Section 3:

Fundamentals of Nat Cat modelling

Estimated time: 20 min

Contents

Learning objectives

- Describe why and how to assess risk in re/insurance
- List the typical steps in the loss modelling process
- Interpret a loss frequency curve and exceedance probability curve

Nat Cat Losses, event loss, and modelling

By definition, a natural catastrophe is a major event produced by natural processes and causing significant adverse results. The natural cause of the event separates Nat Cat losses from attritional (NonCat) losses.

An event loss is defined as 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 events”. To identify a particular event as cause, it is common to apply an “hours-clause”, i.e. aggregate all losses within a certain period of time.

Swiss Re reports on global Nat Cat losses in its sigma studies on natural catastrophes and man-made disasters, published annually. As an illustrative example of sigma's focus, Figure 1 shows a time series of global insured catastrophe losses per year (adjusted for inflation). Even on this aggregate level, the large volatility of losses is evident. As indicated by the diagram, each year with exceptional losses can be related to one or more large catastrophic events. For a specific region or a single peril, the volatility is even much larger. Also, there is a clearly visible increase in insured losses starting in about 1990.

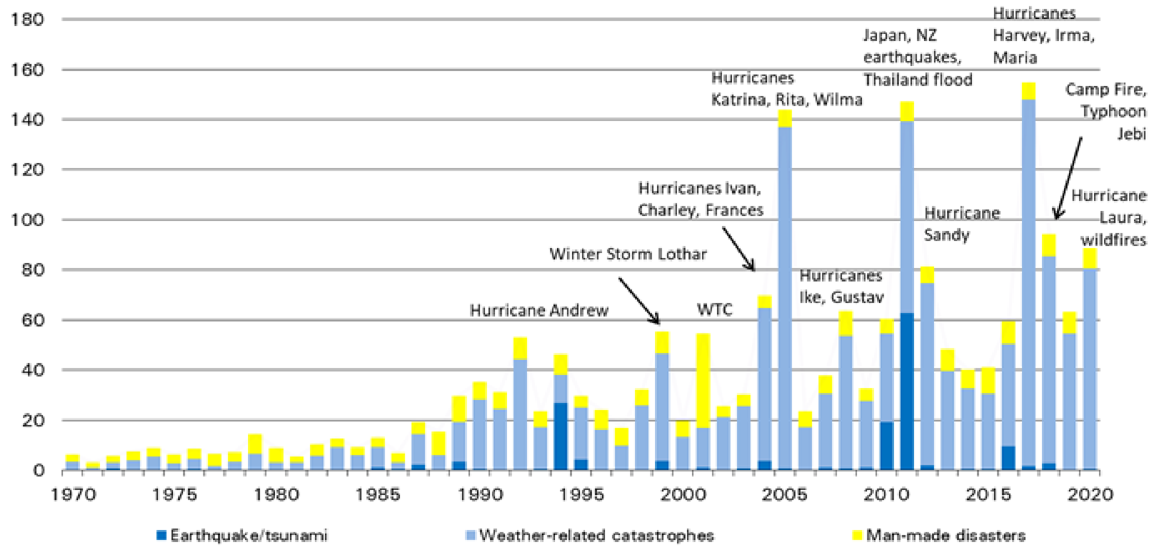

Figure 1: Insured catastrophe losses 1970-2020 in USD billion at 2020 prices. Source: (Sigma database, 2021)

The high volatility of losses, and the rareness of a large catastrophe of a specific peril in a specific region, prohibits insurers from assessing their risk from natural catastrophes purely on an experience-based approach with actuarial methods, as would be the case for other losses such as from fires.

Therefore, the insurance industry utilizes models based on scientific data and principles in order to quantify losses expected from natural catastrophes.

The correct assessment of potential losses due to a rare, yet possible catastrophe is vitally important to re/insurers. However, this task remains challenging, even with today's technology and scientific understanding. In the case of natural catastrophes such as earthquakes, floods or storms, however, the loss might be significant as a result of many policies triggered simultaneously. This makes the process of assessing extreme loss events much more difficult. The insurance industry is well advised to use scientific models to estimate the impacts of natural catastrophes.

Which type of modelling: deterministic or probabilistic?

