Natural catastrophes: causes, trends and risk management. The challenge of submarine mass movements – an insurance perspective

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The growing loss burden from natural disasters calls for a holistic risk management approach which encompasses the elements of risk identification, risk evaluation, risk control and risk financing. Financing and controlling the growing risk can be achieved by a cooperative effort from all parties involved which aims at mitigating and reducing the losses from future events. Under the heading of "risk partnership" the roles played by the persons and entities affected, the financial sector and the state are described from an international perspective based on actual business practice. The specific challenges made by extreme natural hazards like tsunami and submarine slides to risk management are discussed and exemplified by the South Asian megatsunami of Dec 26th, 2004.

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Growing losses – Need for action

The loss data on great natural disasters since 1950 show a dramatic increase in catastrophe losses over the last few decades. Actual loss figures and trend curves are shown in the figure below. The reasons for this development are manifold and encompass the following:

- The increase in world population and related effects
    - increasing values
    - concentration in large conurbations
- Social and economic factors
    - development of highly exposed regions
    - high vulnerability of modern societies and technologies
- Changes in the natural environment

(e.g. global warming and the related regional effects)

As the underlying factors for the observed loss trend remain unchanged, a further increase in losses from natural disasters is inevitable. The development of coastal areas for residential, commercial and industrial use is just one phenomenon which exemplifies this trend, as demonstrated by the staggering losses produced by the South Asian tsunami of 26 December 2004, and Hurricanes Katrina and Wilma affecting the US Gulf coast, Florida and Yucatán in 2005. Hurricane Katrina also illustrated the potential worldwide implications of natural disasters by the severe shortage in oil-producing and refining capacities and the ensuing sharp price increases in the global oil market.

Risk management in the context of natural disasters

Coping with future loss burdens as outlined above represents a formidable challenge to the insurance industry and requires a holistic approach to risk management. Such an approach comprises the following steps:

- Risk identification
- Risk evaluation
- Risk control
- Risk financing

For the ensuing discussion it is useful to bear in mind that risk consists of three components: the hazard, the vulnerability of objects exposed to a hazard, and the value of the exposed objects. The hazard is usually defined as the exceedance probability of an event of a specified minimum size, e.g. the wind velocity in the case of windstorms or the ground shaking in the case of earthquakes. The vulnerability is expressed as the expected average loss as a percentage of the replacement value and is a function of the pertinent hazard parameter.

Risk identification

As a consequence of great natural disasters which occurred in less developed regions but had an unexpected impact on the international reinsurance market –

