Natural catastrophe know-how for risk management and research

Many decades of acquired experience in researching, documenting, analysing and evaluating natural catastrophes have made the NatCatSERVICE one of the most valued data sources for information on natural loss events worldwide. This unique archive provides comprehensive, reliable and professional data on insured, economic and human losses caused by any kind of natural peril.

NOT IF, BUT HOW

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The NatCatSERVICE is a global database of natural catastrophe (“nat cat”) data. Since 1974, Munich Re has been systematically recording information on nat cat loss events from around the world. This unique archive has developed into one of the world’s most comprehensive databases for information on nat cat loss events caused by all sorts of natural hazards. The database entries begin with the historic eruption of Mount Vesuvius in AD 79. However, data deemed suitable for systematic and analytical evaluation on a worldwide scale are available from 1980 onwards. Currently, about 1,200 events are added each year. Annual loss data and significant loss event information have been published in “Topics Geo” annual reviews since 1994. The database forms the basis for a wide range of tools and services applied in risk assessment and risk management that not only concern the insurance and finance industry, but also the research communities and interested members of the public.
2. The database

2.1 Database structure and content

All nat cat events can be divided into events that only affect a single country and events that affect multiple countries, so-called region events. The NatCatSERVICE database contains event information per country and, in the case of region events, summarises the related country information into region event information. This concept makes it possible to perform analyses at a country level or regional (such as continental) level.

The NatCatSERVICE database systematically stores event loss information of the following kind:

- **Peril type** – What caused the loss?
- **Loss location(s)** – Where did the loss(es) occur?
- **Event period** – When did the event begin (first loss), when did it end (last loss)?
- **Event description** – What happened? What was damaged/destroyed?
- **Direct economic loss estimates** – All physical/tangible losses, expressed in monetary estimates (US$, EUR, local currencies)
- **Insured losses** – All paid-out insured losses through all affected lines of business (“market loss”)
- **Fatalities** – Number of people killed in the event
- **Source of information**

2.2 Data sources

Rigorous and systematic data sourcing and data mining forms the backbone of the NatCatSERVICE database. Surveys are carried out through internet queries of news portals, mailing lists, direct contacts to institutions, companies and offices that collect/provide regional or local nat cat information, and direct contacts to our international offices. Contradictory information from different sources is presented to our internal experts for re-assessment and the consolidated information is stored in the NatCatSERVICE database to ensure solid quality. The image below gives an overview of a selection of sources that are surveyed on a near-daily basis to gather worldwide nat cat information.
2.3 Peril classification

The peril classification of NatCatSERVICE loss events is presented in the following diagram. It is closely in line with the internationally standardised IRDR DATA “Peril Classification and Hazard Glossary” (2014), which can be found here: http://www.irdrinternational.org/wp-content/uploads/2014/04/IRDR_DATA-Project-Report-No.-1.pdf

The overarching category is the peril “Family”. It combines the types of hazardous “Main event”, such as perils originating in the Earth’s crust, different kinds of storms, different types of floods or a group of other weather-related perils, all of which in turn are compounds of “Sub-perils” that describe the physical forces that effectively cause the damage.

Each nat cat loss event is assigned to a “Main event” and one or multiple “Sub-perils”. The colour-coding is a guide for the most typical combinations of perils. Of course there are exceptions, for example a thunderstorm-triggered flash flood that overlaps with meteorological and hydrological “Sub-perils”. In consequence, the NatCatSERVICE analysis tool allows analyses on a “Main event” level and for selected meaningful “Sub-peril” combinations.
A nat cat event, such as a hailstorm, can cause losses at multiple locations. All location information is stored in two ways: the location name (name of a town, district or state) and the corresponding geocoded location expressed in geographic coordinates (longitude/latitude). Each event has an assigned main coordinate which corresponds to the most-affected/most-prominent location among all listed locations. Due to the format of the assigned loss data (see next paragraph), it is not systematically possible to divide the losses into actual share of loss for each of the affected locations. Such detailed information only exists for a very small number of (recent and well-documented) events.

The image shows a list of affected locations from a hurricane making landfall on the Texas coast near Houston. Losses also occurred in towns in other states besides Texas. All towns and the corresponding geographic coordinates are listed.
2.5 Loss data and loss estimation

Every nat cat loss event in the NatCatSERVICE database has an assigned direct economic loss expressed in nominal US$ values. Some events (where applicable) also include an insured loss. Depending on the affected area and severity of the event, the quality of available information that is needed for solid loss estimation can differ considerably. Sometimes there are official institutions that release loss estimates (either overall or insured or both), in many cases we have to come up with an estimate by ourselves. Our concept is to perform systematic loss estimations for all of the nat cat events ourselves and if our estimates are in line with other official estimates, we see this as confirmation of the robustness of our loss estimation procedures.

