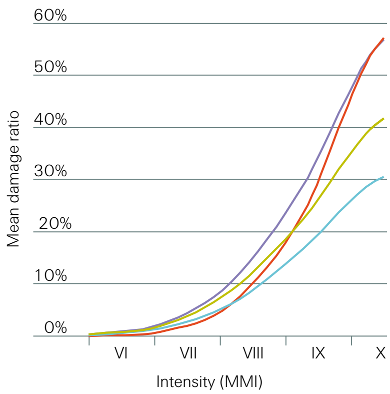
Mean damage ratio (MDR)
Ratio of the total loss amount to the total value of all insured objects (including loss-free insurance objects) in a given zone (expressed as a percentage)

Mean damage degree (MDD)
Ratio of total loss amount to the total value of the damaged insured objects in a given zone (expressed as a percentage)

The *mean damage ratio* (MDR) is therefore determined not only by the intensity of the event but – to a large extent – by the characteristics of the insured objects. The role of the vulnerability module is to define the mean damage ratio of various insured objects on the basis of the intensity of a modelled event. A large number of different vulnerability curves are thus stored in this module to illustrate the link between intensity and the mean damage ratio (Figure 7).

Clearly, when producing a model, it is not possible to analyse the characteristics of each and every insured object in detail. Therefore, objects are grouped into classes for which a common vulnerability curve can be used. For example, residential buildings would be grouped together in one risk class to produce one common vulnerability curve. A distribution around the mean damage ratio is used in order to allow for fluctuations in vulnerability within these categories resulting from quality of materials, ground plan symmetry, construction, and so on.

Figure 7
Typical earthquake vulnerability curves for:
- Residental buildings (single family)
- Residental contents (single family)
- Commercial buildings mix
- Industrial equipment and machinery



Loss vulnerability varies enormously between insurance lines (property, motor, etc), client segments (residential, commercial, industrial, etc) and insured interests (building, contents, business interruption). Individual vulnerability curves must reflect these fundamental differences in the various parts of the portfolio. Depending on the type of hazard concerned, it may be advantageous to break down the categories even further to produce more segmented vulnerability curves: eg dividing buildings into categories such as brick, wood, concrete and steel for the purposes of assessing vulnerability to earthquakes.

Ideally, vulnerability curves should be based on authentic loss data on as many events as possible, and the more recently these events happened, the better. As large, high-intensity losses occur infrequently, re/insurers often use technical and engineering data to aid them in their assessments.

Accurate vulnerability curves play a key role in the process of modelling natural hazards, even though significantly more attention is often paid to developments in the hazard module field. It is important to realise that all four modules impact the outcome of a loss assessment and that accurate vulnerability curves are just as important as a representative event set. It is in the interests of the whole insurance industry to conduct detailed loss analyses after major events, as these contribute to improving vulnerability curves and the overall quality of risk assessment.

3.3.3 Value distribution module: Where are the concentrations of value?

Data on the insured objects to be modelled must be available in the value distribution module. The location (intensity) and the type of insured object (vulnerability) are very important factors in estimating the expected loss; but in order to be able to put an amount on the loss, it is also necessary to know the value of the insured objects. Clearly, if a roof is torn off a barn, it will cost the insurer less than if the same thing happens to a luxury estate.

It is imperative for insurance companies to acquire accurate data on the whole insured portfolio ("accumulation control") to be able to reliably model natural catastrophes. There are several standards available for capturing and exchanging such data (eg CRESTA, UNICEDE).

CRESTA
Following what seemed then to be several unusually large earthquake losses in Central America, an organisation known as CRESTA (www.cresta.org) was founded by a group of re/insurers. CRESTA aims to raise awareness of the need to strengthen accumulation control and develop standards for data acquisition.

So-called CRESTA zones are now widely recognised as the global standard for the geographical breakdown of insurance data throughout the insurance sector. In some insurance markets, there has recently been a trend towards defining locations even more precisely (postcode, address), which is a welcome development. This kind of geographical detail is particularly relevant when it comes to modelling flood losses (see text box "Modelling river floods", page 24).

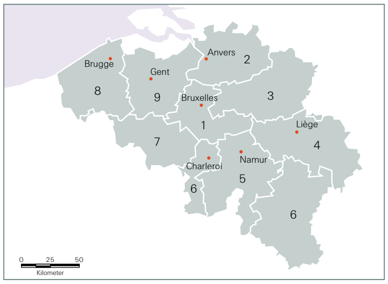
In addition to suggesting a breakdown into geographical areas, the CRESTA standard also contains recommendations for breaking down insurance data into various risk classes. These are generally based on business sector divisions common in the insurance industry and on the differences in vulnerability already mentioned (Figure 8).

It should be noted that, when it comes to running a loss model, it is always the *replacement cost* of the object that should be used, irrespective of the *sum insured* agreed upon. This is particularly relevant for commercial or industrial insurance objects where the *sum insured* is frequently lower than the total value (Figure 9).

Figure 8
This chart shows accumulation control data, ie the acquisition of data for an insurance portfolio. The map at the top right illustrates CRESTA zones for Belgium. The insured values are aggregated by CRESTA zone and are broken down into client segment and insured interests. If a model is to be reliable, limits and deductibles must complement this vital information. Accuracy can be further improved by providing data on the number of insured objects, on the quality of building materials, occupancy, etc.