The simplest way to assess the loss potential of an insurance portfolio is to simulate an individual natural catastrophe by applying a scenario to a portfolio. This is known as "deterministic" or "scenario-based" modelling. Such models often refer to major historical loss events and can be applied to the insured values that exist today ("as-if" analysis). This permits the assessment of a single, extreme, individual event loss. Combining loss estimates from a scenario analysis with a Pareto model allows us to derive loss cost metrics such as Annual Expected Loss or Loss To Layer. However, for deeper insight and analysis, a reinsurer needs to obtain a full range of potential event losses with associated probabilities.

To provide these insights, we use probabilistic modelling, an approach established in the early 1990s. These models are selected as a quantitative approach to assess the probability of a large set of possible outcomes that go well beyond the scope of observed historical events. This type of modelling produces a "representative" list of event losses (i.e. losses that accurately reflect 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.

Probabilistic modelling: The 4-box principle

Probabilistic Nat Cat Models are commonly designed in 4 modules (often called boxes), each addressing a specific aspect of the problem (see Figure 2: The 4-box modelling approach) . This 4-box concept is thoroughly discussed in a Swiss Re publication, (Cat Perils , 2003)

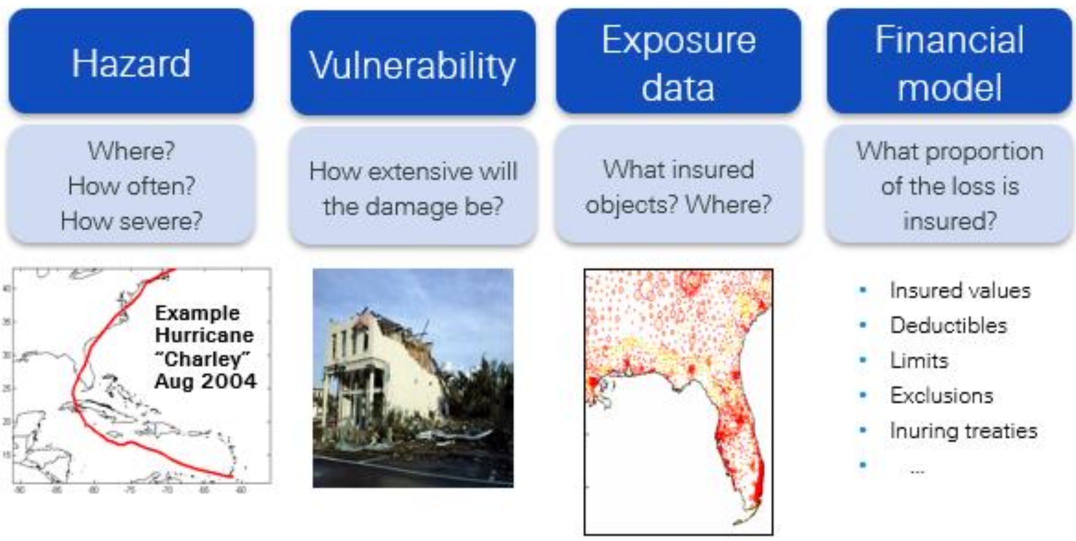

Figure 2: The 4-box modelling approach

Hazard: Where, how often, and with what intensity do events occur?

Vulnerability: What is the degree of damage expected for a given intensity?

Exposure: Where are the insured objects located and what are their values?

Financial module: What part of the loss is insured?

Hazard module: where, how often, how severe?

Historical Data:

Historical event catalogues of natural perils and scientific research into physical characteristics of natural phenomena are used as a starting point to quantify the main parameters of the hazard module. The further back a historical data series reaches, and the more complete it is, the more likely it provides a reliable reflection of the real risk. Unfortunately, reliable and quantitatively comparable information on natural catastrophes is often limited and rarely goes back several decades. Furthermore, it would be entirely possible for no extreme event to have occurred during a given time period, or for such an event to have struck a sparsely populated area when it could just as easily have struck a nearby city.

Event set

The length and richness of catalogues of historical events is limited and depends strongly on peril and region. A 100-year dataset on Tropical cyclones may contain 1000 storms, whereas 2000 years of earthquake history may result in a catalogue of only a few hundred large events. This exhibits another problem: while in the distant past only the largest events may have been reported, in more recent times the catalogue will contain smaller and smaller events as the breadth and quality of our observations improve. This observational bias complicates interpretation of historical catalogues. Therefore, the assessment needs to be supplemented by scientific research on the genesis and dynamics of natural hazards. Based on known historical events, many additional hypothetical events are generated by varying specific parameters (e.g., geographical location, intensity, etc.) based on e.g. climatological, physical or statistical insights and assumptions.