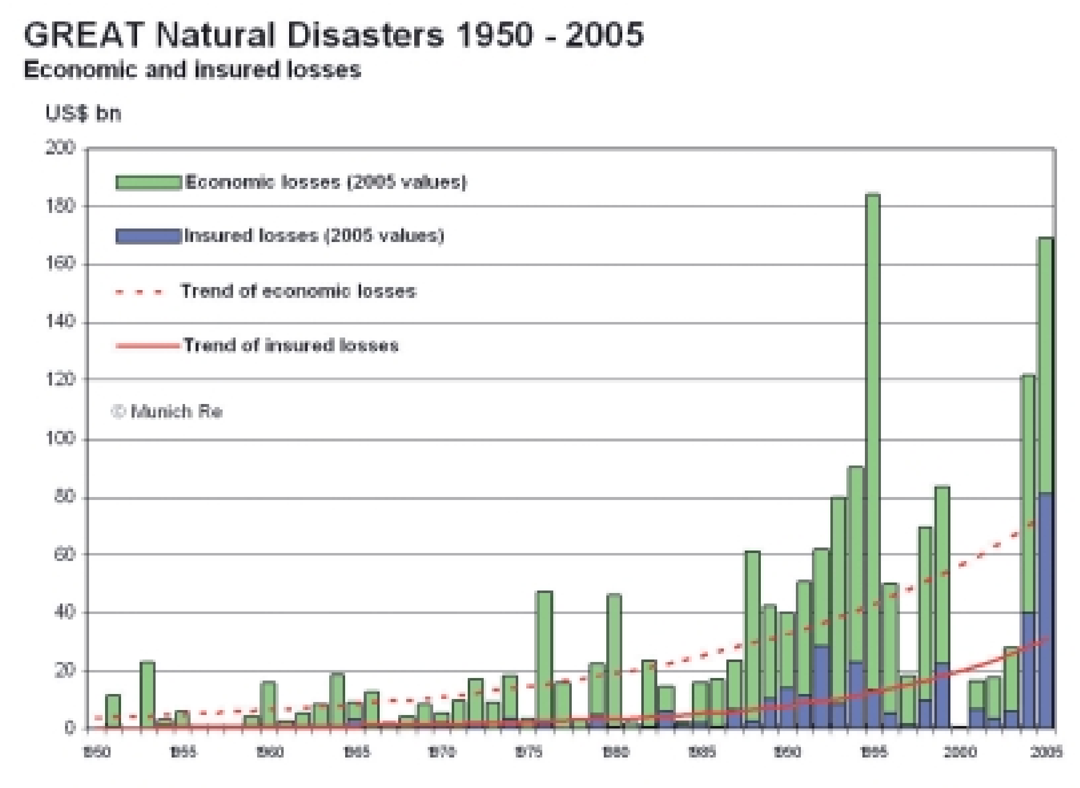

Fig. 1: Losses from great natural disasters (far exceeding 100 deaths or US$ 100m in losses), 1950-2005. Figures are adjusted for inflation.