Accumulation control

Country: Belgium
Natural hazard: Windstorm
Geographical breakdown: Aggregated data per CRESTA zone

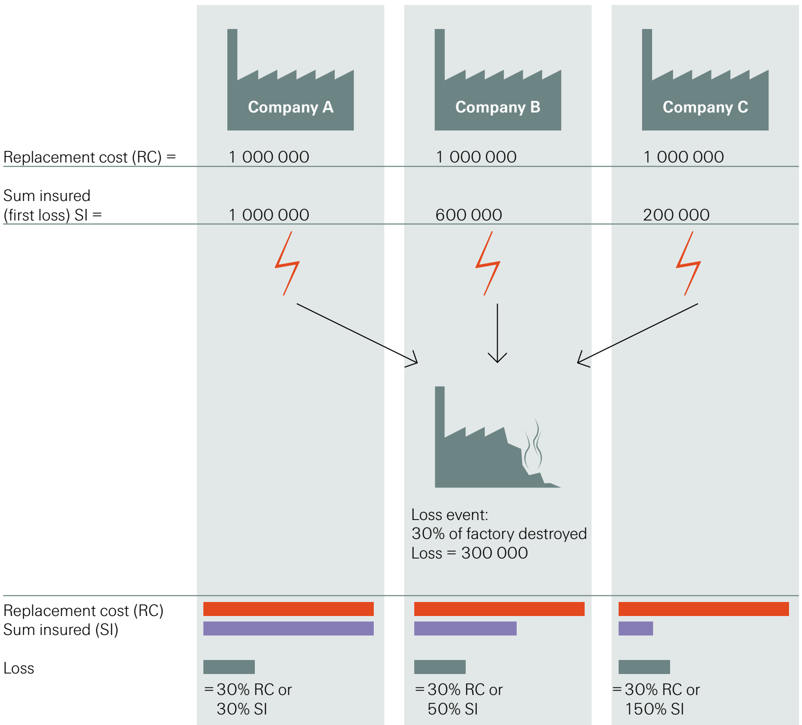


Agricultural
Industrial
Commercial
Residential

CRESTA Zone	Value Building	Value Contents	Value BI*	... Additional fields, eg number of insured objects, limits, deductibles, etc.
1	2304.57	451.88	0.00	....
2	456.78	106.23	0.00	....
3	396.45	70.80	0.00	....
4	299.93	76.91	0.00	....
5	1398.45	332.96	0.00	....
6	1103.29	204.31	0.00	....
7	932.30	198.36	0.00	....
8	304.42	63.42	0.00	....
9	102.23	23.23	0.00	....

*BI = Business interruption

Figure 9
This graph illustrates the difference between the replacement cost (RC) and the sum insured (SI). The three industrialists A, B and C own identical factories, but insure themselves differently (first loss insurance). A loss event causes a 30% loss on each of the buildings. It becomes clear that the ratio of loss to RC remains constant whilst the ratio of loss to SI varies considerably. This explains why it is essential to use the RC in the "value distribution" module if the loss model is to be accurate. An SI that is lower than the RC can, in some cases, restrict the loss (cf. Company C) and must therefore be given as a limit in the "insurance conditions" module.

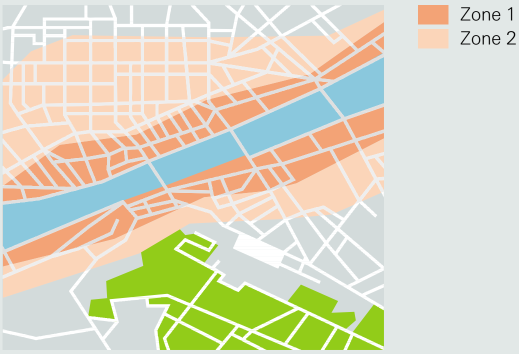


Modelling river floods
Topographical factors and a number of large and small-scale physical phenomena are responsible for causing and determining the course of floods. Regulation of river flows through human intervention radically alters river behaviour and flood risk. These factors make modelling flood hazards a highly complex task: so much so that for a long time insurers considered it impossible to produce accurate estimates for these risks.

Over the past two years, Swiss Re has collaborated with hydrologists, hydraulic engineers, statisticians, environmental experts and geoscientists to develop state-of-the-art risk analysis methods for flood hazards. All of these methods are based on extremely detailed, high-resolution digital terrain models. The most important developments include the following:

- A geomorphological regression method which – using a forecast model – is capable of calculating the probability of a flood occurring in each location (eg once per 100 years). These models, generated using non-linear statistical methods, are based on terrain characteristics which can be derived from a digital terrain model. With the help of geomorphological regression, it is possible to determine zones that are exposed to flood in any given country (Figure 10). This exposure information can then be used directly for the purposes of risk selection and pricing.

Figure 10
A map showing flood exposure generated using a geomorphical regression method. In Zone 1, the probability of a flood occuring is once in one hundred years; in Zone 2, the probability is once in two hundred and fifty years.



- A probabilistic model which allows the re/insurer to simulate the full spectrum of possible flood events whilst taking account of the extreme value distributions of individual hazard parameters calculated by scientists. Series of drainage and water level measurements accumulated over many years are used in conjunction with *Monte Carlo* techniques to generate thousands of new hydrological events. Hydrodynamic simulation software is then used to calculate the flooded areas for each of these hydrological events (Figure 11). In turn, these flood maps can be read into a tailor-made application and merged with insurance portfolios to produce loss frequency curves.

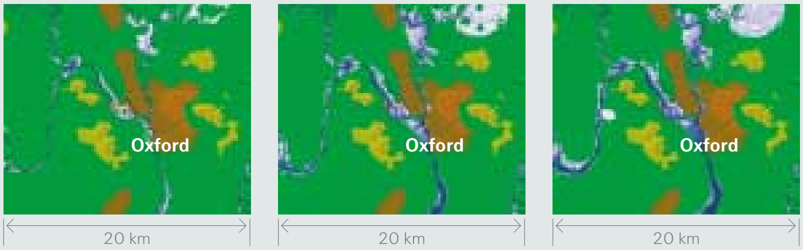


Figure 11
Development of flood areas over time in the region of Oxford, UK in the course of a probabilistic flood event. (The progression from light blue to dark blue indicates the rising water levels.)

Due to this and other technical innovations, it is now possible to predict flood risks and thereby fulfil the key condition of insurability. However, all of this depends on the availability of high-resolution location data on the insured risks: a couple of meters difference in altitude can radically alter the flood exposure of an area, even over short distances.

As far as insurability is concerned, the principal of mutuality as well as assessability plays an important role. A risk community has to be formed in order for a risk to be spread. If flood cover is voluntary, it will only be purchased by those who perceive themselves to be at high risk. This means that it is only possible for a small – albeit highly exposed – risk community to be formed. This effect is known as "adverse selection" and requires insurance premiums to be very high in order to cover the losses of this small, high-risk community. This, in turn, has a negative impact on demand.