As a result, a probabilistic catalogue of events defined by location (e.g. tropical cyclone track, earthquake epicentre location, etc.) and parameters describing their significance (e.g. central pressure, magnitude, ...) is generated. This probabilistic catalogue will resemble statistical quantities of the observed history but extend to much more unlikely or extreme events.

For loss modelling, the effect of each event on the given exposure needs to be calculated. Depending on the peril, one or several parameters are chosen which describe the local intensity of an event and have a strong correlation with damage. Parameters commonly used include: Modified Mercalli Intensity or Spectral acceleration to quantify ground motion related to an earthquake, Peak Gust or Sustained Windspeeds to quantify the strength of the wind in a storm, etc.

Forecasting this intensity metric based on parameters of the source and specificities of the individual location is another building block of the hazard module. This task is typically addressed with the use of empirical equations describing the attenuation of intensity as a function of distance to the source, taking into account site specific factors (e.g. surface roughness for wind, subsoil structure for earthquake, etc.).

To make the event set applicable to any exposure, these parameters must be calculated in all locations affected by the event. The resulting map is known as the event footprint.

The example below illustrates how a storm footprint is created starting from the hurricane data of the U.S National Hurricane Centre wind catalogue. (NOAA, 2020)

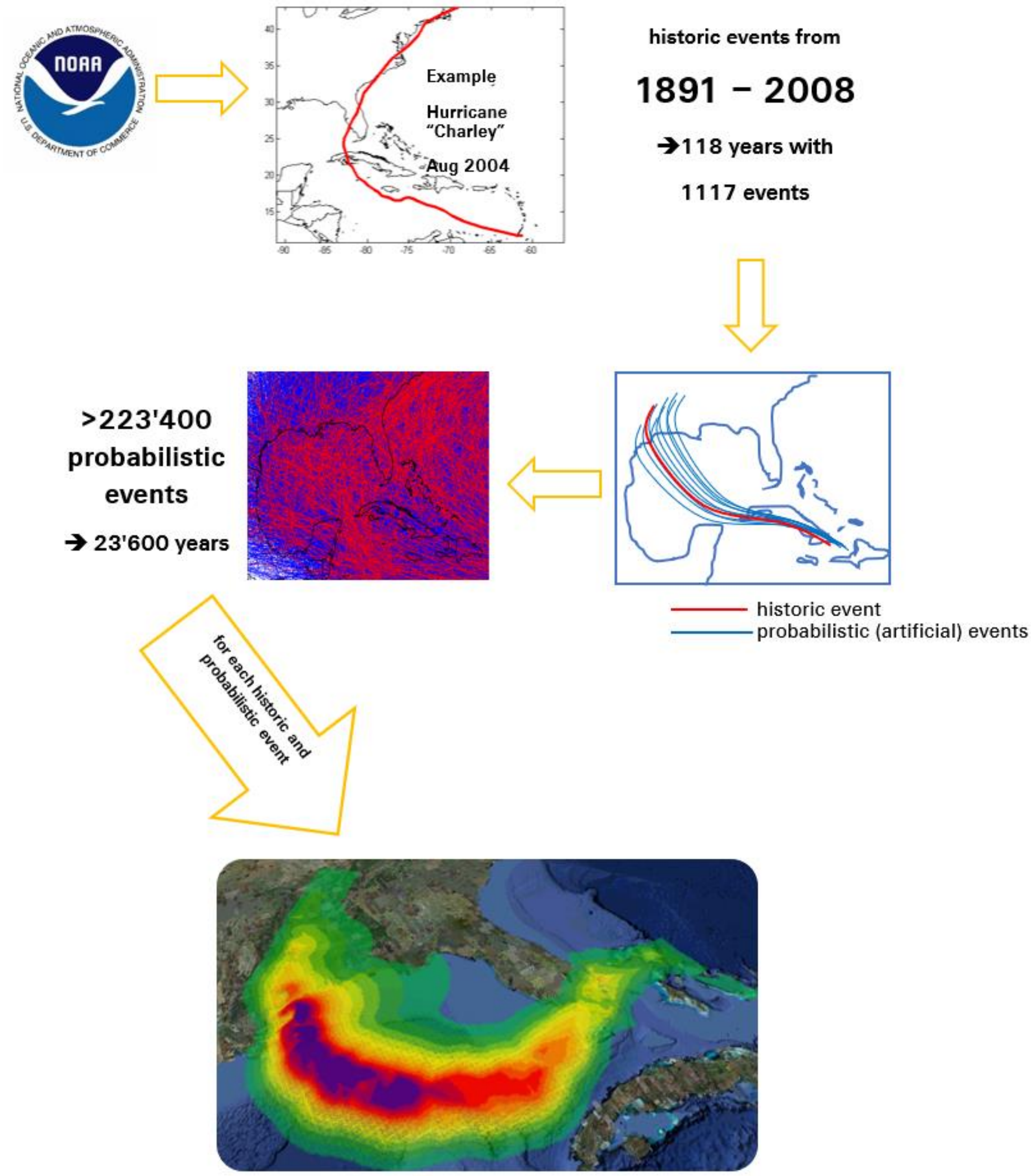

Figure 3: An example of a wind footprint that is created using historical data and probabilistic approach

Vulnerability module: how severe will the damage be?

When natural catastrophes strike, the extent of damage can vary significantly between two risks in locations which experience the same intensity. The damage to a building may depend on the type of construction, age, height, or other characteristics of the building. For example, a masonry building will behave very differently than a steel construction during an earthquake.