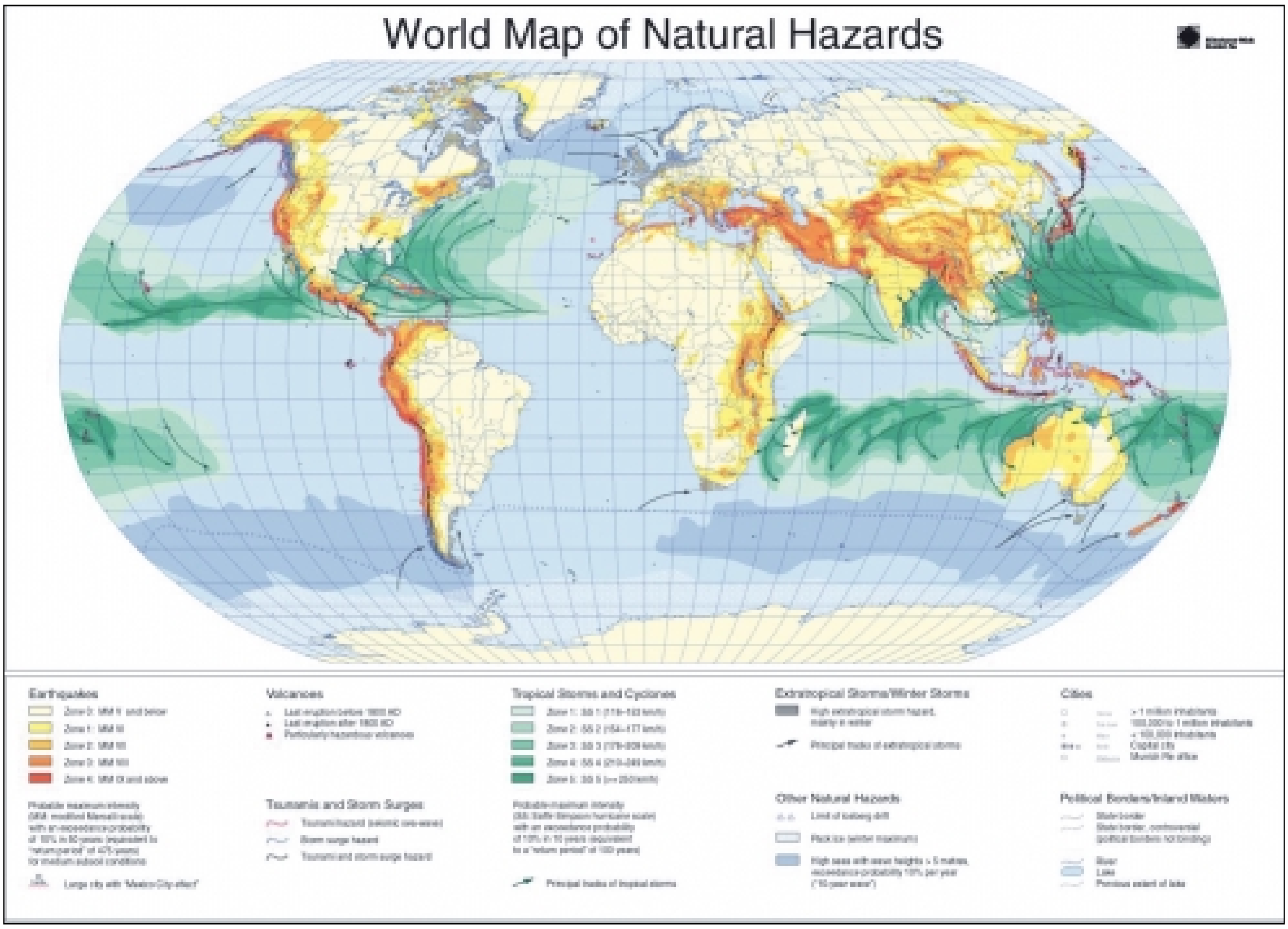

Fig. 2 World Map of Natural Hazards. Earthquake hazard is shown in yellow-brownish colours and has been classified into five grades according to the minimum intensity (Modified Mercalli scale) to be reached or exceeded once in 475 years. Darkest colour means highest hazard. The hazard of tropical windstorms is presented in green colours, again darkest colour corresponds to highest hazard. Classification is according to the 5-degree Saffir-Simpson scale. Green arrows represent the main cyclone tracks. Other hazards shown are extratropical storms (gray shading) and active volcanoes (small black symbols).

the earthquake in Managua/Nicaragua in 1972 and the tropical cyclone Tracy in Darwin/Australia in 1974 – Munich Re already recognised in the early 70s the growing importance of natural disasters for the insurance industry. Therefore, the Geo Risks Research Group was founded in 1974. It now employs about 20 geoscientists from different disciplines. For the purposes of risk identification, a global natural disaster database (Munich Re 2003) was developed. Another successful product was the World Map of Natural Hazards, first published in 1979 and now in its third edition (Munich Re 1998), and also available on a CD-ROM. The World Map already marks the transition to risk evaluation in the sense that it describes probabilities for one component of risk, which is the hazard, see Fig. 2.

Risk evaluation

The year 1987 marked the starting point for the construction of the first fully probabilistic earthquake risk model which allowed the calculation of average annual losses (abbreviated AALs, or net rates) and probable maximum losses (abbreviated PMLs). See below for an explanation of these terms. The use of such risk models has become commonplace in the insurance industry in the meanwhile. In such models, data on the hazard, e.g. earthquake intensities, wind speeds or flood heights and their distribution in space and time, on the distribution of exposed objects per site and construction

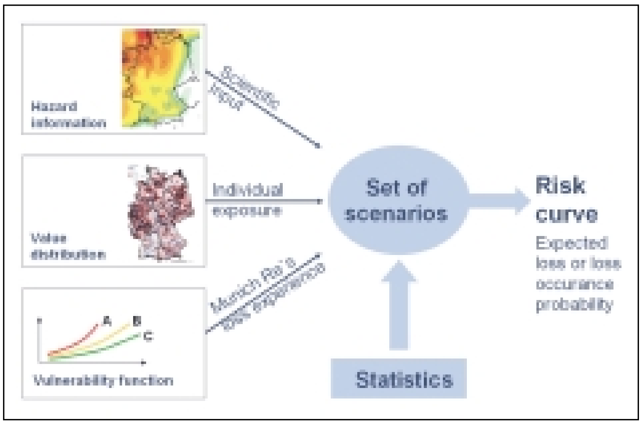

Fig. 3: The Munich Re risk model MRHazard. Data on hazard, exposed values and vulnerability are combined probabilistically. This results in an event set which serves as the basis for calculating insurance rates and probable maximum losses.

type and/or type of use and on their vulnerabilities to nature's forces are combined and evaluated. The result of this calculation process is a stochastic event set which describes the full probability distribution of potential event losses in the investigated region. Fig. 3 shows schematically how such models work.