The problem of high premium rates resulting from adverse selection can only be solved by expanding the size of the risk community, eg by bundling flood with fire and/or other natural hazard covers and by excluding low-quality risks. Swiss Re summarised possible ways of dealing with this problem following the European floods in August 2002 in a Focus Report entitled "Floods are insurable!" (*www.swissre.com*).

3.3.4 Insurance conditions module: What proportion of the loss is insured?

Insurance conditions, including deductibles and limits, are important tools allowing the re/insurer to keep its share of any loss within reasonable limits. These tools have two key effects: firstly, they restrict the amount the re/insurer is liable to pay in the event of a loss; and secondly, they reduce the re/insurer's administrative burden by avoiding the need to process large numbers of minor claims (Figure 12). Thus the amount the insured has to pay by way of premium can be reduced and limited insurance is made affordable in certain markets where cover might not otherwise be possible. Hence, the function of the insurance conditions module is to calculate the insurer's net loss on the basis of the ground up loss.

Conditions vary according to the market, natural hazard and insurance object. The conditions most commonly applied include:

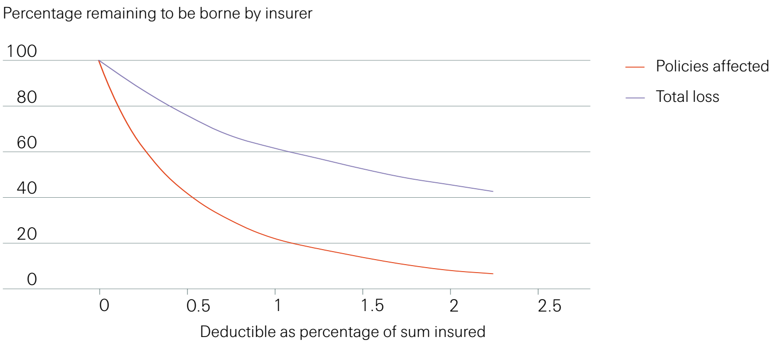
Deductibles	– Percentage of the sum insured – Percentage of the loss (also known as "coinsurance by the insured") – Fixed amount – Franchise (Losses below the franchise amount are not reimbursed. However, losses that exceed the franchise are reimbursed in their entirety, ie without any deductions.)
Limits	– Percentage of the sum insured – Fixed amount

These insurance conditions may apply to an individual insurance cover (eg on a building) or to several insured interests in the same location (eg building, contents and business interruption combined). In the case of a global corporation, for instance, they may also apply to the sum of all insured interests in various locations.

Furthermore, certain conditions may involve a time component (eg annual loss limits) or location/hazard-specific event limits (eg "California earthquake" limit). As insurance conditions are able to be set in a wide variety of different ways and can have a major impact on the insured loss, it is vital – for the purposes of accumulation control – to ensure that this data is acquired correctly.

In addition to sharing the loss burden with the insured, the insurer may use other techniques to limit the loss potential of individual risks, such as facultative reinsurance or proportional coinsurance with other insurers.

Figure 12
Even minimal deductibles have a significant impact on the insurer's loss burden. No less important is the fact that such deductibles dramatically reduce the number of claims that need to be processed. Insurers are often faced with a mass of small claims where the amount of administrative effort required is disproportionately large compared to the actual size of the losses incurred. This is particularly true in the wake of major loss events. As deductibles reduce costs (and therefore insurance premiums) as well as processing times, they benefit the insured as well as the insurer.



3.3.5 Combining the four modules

The last step in the loss-modelling process involves combining the four modules outlined, namely: hazard, vulnerability, value distribution and insurance conditions. This enables the re/insurer to provide answers to the questions raised at the outset regarding expected annual loss and measurement of extreme event losses. The results of a loss analysis are frequently shown in the form of a *loss frequency curve* (LFC). Each of the four modules can influence the results of the model dramatically. In other words, the final outcome is only as strong as the weakest link in the module chain.

When modelling natural hazard losses, the hazard module is generally defined and cannot be altered by the user. Likewise, standardised curves are usually prescribed for the vulnerability module. However, the value distribution and insurance conditions of the portfolio to be analysed must be entered by the user.

From this point on, the computer functions like a time-lapse film camera. The entire event set of the hazard module – representing a period of several thousand years – is virtually applied to the whole portfolio. Using the remaining modules, an event loss is estimated for each of these events (see text box "Models and uncertainty".) This process produces a list detailing all of the relevant portfolio's expected event losses for the modelled time period (see "Example of a natural hazard model, Part I", page 30).

Models and uncertainty

Models are nothing more than simplified representations of reality, and uncertainty will therefore always play a role. This is also true of the natural hazard models presented in this brochure.

First of all, there is uncertainty about whether the event set really gives a representative picture of the hazard (*hazard uncertainty*). Let us assume that the fundamentals are accurate and that a probabilistic event really does occur. Due to many factors, the event loss would vary depending on the time of occurrence (*loss uncertainty*). Taking this into account, the models arrive at more than one event loss per event. The key parameters are represented as a probability distribution, thereby producing a distribution of event losses. This ensures that even the more unlikely scenarios are taken into consideration in the model.

Loss uncertainty means that the loss arising from a real event can differ from the expected value calculated using the model. However, the average of all modelled event losses *will* correspond to the real risk, provided the hazard, vulnerability and insurance data are correctly reflected in the model.

Volcanic eruption: In January 2001, the Nyiragongo volcano in the Democratic Republic of Congo erupted. A few hours later, streams of lava cascaded through the town of Goma, destroying everything in their path. The loss potential of some of the world's approximately 1500 active volcanoes is enormous, but many of them are not monitored with sufficient care.

Example of a natural hazard model
Part I – Using risk assessment tools to calculate event losses

The following is an analysis of an insurer's hypothetical portfolio containing 1000 insured buildings – representing a sum insured of 1000 million – in an earthquake-prone region. For the sake of simplicity, let us assume that the risk assessment tool only contains 12 potential events over a projected period of 200 years. The following calculations would be performed:

a) The hazard module generates the expected intensity for event no.1 and building (or location) no.1.

b) The vulnerability curve corresponding to the building then shows the insurer which mean damage ratio (MDR) this intensity will inflict on the building.

c) The ground up loss is calculated by multiplying the MDR and the value of the building.