The task of building a generically applicable vulnerability module for a peril is hence twofold: a) classification of risks by main vulnerability parameters and b) quantification of the vulnerability (I.e. the variation of damage for varying intensity) for each class.

The knowledge basis for both tasks is a mix of claims information, damage observations, expert opinion and engineering knowledge.

Ideally, vulnerability curves should be based on authentic loss data from as many events as possible; and the more recent these events, the better. Large, high-intensity losses occur infrequently. For this reason, re/insurers often use technical and engineering data to aid them in their assessment. A general vulnerability curve is presented in Figure 4.

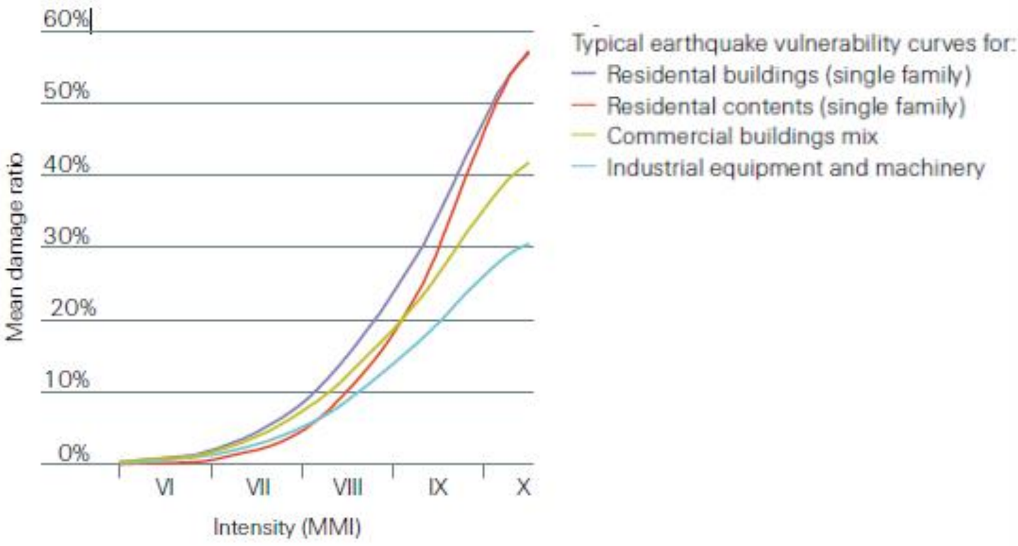

Figure 4:Typical earthquake vulnerability curves

The Mean Damage ratio (also known as MDR) is the 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. This value is therefore determined not only by the intensity of the event, but by the characteristics of the insured objects. The role of the vulnerability module is to define the MDR of various insured objects based on the intensity of a modelled event. The MDR is the product of two parameters:

- **MDD** which is the mean damage degree, and expressed as the ratio of total loss amount to the total value of the damaged insured objects in a given zone
- **PPA** which is the probability of a property/policy/portfolio/... to be affected. The PPA value is between 0 and 1. The PPA is usually used to scale the frequency of a loss. For instance, if an event with an occurrence frequency f of 1/10,000 years is simulated, and the PPA of a property is 0.5, then the chance to have a loss on this specific property from this event is 1/20,000 years, i.e. f * PPA

Representative vulnerability curves play a key role in the process of modelling natural hazards. Therefore, conducting detailed loss analyses after major events benefits the entire re/insurance industry, as these contribute to improving vulnerability curves and overall risk assessment quality.