Fig. 4 is the graphical presentation of the calculation result called a loss exceedance curve. The example shows that a loss of 2.4% (or higher) of the total values in the considered region has to be expected on average once in 100 years and a loss of 6.5% once in 1,000 years. In insurance parlance, such a single value is called probable maximum loss. PMLs form the basis for measures to guarantee the financial stability of a company by means of reinsurance protection and limitations of coverage (see also the following chapter). The other important application of such risk models is the calculation of an adequate rate, i.e. the net insurance rate which would be necessary to compensate for all possible losses over time. This is the average annual loss AAL. In mathematical diction, this is the integral over the full probability distribution.

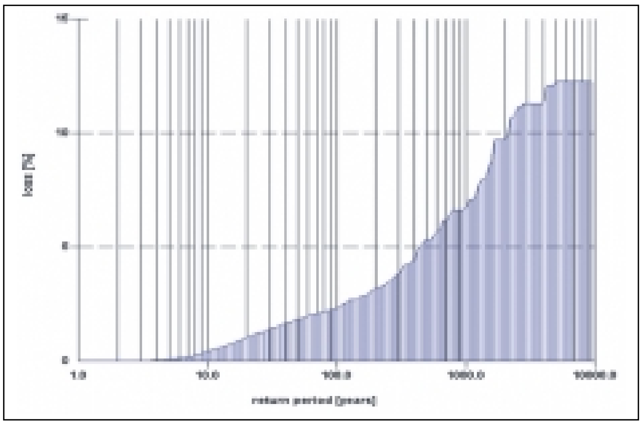

Fig. 4: MRHazard – example for a PML curve

Risk control

The next step after identifying and evaluating the risks is risk control. The insurance industry has various measures at its disposal to keep its risk within affordable limits. They are briefly introduced below:

- Calculation and application of a risk adequate price (insurance rate)
- Accumulation control, i.e. monitoring the insured liabilities within a country or region
- Self-participation of the insured party in the loss, in the form of deductibles which reduce the number and amount of small insurance claims in the event of large disasters
- Liability limits, which reduce the exposure from very large insurance claims from the top (i.e. losses are compensated only up to the limit)
- Exclusion of particularly exposed areas or certain hazards. An example would be regions which are frequently flooded and therefore do not fulfil one of the principal preconditions of insurability, which is the lack of foreseeability of an event
- Improved claims settlement, which requires the for-

mulation of contingency plans for regulating sometimes hundreds of thousands or even millions of claims in one single disaster as observed in the Northridge (Los Angeles) earthquake of 1994, the European windstorms of 1999, or Hurricane Katrina in 2005.
- Reinsurance, retrocession: Whereas the aforementioned measures work on the level of the original insurance policy, reinsurance and retrocession (which is the equivalent of reinsurance for the reinsurance sector itself) serve to limit the exposure from the large number of claims to be expected in great natural disasters by means of reinsurance contracts.
- Catastrophe reserves: Premiums from natural disaster insurance cannot be considered as "earned" premiums after one year. Great disasters happen rarely, and therefore the relevant premiums have to be set aside for forming financial reserves which are then tapped when the event occurs.
- Loss prevention: The trend to dramatically growing losses as demonstrated in the introductory section shows that it is indispensable to strengthen the efforts in loss prevention and mitigation, i.e. taking proactive measures to reduce losses from future disasters by means of land-use planning, construction techniques and contingency plans.

How such measures are brought to fruition, and by whom, is the subject of the following section.

Risk financing - The principle of risk partnership

Coping with future loss burdens represents a formidable challenge which requires the cooperation of all parties involved, i.e. the potentially affected private persons and industries, the financial sector and the state. More specifically, and introducing the role to be played by insurance within the context of natural disaster relief, we can distinguish between

- the insured persons or entities,
- primary insurers,
- reinsurers,
- capital markets, and
- governments/public authorities.