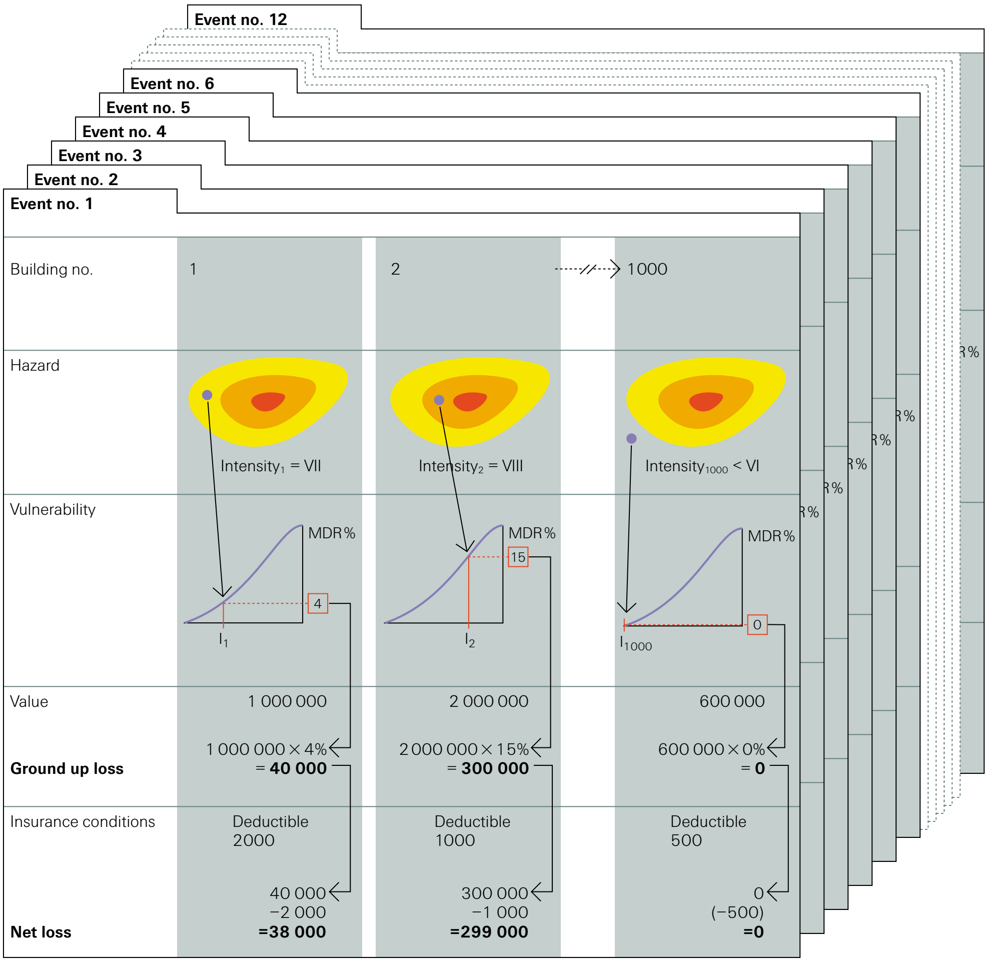
d) The insurance conditions are then applied to this ground up loss figure. The result is the net loss of the insurer for building no.1.

e) Steps (a)–(d) are performed on all buildings in the portfolio. The sum of all losses produces the total loss from event no.1, ie event loss no1.

f) Steps (a)–(e) are performed on all the other events in the event set. Upon completion of all these stages in the modelling process, a list of all event losses is produced. Parts II and III of this example explain the subsequent stages in processing this information.

It should be noted that event sets must comprise a large number of potential events and extensive time spans if they are to be implemented successfully, and that this simplified example is used merely for the purposes of illustrating methodology. Quoting any specific currency has been deliberately avoided.

Figure 13
A diagram of the loss modelling process



Event loss											
No. 1 =	(38 000	+	299 000	+	… …	+	… …	+	0)	=	23.5 m
No. 2 =	(0	+	25 000	+	… …	+	… …	+	54 000)	=	42.5 m
No. 3 =	(75 000	+	36 000	+	… …	+	15 000	+	0)	=	74.8 m
No. 4 =	(0	+	0	+	… …	+	… …	+	63 000)	=	8.9 m
No. 5 =	(… …	+	… …	+	… …	+	… …	+	… …)	=	13.1 m
No. 6 =	(… …	+	… …	+	… …	+	… …	+	… …)	=	69.6 m
No. 12 =	(0	+	0	+	… …	+	… …	+	63 000)	=	58.6 m

The list of event losses allows the re/insurer to calculate the expected annual loss arising from the modelled hazard for the portfolio in question. To do this, all event losses are aggregated and divided by the number of projected model years. This process provides the re/insurer with the basic information needed to calculate the amount he must incorporate into the premium to cover future losses in the long term. The largest modelled event losses give the re/insurer an idea of the loss amount it could be liable to cover in the event of an extreme catastrophe scenario. There are a number of reasons why it does not generally make sense for a direct insurer to cover the risk of extreme event losses with its own financial means. As explained in Section 4, it is advisable to transfer such risks, eg to a reinsurer. The event losses that have been calculated are frequently displayed in the form of a loss frequency curve in order to decide at what point (ie loss amount) this risk transfer should be effected (see "Example of a natural hazard model, Part II", page 34).

The simplest way to produce an *event loss frequency curve* is to order all the event loss amounts from the largest to the smallest. As the probabilistic event set of the hazard module represents a specified period of time, a return period (or an annual occurrence frequency) can be assigned to any loss level desired. An *annual loss frequency curve* can be generated by distributing the event losses across virtual model years.