For this procedure we have identified five levels of information quality, each of which requires a separate approach or a combination of different approaches. The five levels are:

1. Information on **insured losses** in industrial countries with high insurance penetration, compiled by institutions such as Perils AG, PCS, CatIQ or various insurance associations

2. Partial information on **insured losses** in developing markets/countries

3. Information on **overall losses**, often from government (but no information on insured losses)

4. Partial information on **overall losses** (e.g. monetary losses to agriculture, infrastructure, etc.)

5. **Description of event** only (e.g. number of houses damaged/destroyed by flood, storm, earthquake, etc.)

Overall loss estimates based on insurance market data (i.e. information level 1) offer the best quality if there is high insurance penetration for the peril (e.g. storms in industrial countries). It opens up an easy way to scale up the values as the following diagram reveals (see below). The only necessary secondary information are the insurance take-up rates by line of business and a few assumptions on the percentage of uninsured losses (effect of deductibles/underinsurance, uninsured infrastructure, etc.). Such a scaled-up value can be modulated based on event-specific individual loss characteristics, e.g. a higher share of uninsured losses because of the occurrence of (less insured) flash flood damage during a storm.

![Economic loss estimation based on insurance market data is of best quality! ...and easiest way to scale up (info quality level 1)](image-url)
In the case of low-quality information levels, e.g. when there is only an event description with the number of homes damaged/destroyed available, one has to rely on asset-value assumptions. We apply typical home values and typical repair costs to the listed damaged/destroyed assets, we make assumptions on infrastructure and public building costs and include specific damage estimates from the agricultural sector. Photos of the disaster help to estimate the scale of impact as well as the average loss of a damaged or destroyed house.

Loss estimation relies heavily on assumptions and interpretations. The quality of the estimates is limited by the accuracy of the assumptions as well as the available information in the event description. But one can generally say that...

1. Large loss events have large uncertainty in absolute values, but small uncertainty in relative values!

2. Small loss events have small uncertainty in absolute values, but large uncertainty in relative values!

This has two reasons: (A) There is better information quality for large loss events due to a higher level of general interest. And (B) the larger and vaster a loss event, the greater the chances that errors in the assumptions will balance out in the estimation procedure (central limit theorem).

How large are the uncertainties? Our experience tells us that errors in multi-billion-dollar losses in developed and some emerging countries are typically less than 10%, while errors in losses of just a few million dollars can easily exceed a factor of 2.

From a risk management perspective this is not a problem because, due to the skewness of loss distribution functions, the total risk is typically determined by the few largest loss events per year. The sum of losses from the many small events does not outweigh the loss from large or catastrophic events.

The loss values in the NatCatSERVICE database are not static, i.e. they are updated every time there is new information available that leads to a re-evaluation of a loss estimate. This can affect both recent events and historic events.

2.6 Currency conversion

Loss values are typically expressed in US$ but might be issued in other key currencies as well. In the NatCatSERVICE database we convert local currencies to US$ based on the exchange rates in the month when the event occurred. This is important when expressing the losses in nominal values. For the NatCatSERVICE online tool we have decided to provide the analyses in US$ only to avoid misunderstandings and confusions in the interpretation of the data.

Currency conversion also plays a role in inflation adjustment and loss data normalisation (more on this in the next sections). To convert inflation adjusted from the local currency to US$ we use year-to-date rates, i.e. the average of all daily rates from 1 January to 31 December of the current (i.e. most recent) year. Normalised losses are expressed in US$ (derived from nominal loss values in US$). If they need to be expressed in local currency, one needs to apply the inverse of the year-to-date rate of the current (i.e. most recent) year. The applied currency exchange rates are extracted from official sources such as the International Monetary Fund, the United Nations Statistics Division and Bloomberg.
2.7 Inflation adjustment

Losses are estimated in monetary units (currencies) which are prone to changes in value over time. Such changes are called inflation (reduced purchasing power of money) or deflation (increased purchasing power of money), and are direct consequences of changes in the price levels of goods and services in the currency zone. The changes (or “inflation rates”) are reflected in the so-called consumer price index (or CPI), a measure constructed from a selection of consumer goods and services. It is a simple factor that describes the change in the value of money between any given year and today.