Each of these parties has its own tasks and responsibilities in managing the risk arising from natural disasters. Beyond the pure financing of future losses, which is a reaction after the event, much more effort than hitherto has to be invested in a pro-active strategy, i.e. in reducing and preventing future losses. Such a strategy is not only a matter of financial resources, but also, and maybe even more so, a result of good and foresighted planning and of coordination at all levels, from households and industrial companies to public institutions and authorities. What precisely are the tasks of these parties?

- The insureds: Householders and business owners can do a lot in order to reduce the risk to their property by proper maintenance and securing sensitive items like equipment, electronic installations and machinery. In industrial businesses emergency planning can help to prevent or minimise losses from future disasters. Finally, a certain portion of the financial risk has to be borne by the insureds in order to keep the interest in loss reduction awake. Typical forms of self-participation are deductibles, preferably expressed as a percentage of the sum insured, and/or coinsurance, i.e. a percentage participation in each and every loss, see section 4.
- Primary insurers: Primary insurers have to provide and secure capacity by
  - charging technically adequate rates,
  - applying appropriate underwriting guidelines,
  - accumulation control and portfolio management,
  - establishing reserves for natural perils,
  - limiting their liability according to their financial strength => reinsurance protection.
- Reinsurers: Reinsurers are often the main risk carriers in the field of natural disaster losses, making proper risk management all the more a primary task which includes
  - balancing the risk over time and regions,
  - providing technical support to the clients in rating considerations and assessments of probable maximum losses (PMLs),
  - controlling and limiting liabilities (setting cession/occurrence limits, budgeting, retrocession).
- Capital markets: They came onto the scene only a few years ago. This type of alternative risk transfer (ART) must be seen as a supplement to reinsurance rather than competition. Their main function is to provide additional capacity for top-rank losses. Typical ART products are so-called cat bonds (in popular terms, this means betting against the occurrence of a disaster within a specified timeframe), swaps (an exchange of risks from specified disasters between two companies, e.g. earthquake in Tokyo against windstorm in Europe) and weather derivatives.
- The state: In the insurance context, the state has to act as a reinsurer of last resort for very rare, extraordinary losses and/or uninsurable risks which exceed the capacity of the private sector. The main task of the state lies, however, in the field of risk management and risk reduction and involves
  - designing and enforcing land use and building regulations,
  - securing the serviceability of critical facilities and infrastructure,
  - developing emergency plans defining precisely the responsibilities and the coordination of the

authorities involved, and
- granting tax exemption for private insurers' catastrophe reserves.

Within this context, the role of the insurance sector is well-established. The capital markets, on the other hand, still have to prove that they are willing to provide reliable and continuous capacity when investors have lost their money after large disasters. Furthermore, it is worth mentioning that almost the entirety of ART programmes have so far been placed for highly developed countries. Complexity of the programmes and the connected transaction costs, as well as investors require usually mature insurance markets. The state should create an environment in which the greatest possible use is made of private resources for disaster recovery, combined with the availability of protection for as many people as possible. Linking the availability of such protection to the observance of building regulations can provide an efficient mechanism for code enforcement, especially where new constructions are concerned. Notwithstanding, mechanisms aiming at code compliance may serve to encourage rehabilitation measures as well. Another important role in the "mitigation cycle" could be, and increasingly is, played by mortgage banks requiring natural disaster insurance as a precondition of the loan (see below).

Disaster insurance – A tool for risk mitigation?

The use of disaster insurance as a motivating tool within the framework of loss mitigation programmes has been discussed to an increasing extent in recent years. So far, however, actual implementation of this concept lags far behind its potential. The reasons are manifold. The public at large is often unaware of insurance mechanisms or has an idealistic perception of the function of insurance. In the insurance sector, competition and a short-term financial perspective do not create a favourable environment for actively promoting prevention and mitigation measures, as the timescale for a possible positive outcome tends to be too long. A projects as the community classification scheme of the insurance-sponsored Institute of Home and Business Safety (IHBS) in the US, where communities are classified according to code compliance with the final aim of promoting loss prevention, is unique so far.