The loss amount considered as a risk measure for an extreme event loss can be deduced from the loss frequency curve. This amount can be defined in various ways, depending on the way the question is formulated. The terms EML (*estimated maximum loss*) and MPL (*maximum possible loss*) – derived from fire insurance terminology – are frequently used in natural hazard insurance. However, the so-called *shortfall* provides a more comprehensive picture of extreme event loss risk and is therefore the preferable way to measure risk. (see text box "Gauging the risk of extreme event losses: EML, MPL and shortfall", page 33). The size of extreme event losses is an important factor in deciding on the scope of the desired reinsurance coverage.

Once an appropriate reinsurance cover has been set using the loss frequency curve, it is possible to calculate – for each of the modelled event losses – which proportion of the loss is to be borne by the direct insurer and which by the reinsurer. The list of event losses thus provides a transparent and comprehensible basis upon which to structure and price re/insurance covers (eg CatXL, stop loss) or alternative risk transfer (ART) solutions (eg cat bonds).

Gauging the risk of extreme event losses: EML, MPL and shortfall

Similar to definitions used in fire insurance, the terms EML and MPL are defined as follows in the natural hazards field:

- EML: The loss resulting from a large event in an area with a high concentration of value in the insurance portfolio. The setting of the EML depends on many factors and normally involves a loss with a return period of between 100 and 1000 years.
- MPL: The loss resulting from the largest possible event in the location with the highest concentration of value in the insurance portfolio (worst case).

Both EML and MPL only provide a snapshot estimation of the expected financial burden arising from extreme natural hazard events, and may therefore be somewhat one-sided. Swiss Re prefers the "1% shortfall" method of gauging extreme event losses. This is defined as follows:

- 1% shortfall: The average annual loss in the worst 1% of loss years, minus the expected annual loss of all years.

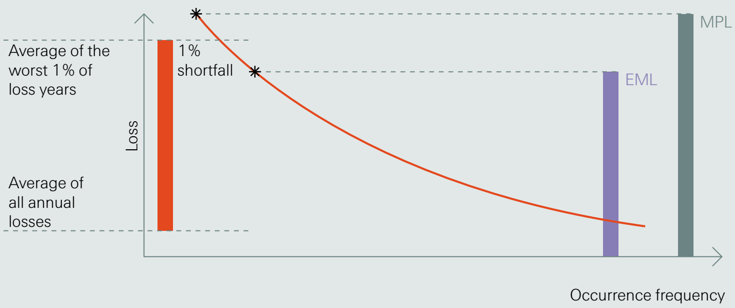


Figure 14
Representation of EML, MPL and shortfall on a loss frequency curve. EML and MPL each only reflect a single point on the curve. The calculation of the shortfall, however, takes account of all rare, large-scale events (in this case, all those with a return period of >100 years) and therefore offers a more reliable method for gauging the risk of extreme event losses.

Example of a natural hazard model

Part II – From the list of event losses to reinsurance

The following complete list of all event losses has been taken over from the event set used in Part I (see page 30):

Event loss	*in millions*
No. 1	23.5
No. 2	42.5
No. 3	74.8
No. 4	8.9
No. 5	13.1
No. 6	69.6
No. 7	20.8
No. 8	33.4
No. 9	17.4
No. 10	11.2
No. 11	26.2
No. 12	58.6

The expected annual loss may be calculated by aggregating all event losses and dividing them by the number of model years:

Sum of all event losses	400	million
Number of model years	200	years
Expected loss per year	2	million

The expected loss is often expressed in per mille of the sum insured:
2 m per year/1 000 m = 2‰ per year

A loss frequency curve is created in order to assess extreme event losses and determine an appropriate reinsurance level. In this process, the event losses are sorted according to size. The link between loss amount and loss frequency can be calculated in the following way:

- A loss of 74.8 million or more will occur once in 200 years. This translates to an occurrence frequency of 0.005 per year.

- A loss of 69.6 million or more will occur twice in 200 years (or once in 100 years). This translates to an occurrence frequency of 0.01 per year.

- A loss of 58.6 million or more will occur three times in 200 years (or once in 67 years). This translates to an occurrence frequency of 0.015 per year.

Let us assume that a direct insurer wishes to protect itself against large losses with a return period between 50 and 100 years and is therefore only prepared to assume losses up to 50 million. The direct insurer covers itself against loss amounts exceeding this figure by means of reinsurance.

In the case of the event losses used in this example, reinsurance cover would be triggered three times:

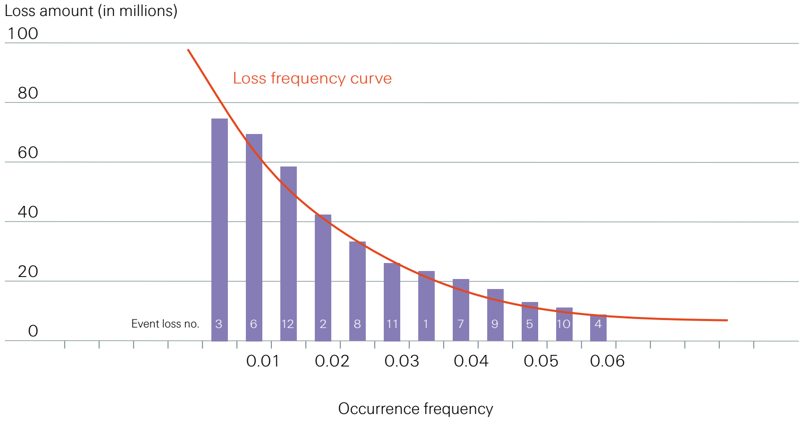
- Event loss No. 3:
  74.8 million – the reinsurer would assume 24.8 million
- Event loss No. 6:
  69.6 million – the reinsurer would assume 19.6 million
- Event loss No. 12:
  58.6 million – the reinsurer would assume 8.6 million

Event loss No. 3	24.8 million
Event loss No. 6	19.6 million
Event loss No. 12	8.6 million
Loss covered by reinsurance:	53.0 million

The expected loss for the reinsurance treaty would therefore amount to:
53 million/200 years = 265 000 per year

The expected loss for this reinsurance treaty – 265 000 per year – is a crucial factor in determining the premium rate. In the third and final part of this example, the additional costs the reinsurer takes into account when calculating the premium for this reinsurance coverage are illustrated.