If one wants to learn how much a historical nat cat loss would cost today, a simple way to answer the question is to inflate the historical loss value by multiplying it by the corresponding CPI factor.

In contrast, when asking how much loss a historical nat cat event could cause today, inflation adjustment does not help to answer the question since it does not account for any (potential) increase in local assets and values that would be prone to the natural forces if they re-occurred today. To answer this question, loss data normalisation is required (see next section).

The NatCatSERVICE utilises the CPI data from various sources. The main source is the Consensus Data from Oxford Economics. Other sources include the United Nations Statistics Division and the World Bank and our experts in Munich Re Economic Research. If there are no official data available (typically for smaller countries and island states), we apply proxy data from related or associated countries where currencies are coupled through fixed exchange rates. In the few cases when there was hyperinflation in a country, we use the US CPI to scale the losses to today’s values.

2.8 Loss data normalisation

A common question in the context of historical nat cat losses is what damage a historical nat cat event could cause under today’s conditions (i.e. today’s exposure and prices). This question cannot be sufficiently answered by pure inflation adjustment, but rather by considering changes in hazard-prone assets and goods at the location(s) of the hazardous event. Such a procedure is called loss data normalisation and it is the method of choice to make historical losses comparable to today’s losses.

A necessary requirement for loss data normalisation is good and reliable data that describe the local or regional developments of wealth and assets on a worldwide scale. Macroeconomic data such as gross domestic product (GDP) have become the established economic proxy data.

If the GDP data relate to an entire country or a region that is significantly larger than the area affected by the natural catastrophe, one cannot automatically assume a proportional correlation between national GDP and changes in value in the area affected. To smooth this distortion, we have developed a method that we call peril-specific regionalised normalisation. A global 1°x1° grid forms the centrepiece of this normalisation version. The annual proportion of a country’s GDP is calculated for each cell, beginning with the year 1980. A weighting is performed using the population development in the cell, in some cases interpolated or extrapolated. The special feature of this approach is that each individual cell contains a time series with the GDP share attributable to it since 1980. Cells that cross national borders are recorded several times, along with their corresponding share. The figure below displays such grids with the corresponding cross-cell product data (or GCP). Comparing the value of each cell for the year of occurrence of a nat cat event with the respective one today reflects the change of wealth within the cell over the considered period. The sources of the applied GDP and population data are: Munich Re Economic Research, Oxford Economics, United Nations Statistics Division, the World Bank, and SEDAC data from CIESIN at Columbia University.
NatCatSERVICE, Munich Re’s global loss database, includes the geographic coordinates for the locations and regions that are worst affected in a loss event. These form the basis for what is known as the loss footprint of an event, i.e. a perimeter within which all or most of the losses have occurred. In addition, each natural hazard has its individual geographic extent, which is known as the hazard footprint.

A winter storm normally covers an area many times bigger than that of a thunderstorm. In turn, the geographic extent of a thunderstorm is typically much bigger than that of flash floods following torrential rain. The aim is to achieve a kind of geometric compromise between the hazard footprint and the loss footprint on the 1°x1° grid. An individual normalisation footprint is obtained for each event from the geocoded loss-location information and the hazard-specific selection pattern derived from it. This specifies which cells should be used to calculate the normalisation factor. Munich Re’s NatCatSERVICE has calculated the typical footprints for five basic types of loss event. When sorted according to extent, these are:

1. Small-scale events (including flash floods and landslides)
2. Local events (including severe thunderstorms, earthquakes and wildfires)
3. Flood events (riverine floods)
4. Coastal events (tropical cyclones, storm surges, tsunamis)
5. Large-scale events (including winter storms, droughts and heatwaves)

Some of these hazard-specific cell-selection patterns can be seen in the graphs below. These graphs are available for all of the country-based events since 1980 that are included in the NatCatSERVICE.
To determine the particular normalisation factor, we take the sum of the cell values of the whole footprint for the year in which the event occurred, and compare this value with the sum of the cell values of the footprint for the current year. This deviates from a classical normalisation method where country-wide data is applied (see figure below).

- losses in nominal (grey), inflation adjusted (green) and normalised (red) values between 1980 and 2016. Only the red curve permits a comparison of the severity of nat cat impacts over time.
2.9 Catastrophe classification (Cat Class)

Loss data normalisation makes historical loss values comparable over time. However, loss data normalisation does not take into account that a loss of, for example, US$ 100m is of quite different significance in Haiti or Bangladesh than in Germany or the USA. To be able to compare the impact of loss events on different countries, we need a severity or impact classification scheme that takes these differences into account.