Exposure: Where, what and how valuable

The input to all loss models is exposure data, which provides the model with the information necessary to run: WHAT peril, WHERE is the risk located, WHAT type of risk, HOW MUCH is its value. The principle aspects of exposure information are illustrated in Figure 5. The preferred input to a loss model is on a detailed latitude/longitude level with all the possible risk characteristics. However, exposure data of this granularity is not always available. In some markets, for example, only information aggregated by some geographic zone (i.e. Zip Codes, CRESTA Zones, etc...) may be available. Sometimes, the data is missing reliable information on construction details.

Figure 5: The principle aspects of exposure information.

The ability to handle various levels of data quality is an important feature of probabilistic risk models. To do so, the model needs to make assumptions on the aspects not covered in detail in the exposure data.

In the above example of geographically aggregated data, the model makes an assumption on the exact distribution of the values. This process is known as disaggregation and is illustrated in Figure 6.

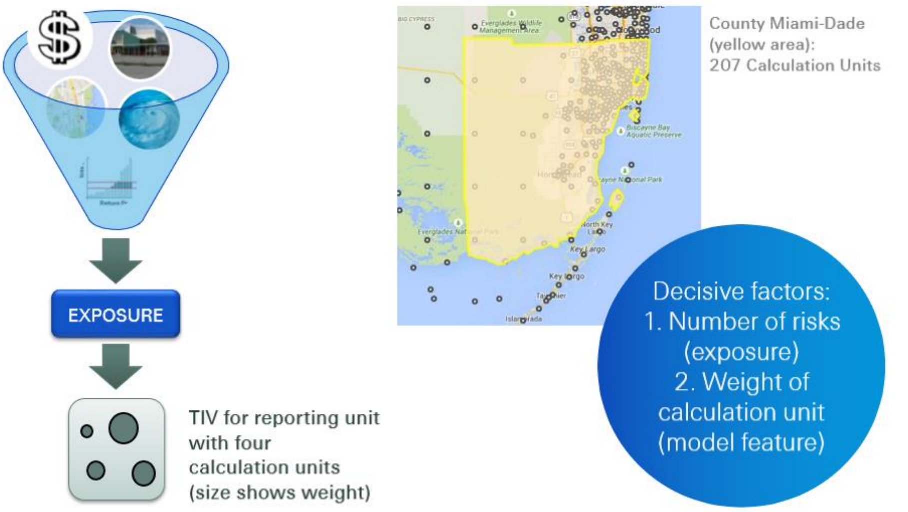

Figure 6: The process of disaggregation, to place the reported sites in the model world

Financial Module: what proportion of the loss is insured?

Insurance conditions, including deductibles and limits, are important tools that allow the re/insurer to keep its original loss within reasonable limits. These tools have two key effects:

- They restrict the amount that the re/insurer is liable to pay in the event of a loss
- They reduce the re/insurer's administrative burden by making it unnecessary to process large numbers of minor claims

Conditions vary according to the market, risk, and insured peril. The most frequently applied conditions include:

Deductibles:

- Percentage of 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, i.e. without any deductions)

Limit

- Percentage of the sum insured
- Fixed amount

Any combination of these conditions can be defined and applied on individual risks or groups of risks defined by common location or owner.

The purpose of the Financial Module is to calculate the insurer's net loss resulting from a given ground up loss (i.e. the loss for the owner of the risk). That is done by sampling the uncertainty distributions around the losses simulated in the previous three boxes and applying the insurance conditions to each sample individually. That way, the effect of any combination of the insurance conditions listed above can be adequately modelled.

Event set and loss frequency curve (LFC)

Calculating the expected loss of thousands of probabilistic events produces a list of event losses for the portfolio, which has the benefit that:

- It allows the re/insurer to calculate the expected annual loss.

- It provides the re/insurer with a loss-frequency distribution to estimate the impact of rare and extreme events (tail risks).

- It provides a transparent, easily understandable basis for structuring and pricing re/insurance covers (e.g., CatXL, stop loss) or alternative risk transfer (ART) solutions (e.g., cat bonds)

A set of modelled event losses can be translated into a loss-frequency curve by ordering all event losses from the largest to the smallest, see Figure 7.