Figure 15
Loss frequency curve of the event losses Nos. 1 to 12, used in the example.



3.4 Conclusion and outlook

Today, probabilistic loss models of natural hazards are based on computer simulations of a large number of potential loss events (event set). Event losses are estimated by combining the four elements of hazard, vulnerability, value distribution and insurance conditions. A probabilistic, event-based loss model produces a list of event losses that is representative for the portfolio in question. This forms a basis for estimating average and extreme loss burdens and can be displayed in the form of a loss frequency curve.

Substantial progress has been made in assessing the loss potential of natural hazards over the past few decades. Several commercial providers, brokers and reinsurers have developed software tools for modelling natural hazard insurance losses. Swiss Re uses its own probabilistic modelling programmes for natural hazards such as earthquake (global), tropical cyclones (global, including storm floods), winter storms (Europe), floods (selected markets) and hail (Central Europe). Using the same hazard and vulnerability data, it is possible to model aggregated portfolio data (*aggregated modelling*) as well as individual insurance objects (*detailed modelling*) (see text box "Single risk evaluation vs portfolio risk evaluation", page 37).

There are, however, several areas in which the quality of natural hazard modelling could be improved. As far as exposure to natural hazards is concerned, historical data on the risk areas are generally already well documented and accessible to the public. Progress may be made as a result of improved numerical models (eg development of a windstorm event set using dynamic models of the atmosphere). If it becomes possible in the near future to acquire more reliable forecasts of temporal hazard shifts (eg time dependency of earthquake hazards), this information may also be integrated into models. Furthermore, any correlation between various natural hazards (eg storm and flood losses) should also be taken into consideration.

As regards vulnerability, little data is publicly available, and access to such information is crucial to the creation of reliable risk models. As large loss events occur rarely, vulnerability curves are often not backed up with sufficient real data. It is therefore in the interests of both insurers and reinsurers to acquire high-quality data in the wake of future events, as this will improve the accuracy of loss models. There is often considerable room for improvement in the quality of insurance data used for natural hazard modelling: improvements should be made in the accuracy and quality of information on the location, value, risk characteristics and insurance conditions of insured objects, as well as to the ability of computer programmes to process this data correctly.

From an underwriting perspective, it would make sense to place the event sets of all relevant natural hazards on a shared platform. This would contrast with the current trend of separating models into individual natural hazard categories (earthquake model, windstorm model etc) and would make it possible to evaluate any combination of insurance covers (eg "all risk" covers) more effectively. Up until now, the computer programmes used to model natural hazards have, to a very large extent, been designed with property insurance in mind. However, there are indications that – depending on the potential exposure – it might become standard to integrate other lines such as motor, marine and CAR/EAR or life insurance into such models. Having developed its own programmes, Swiss Re is well positioned to respond rapidly to new requirements.

Single risk evaluation vs portfolio risk evaluation
In principal, the same method is used to determine the expected loss whether one is dealing with an individual risk or an entire portfolio of aggregated individual risks; yet there are also certain important differences.

When modelling an event loss for aggregated individual risks in a given area (eg in a CRESTA zone), a loss distribution is produced on the basis of the loss uncertainty. However, as there will already be a certain levelling out between the individual insured objects within the zone, this distribution curve would be relatively gentle. With individual risks, however, there is no balance: the loss distribution is much more pronounced. It is particularly crucial to be aware of this principle when establishing the probability of total loss scenarios. A portfolio will never suffer a 100% loss in the event of a natural catastrophe; an individual risk, on the other hand, may very well experience a total loss.

When modelling individual risks, it is also important to ensure that the event set is sufficiently dense, ie that an appropriate number of events of all intensity levels are captured for each spot in the region under consideration. Clearly, this can be achieved more easily when dealing with areas containing an aggregation of insured objects (eg a CRESTA zone) than when dealing with a precisely localised individual risk.

Storms: Sun and sea make Florida an attractive place to live, and, not surprisingly, the state's population has grown significantly. Less attractive, however, is the huge cumulative loss potential associated with the tropical cyclones (hurricanes) that frequently lash Florida and the Caribbean islands.

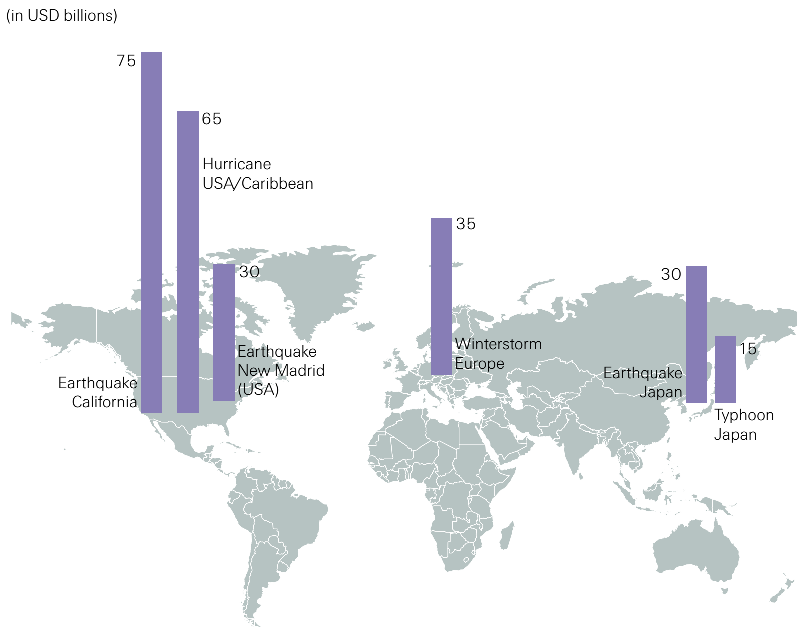
4 Some aspects of reinsuring natural hazards

Although hurricane *Andrew* was the most costly natural catastrophe of all time – claims paid amounted to approximately USD 20 billion – potential event loss liabilities for the insurance industry are significantly higher.