Our Catastrophe Classification (“Cat Class”) methodology is a filter system that considers the annually assigned World Bank income group (1 to 4, or high to low income class) for every country. The development of the threshold values between low, lower-middle, upper-middle, and high income countries are shown in the graphs below, in nominal US$ (as issued by World Bank under:


The left figure displays the threshold values in nominal US$ between the four income groups as defined by World Bank. Black: threshold between low and lower-middle income, red: threshold between lower-middle and upper-middle income, and blue between upper-middle and high income. The right figure shows the same, but in units of the 1989 value (1989 = 1). All three curves appear to follow a very similar course.
The metric proposed for classifying catastrophes is displayed below, whereby the degree of severity of an event depends on the particular income group of the affected country. With each income group, the per capita gross national income increases by a factor between 3 and 4, which translates into a set of threshold values for classifying the severity of the event. The number of fatalities is also incorporated into the measurement of the degree of severity. The Cat Class metric is displayed in the table below.

The five Cat Classes (0 to 4) can be paraphrased as follows:

- **Cat Class 0**: Marginal impact (no noteworthy or firmly measurable loss occurred)
- **Cat Class 1**: Small loss, small impact
- **Cat Class 2**: Medium loss, moderate impact
- **Cat Class 3**: Large loss, major impact
- **Cat Class 4**: Catastrophic loss, catastrophic impact

For reliable and robust statistical analyses, we only allow events of Cat Class 1 to 4 (called **relevant** events) and deliberately ignore all Cat Class 0 events. The reason for this comes from a reporting bias which affects the number of detectable events over time due to better reporting of loss event information today than, say, twenty or thirty years ago. This effect would account for most of the trend in the increasing number of events over time. The bias, however, only affects the very small loss events. Medium and large loss events have always been reported in sufficient quantity and quality. These small loss events do not notably contribute to the sum of losses (due to the skewness of the loss distribution). Hence, by ignoring the smallest events we can correct this bias in the frequency without having a distortive effect on the (aggregated) loss intensity.

In the NatCatSERVICE analysis tool we do not show particular Cat Class 4 events where the loss estimation – the basis for the classification – is very uncertain. These are typically loss events in poor countries, where no quantitative information was available for the loss estimation.
2.10 Fatality data

The NatCatSERVICE database contains fatality information for every event. One can query the raw fatality numbers or – for better comparison – a Nat Cat Fatality Rate Index. This index indicates the humanitarian vulnerability of a country from natural disasters based on the annual mortality rate standardised per 1m population. It encompasses a timespan of 37 years (1980–2016) for all peril families of natural disasters. For each year, the number of a country’s fatalities is expressed in relation to its population. With this method, the development of fatalities in a given country is adjusted to the change in the number of population per year. The Nat Cat Fatality Rate Index is split into four categories: low, lower-middle, upper-middle and high mortality rate with the corresponding thresholds of < 1, between 1 and 5, between 5 and 25 and ≥ 25 fatalities per 1m population. The index is key for ascertaining whether prevention measures or early warning systems have effectively reduced the number of fatalities in a country.

2.11 Insurance density, insurance penetration

When evaluating insured losses, it is important to put them into perspective with other insurance-relevant parameters. Two prominent parameters are insurance penetration and insurance density. Insurance penetration is defined as the sum of all primary insurance premiums expressed as a percentage of a country’s GDP on an annual basis. Insurance density is the average primary insurance premium per capita of a country on an annual basis. Since nat cat business reflects only a sub-sector of the insurance business, it is important to utilise only values from non-life business, which is defined as property & casualty business and health insurance. The data is provided through national supervisory authorities or insurance associations. When there is no data available, experts from Munich Re Economic Research have made best-guess assumptions to fill the gaps. To avoid the false impression of exact knowledge of worldwide insurance premium data, the NatCatSERVICE online tool provides the insurance density and penetration data in coarse categories of four levels: high, medium, low, and very low. The corresponding threshold values for the insurance density data are ≥ 1,000 US$, 100 to 1,000 US$, 10 to 100 US$, and < 10 US$ of (inflation adjusted) average primary insurance premium per capita and year. For the insurance penetration the applied threshold values on the ratios between nominal property & casualty plus health insurance premiums and the nominal GDP per country are ≥ 2, between 1.3 and 2, between 0.6 and 1.3, and < 0.6.
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