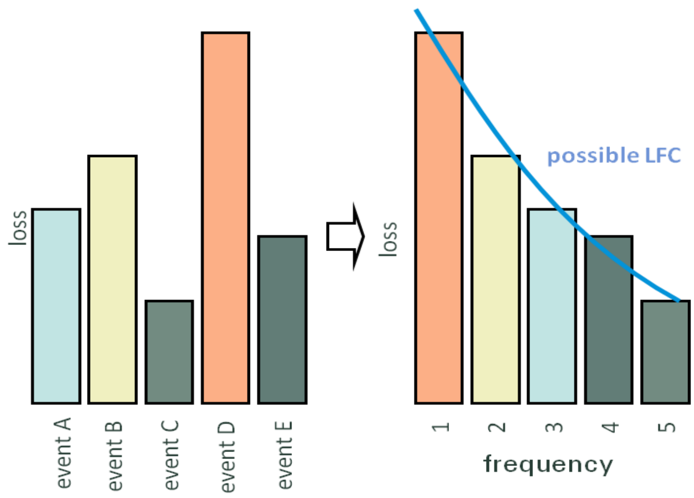

Figure 7: Event losses ranked by size to estimate the possible loss frequency curve (LFC).

The return period of any loss amount can be determined as each event has a designated frequency. The loss frequency curve (see Figure 8) provides the re/insurer a structure to select appropriate re/insurance programmes with adequate risk premium.

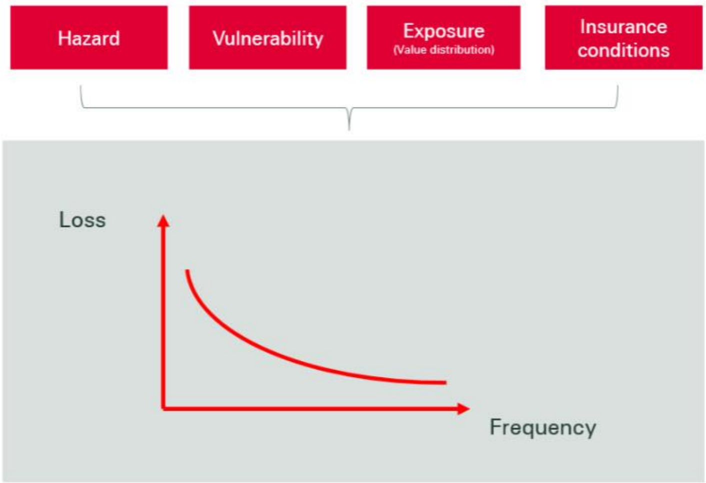

Figure 8: Loss frequency curve as the main result of combination of the four modules:

The 5th box

Natural catastrophe modelling is traditionally conducted within a 4-box-modelling framework – hazard, exposure, vulnerability, insurance conditions (e.g. Figure 9) that In recent years, unmodelled complex loss components have contributed to adverse loss developments, pushing Nat Cat losses higher than expected.

Some examples are listed below:

1) Litigious environment driving social inflation in Florida

Loss associated with 2017 hurricane Irma has reached a loss creep of 66% in Florida (21.8bn vs 13bn, Figure 10), partially due to assignment of benefit (AOB) lawsuits as well as proliferation of litigation (social inflation). Although AOB claims have decreased slightly in response to reforms passed in 2019, first party litigation and excessive attorney fees are still responsible for incentivizing inflated lawsuits against insurers.

2) Social awareness of subsidence claiming possibilities in France

In France, a CatNat declaration, proactively requested by a municipality, is required to file a subsidence claim. Declaration approval is based on geological and meteorological conditions. The recent increase in declarations (occurring in the vicinity of older declarations) cannot be explained solely by new drought patterns. A more likely explanation is the rising social awareness of this peril.

3) Storm Chasers/ Claims Advocates in Australia

After recent hail events in Australia (e.g. Queensland hail in April 2020), so called "storm chasers" have targeted people impacted by severe hail events. They claim to advocate on behalf of the policy holder to improve the insurance outcome. This is achieved by putting pressure on the insurers to provide a cash settlement, thereby inflating the volume of claims. Some of these (smaller) claims would not have been reported otherwise.