4.1 Maximum loss potentials

There has been a general increase in the number of objects at risk due to rising population and insurance density, as well as larger concentrations of value and higher degrees of vulnerability. This, together with the possibility of even more formidable natural events (intensity, area affected), means that the insurance industry is potentially exposed to far greater event losses than those suffered in hurricane *Andrew*. Swiss Re uses its natural hazard models to monitor several dozen natural catastrophe scenarios around the globe and produces yearly assessments of their loss potential for the market as a whole and for its own portfolio. The largest scenarios would involve earthquakes and windstorms in the US, Japan and Europe (Figure 16). In the context of *insured* losses, the insurance density – eg the percentage of material assets insured against a given natural hazard – is a key factor to be considered alongside exposure. California is now the area with the largest loss potential: with insurance density currently at approximately 20 percent, a major earthquake in the Los Angeles area would cost the insurance industry an estimated USD 75 billion.

Figure 16
The insurance industry's largest potential event losses with a return period of between 100 and 500 years. (Earthquake Japan does not include claims that would be paid by Japan Earthquake Reinsurance Co, JER).



4.2 Reinsuring natural catastrophe risks

Policyholders, direct insurers, reinsurers, and in some cases the state: all carry some of the burden of natural hazard losses. The role of the reinsurer is generally to assume responsibility for covering rare but extreme event losses.

There are many reinsurance solutions designed to protect against natural hazards, though to detail all such covers would go beyond the scope of this brochure. When reinsuring entire portfolios (treaty reinsurance), so-called *proportional covers* are still quite common in many markets. In such solutions, the reinsurer assumes responsibility for a contractually defined percentage of all the losses.

However, *non-proportional covers* – especially so-called *catastrophe excess of loss* or *CatXL* treaties – are becoming increasingly widespread as they are designed specifically for natural hazards. In a CatXL treaty, the reinsurer agrees to indemnify the insurer – per event – for that portion of the loss amount (itself comprised of numerous individual losses), which exceeds a specified minimum (retention). The ceiling of the CatXL is known as the upper limit of cover (Figure 17). As CatXL reinsurance generally involves large sums of money, covers are frequently divided up into layers. Several reinsurers, in turn, often share the risk within each of these layers. In principle, a CatXL treaty can be triggered several times during one term (usually one year), however a maximum number of reinstatements normally restricts the sum.

Figure 17
Diagram of a CatXL treaty covering the loss portion between 50 and 75 million per event. Such a cover, for 25 million *in excess of* the first 50 million, is written "25 million xs 50 million" in insurance jargon.

a) The loss in Event A falls within the 50 million retention and must, therefore, be borne exclusively by the direct insurer.

b) The loss in Event B is between 50 and 75 million: the amount that exceeds 50 million is, therefore, borne by the reinsurer.

c) The loss amount in Event C exceeds the upper cover limit: the reinsurer is, therefore, liable to pay 25 million. The remaining loss amount above the upper cover limit falls to the direct insurer.

The premium demanded by the reinsurer for a treaty has several components. The event loss estimates – which are generated using natural hazard models and form the basis for calculating the expected annual loss for the desired cover – are important determinants of the premium rate. However, this value only reflects the sum required to cover the expected losses. In addition to this price component, the reinsurer must charge for its own internal and external costs (eg brokerage) and capital costs, as well as ensure an adequate profit margin (Figure 18). The impact of capital costs on natural hazard CatXL premiums may be seen to be far greater than on any other reinsurance treaties.

Figure 18
Components of a technical reinsurance premium for a CatXL treaty.

Expected annual loss
+ Administration costs
+ Capital costs
+ Profit margin
Technical reinsurance premium

4.3 Capital costs and allocation of capacity

Reinsurance cover
The difference between the retention and the upper limit of cover of a CatXL treaty

If a reinsurer were to conclude only one treaty, its underlying capital would have to be exactly equal to the maximum loss potential, ie to the total *reinsurance cover*. If, on the other hand, the reinsurer has several treaties which cannot all be affected by the same event, then the maximum loss potential and hence the necessary underlying capital is smaller than the aggregate of all reinsurance covers. This risk reduction is known as the “diversification” effect.

The most destructive natural hazards from the point of view of their loss potential – earthquakes, storms and floods – have different physical causes and are thus, to a large extent, independent of one another. In other words, an earthquake will not give rise to a storm. The only losses that seem to be correlated in some way are those from storms and floods. Furthermore, natural hazards are usually geographically independent of one another: an earthquake in the US does not trigger an earthquake in other areas of the world. Globally speaking, it would seem to be relatively easy to diversify natural catastrophes. And yet, in practice, this diversification proves more difficult to achieve, as the insured portions of natural hazard losses are concentrated in a few geographical areas worldwide.

In the highly volatile natural hazard sector, a global reinsurer must make every effort to achieve as broad a diversification as possible. Taking into account the profitability of the various markets, reinsurers attempt to optimise the structure of their natural hazard portfolios by managing their underwriting limits as skilfully as possible under the circumstances given. Diversification can be improved by underwriting business in other lines of business in addition to property.

The broader the diversification, the less likely it is that a large proportion of the treaties will suffer losses simultaneously. The underlying capital vis-à-vis the sum of all potential losses decreases as diversification broadens. This is precisely where reinsurers can be of benefit to direct insurers: by harnessing the reinsurer's greater diversification, the insurer can reduce the level of underlying capital it requires and therefore its cost of capital.

Swiss Re calculates the total underlying capital it needs – the so-called "risk adjusted capital" (RAC) – using a company-wide risk model, which takes the annual loss frequency curves for natural hazards into consideration, as well as curves from other insurance lines, and any interdependencies. On the basis of this Group-wide model, it is possible to calculate what proportion of the RAC will theoretically be blocked by each individual loss potential or reinsurance treaty, respectively.

Due to the high loss potential, a lot more RAC is blocked in natural hazard reinsurance – in proportion to the premium volume – than in other types of treaties. This capital must be available at all times to cover rare top loss scenarios that could strike at any moment. These funds are procured from the capital markets, and interest is charged on them as on risk capital. The capital cost charge, which is factored into the pricing of a reinsurance treaty, is calculated by multiplying the amount of RAC capital that the treaty binds by the interest on capital employed (see "Example of a natural hazard model, Part III", page 43).