4) Claims awareness and temporal demand surge in Japan

Surprise losses were particularly large in Japan after the 2018 tropical cyclone events, e.g. Typhoon Jebi. This can be broken down into two components: 1) unexpected demand surge for building materials due to preparations for the Rugby World Cup in 2019 as well as the (then planned) Olympics in 2020; 2) elevated claims awareness in the Osaka region - where Jebi made landfall - in part due to the impact of social media that either facilitates claim filing or publicly shames insurers in difficult cases.

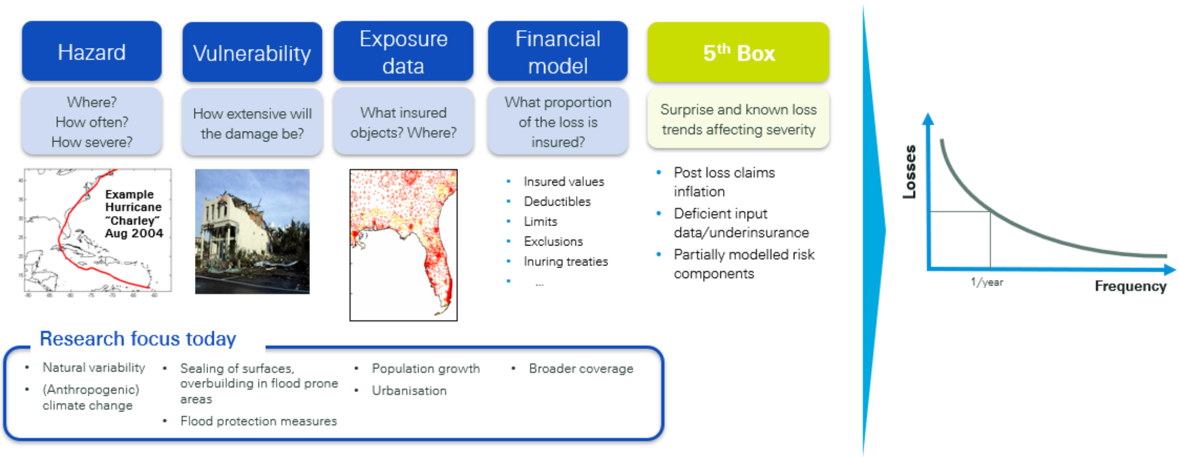

Figure 9: The 5th box in the context of Nat Cat modelling at Swiss Re

The 5th box is designed to improve our understanding of model limitations, thereby enabling underwriters to improve risk selection. It is designed to capture unmodelled loss components beyond the 4-box concept.

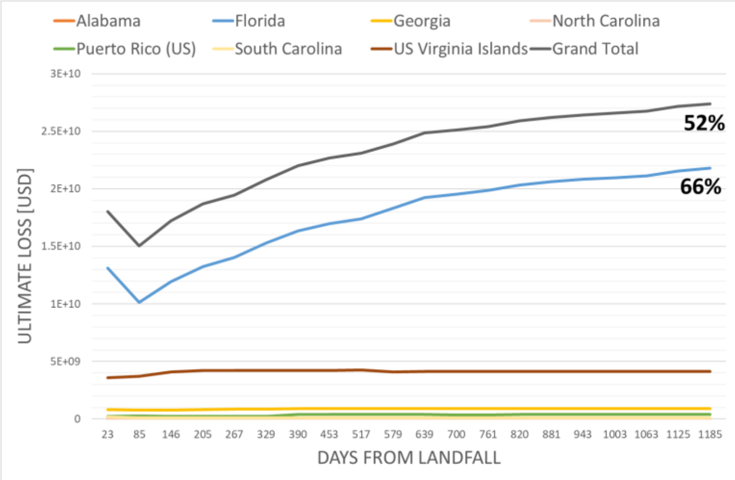

Figure 10: Irma Claims Development after landfall, source: (PCS, 2020), last access 15/01/2021)

Dissecting the 5th box

The fact that the 5th box factors have many dimensions makes it challenging to i) assess them in the first place and ii) quantify their respective impact on the loss. For that reason, we have decided to group the 5th box factors into five individual topics, distinguishing pre and post event features, as laid out in Figure 11.