Experience shows, however, that actual reinsurance premium rates frequently deviate significantly from the technical premium: that is, the sum of the expected annual loss, administration costs, capital costs and profit margin. These deviations are produced by the market, where the dynamics of supply and demand can lead to marked price cycles (see text box "Price cycles in catastrophe insurance", page 44).

Example of a natural hazard model
Part III – From expected loss to reinsurance premium

In Part II of the natural hazards modelling example, the reinsurance cover desired by the direct insurer involved an expected annual loss of 265 000.

Let us assume that this reinsurance cover consists of a CatXL layer 25 million xs 50 million (cf Figure 17) and that a single reinsurer has agreed to carry the entire risk. The reinsurer will request a premium that has factored in administration costs, capital costs and profit margin, in addition to the expected loss amount.

In CatXL insurance – which typically covers rare but extreme event losses – administration costs are generally relatively low. For the purposes of this example, the administration costs have been put at 1‰ of the cover, ie 25 000.

Administration costs
= 25 m (cover) x 1‰
= 25 000

When it comes to capital costs, however, things are quite different: High potential losses and limited possibilities for diversification mean that capital costs for the most dramatic scenarios (earthquake/hurricane in the US/Caribbean, windstorm in Europe, earthquake/typhoon in Japan) are sizeable. Let us assume that the portfolio discussed in Parts I and II, which is insured against earthquake, is located in Japan. The following parameters might be used to calculate the capital costs:

- Risk adjusted capital (RAC): 20% of the reinsurance cover
- Capital costs and profit margin (hurdle rate): 10% of the RAC

Or, expressed in figures:

Capital costs and profit margin
= 25 m x 20 % (RAC) x 10 % (hurdle rate)
= 500 000

The sum of the administration costs, capital costs and profit margin in relation to the cover is known as Loading on Line (LoL):

Loading on Line
= 525 000/25 m
= 2.1%

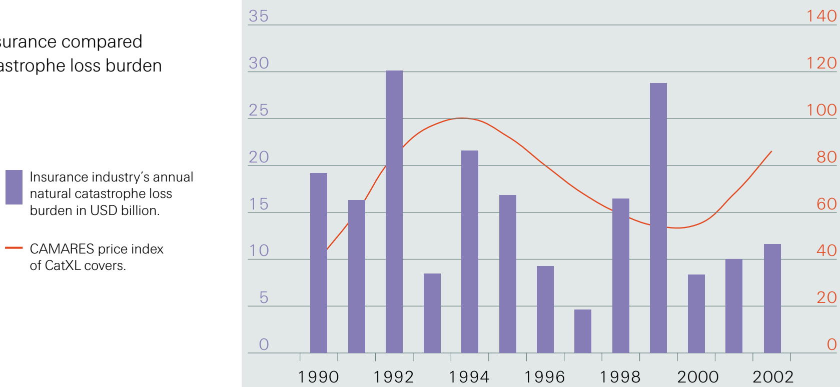
The overall technical reinsurance premium for earthquake CatXL cover of 25 million xs 50 million in this portfolio is as follows:

Expected annual loss	265 000
+ Administration costs	25 000
+ Capital costs + Profit margin	500 000
Technical reinsurance premium	**790 000**

This scenario, explaining how natural hazard modelling and reinsurance pricing work in this three-part example, is highly simplified and should under no circumstances be taken as representative for all reinsurance treaties. In particular, it should be noted that the ratio of expected annual loss to cover – and hence to capital costs – may be quite different, depending on how a CatXL reinsurance cover (retention and upper limit of cover) is structured.

Price cycles in catastrophe insurance
Reinsurance is influenced by price cycles. These may stretch over several years and are particularly pronounced in catastrophe insurance. An analysis of past cycles reveals that two key factors are responsible for influencing price developments: fluctuations in the global loss burden in the re/insurance industry, and the state of the financial markets. Both factors have a direct impact on the capital base of the companies affected. The correlation between loss burden and price can be seen clearly in catastrophe insurance for natural hazards (Figure 19).

Figure 19
Prices for CatXL reinsurance compared to annual natural catastrophe loss burden from 1990 to 2002.



CAMARES
CAMARES is Swiss Re's internal market study, which has been issued annually since 1994. As an analysis of CatXL business in 14 prime markets, CAMARES evaluates the key data of known reinsurance programmes and extrapolates it to 100% for all the respective markets.

The *hard market* phase in the early nineties was triggered by the severe loss burden resulting from hurricane *Andrew* and several winter storms in Europe.
Two factors should be noted here: on the one hand, losses erode the reinsurers' capital base, meaning that less capital is available to underwrite reinsurance covers; on the other, the demand for such covers increases as a catastrophe makes both direct insurers and insureds aware of the risks to which they are exposed. Further, their own capital base has been reduced and the necessity to minimise risks is therefore all the more acute.

This simultaneous occurrence of shrinking supply and rising demand causes prices to increase sharply. High prices induce investors to invest capital in the reinsurance business (eg Bermuda companies in the nineties). This, in turn, increases the supply of catastrophe covers and causes prices to stabilise once again. In the nineties, there were good returns on investments and no major catastrophes. This situation allowed reinsurers to offer premiums at prices below expected loss and costs. Direct insurers likewise had plenty of surplus capital and were therefore able to take on larger risks. This ushered in a period of low premium rates – the *soft market* phase.

The recent massive slump in the financial markets triggered a new shortage of supply from 2001. The new hard market was reinforced by the large loss burden in 1999 (*Lothar/Martin*, earthquake in Taiwan and Turkey, etc) and the attack on the World Trade Center (WTC) on 11 September 2001.

Landslides and rock avalanches: Landslides or rock avalanches do not have the broad geographical impact of earthquakes and storms, but can still cause enormous damage. Slope instability is often caused by prolonged periods of precipitation. As this scene in El Salvador (2001) shows, landslides can also be triggered by earthquakes.

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