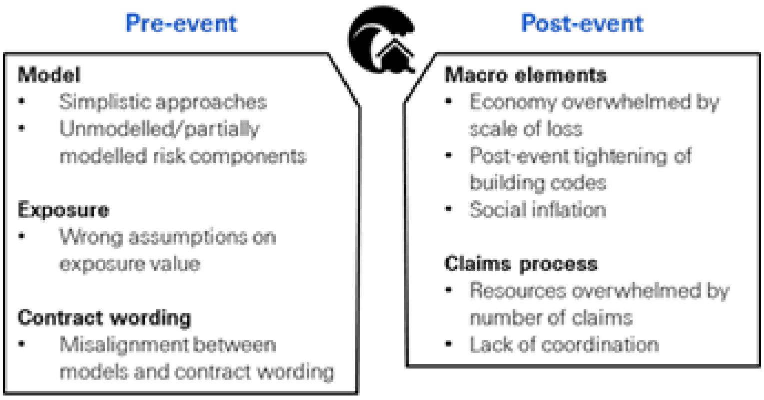

Figure 11- Factors contributing to adverse loss developments, source: (SRI, 2020)

The pre-event topics include everything that can be assessed prior to an event, such as:

1. "known" model limitations as a direct consequence of simplified approaches or limited data availability used to describe complex physical phenomena, such as secondary effects of primary perils (e.g. earthquake-induced liquefaction)
2. Invalid assumptions on exposure data that is provided by clients, such as underestimated reconstruction costs. This was the case in the 2010/2011 New Zealand earthquakes, where the replacement costs were almost three times higher than the insured value indicated in the policies.
3. misalignment between models and contract wording in the original insurance policy or in the reinsurance contracts

The post-event topics revolve around potential loss-intensifying factors that arise after a Nat Cat event has happened. These include:

4. Macro elements such as the socioeconomic environment, where physiological, social, institutional and cultural processes interact with natural events in ways that can heighten the risk.
5. Complicated claims handling process e.g. due to a lack of coordination between various players, or the presence of multiple policies on the same claim.

It is difficult to quantify individual factors as they range from insurance-related (e.g. wording) to rather exogenous factors (e.g. social awareness). Contrary to the other four boxes, the 5th box is less tangible.

It can be seen more as a framework that is consulted during every model development and review process. This does not necessarily mean that every new model is associated with 5th box effects; however, we want to make sure that we do not overlook any relevant factors.

Swiss Re's different types of Cat models

Swiss Re's model world covers major perils from wind and surge to flood, earthquake, and some secondary hazards. Cat models are built in either in-house or a within a vendor's software. Currently, there are only a limited number of modelling schemes available in the industry, and they follow very similar standards. Swiss Re developed (over the years) multiple "kernels" within which a model's losses are simulated. The different kernels of Nat Cat models used in Swiss Re are summarised in Table 1.

Table 1: Nat Cat models at Swiss Re

	Kernel name	**Characteristics**
1	km21	(Next Generation Models) since 2012 - Built for treaty and single-risk portfolios - Scientifically advanced - More granular
2	Classic	Older version (~2000-2010) built predominantly for treaty portfolios
3	BRK (Base Rate Kernel)	- No Stochastic event set - Designed for single-risk costing (used for the US pluvial flood and the US hail models)

Models and uncertainty

The process of Nat Cat modelling contains uncertainties and understanding and quantifying them are important.

The first type of uncertainty to consider is the uncertainty about whether the event set really gives a representative picture of the hazard, a so called "hazard uncertainty". Secondly, due to many factors, the event loss might vary, perhaps as a function of the time of occurrence, which is known as a "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 differs 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 accurately reflected in the model.

Section test:

1- An event loss is the sum of all individual losses resulting from multiple occurrences of different perils
   A. True
   B. False

2- Hazard intensity is perceived as one of the main parameters of the vulnerability module:
   A. True
   B. False

3- The disaggregation of insurance portfolios helps to better understand how much re/insurers are insuring within a specific area. This is essential for some perils associated with ---

   A. Earthquake
   B. Wildfires
   C. Flood and coastal hazard

Answers:

1- B
2- B
3- C

References

Cat Perils , 2003. *Natural Catastrophes and Reinsurance ,* Zurich: Swiss Re.

NOAA, 2020. *National Hurricane Center.* [Online]
Available at: https://www.nhc.noaa.gov/data/

PCS, 2020. *PCS Estimates of Insured Property Loss.* [Online]
Available at: https://www.verisk.com/insurance/products/property-claim-services/estimates-of-insured-property-loss/

Sigma database, 2021. *Sigma Research database ,* s.l.: Swiss Re.

SRI, 2020. *Swiss Re Institute.* [Online]
Available at: https://www.swissre.com/institute/