The classic example of successful loss prevention in property insurance is the inspection of insured objects by fire engineers employed by insurance companies with the aim of giving recommendations on enhanced fire protection. The level of fire protection is a well-established criterion for rating and PML assessment. As far as the earthquake risk is concerned, similar initiatives were taken by private firms as a consequence of the shrinkage of insurance capacity after the Northridge earthquake in California. On the basis of risk management surveys, earthquake protection was improved and the insurance coverage bought was adjusted to the minimum demand or given up altogether in favour of direct investment in loss prevention.

Nevertheless, in natural hazards insurance, and especially in earthquake insurance, other features that foster loss reduction are widely used (see below). These features are risk-adjusted premiums and self-participation on the part of the insured party:
- Risk-adjusted premiums: Tariff schemes reflecting the actual risk level commensurate with the location and the constructional characteristics of the insured object are increasingly being used on a global scale. But the correct application of such schemes presents a problem, and in actual practice, rates are mostly still dictated by pure competition. Sometimes, for instance, rebates are given for alleged compliance with anti-seismic building regulations. Often, however, code compliance has not been checked and – although stated – does not exist in reality. Therefore, in practice, this element can be counter-productive and even unjustified when it comes to older generation codes whose principal goal is avoiding loss of life rather than reducing monetary loss.
- Self-participation: There are three types:
  - Deductibles, expressed as a percentage of the sum insured or as a flat amount. Typical deductibles in earthquake-prone countries start at 2% and go up to 15% in highly exposed regions like California. But even in regions of moderate seismicity deductibles of 10% are used if insurance penetration and, consequently, potential catastrophe losses are high (e.g. in Israel). Insurance payments only commence in excess of the deductible.
  - (Proportional) coinsurance, again expressed as a percentage of the sum insured. Under this arrangement, the insured party carries a fixed proportion of each and every loss. Typical values range from 10 to 25% and reach a level of 70–85% in Tokyo Bay.
  - First loss coinsurance/liability limits, expressed as a percentage or a flat amount. Here, the insurer pays from the ground up or after a deductible up to a certain limit.

All of these elements can be combined and are accompanied by corresponding premium rebates. The greatest incentive to take loss prevention and reduction measures is given by proportional coinsurance of at least 10% or by deductibles of 5% or more, as the insured party has to carry a substantial portion of any loss on its own.

The effectiveness of the above-mentioned elements depends to a critical degree on the actual spread of insurance. In this sense, a distinction can be made between 'free' insurance markets and countries where earthquake coverage is obligatory or semi-obligatory:

- In an unregulated market that is completely exposed to competition, it is a delicate task to find the right balance between tariff elements geared to loss prevention and acceptability for the consumer, with the result that a sufficient spread of insurance is achieved or maintained. A common reaction in such cases is the 'zero option', i.e. no insurance and no loss reduction. This option is neither in the interest of the public, which at the very end has to pay the forthcoming losses without having set aside reserves beforehand, nor in the interest of the insurance industry, which wants to generate business. As a matter of fact, insurance conditions that are unattractive or in extreme cases completely unaffordable result in a situation where, on a global scale, typically less than 10% of the people have any earthquake insurance at all. As a result of such a low market penetration, attempts to foster loss prevention by means of insurance become almost futile.
- A much better environment for using insurance as a direct incentive or as an indirect contributor to loss reduction programmes is provided by insurance markets where the coverage is either mandatory or at least widespread. In these markets, attempts to educate and raise the awareness of the consumer by means of brochures and videos reach many more people and consequently have a greater chance of success than in free markets with low insurance penetration. As already mentioned, mortgage banks can play an efficient role in fostering high market penetration without the support of legal measures by requiring disaster insurance as a precondition for the loan, as practiced in Israel, Colombia and other countries.

In addition, and even more important, all of the above cited direct measures like deductibles, can be brought to real fruition without leaving room for the 'zero option' – if they are used, of course. If, instead of this, full coverage without substantial deductibles is granted under mandatory schemes, the goal of loss prevention is missed again. A portion of the premiums collected under such schemes can be invested in loss reduction programmes or in relevant research. The governmental Earthquake Commission in New Zealand or the Swiss Earthquake Insurance Pool provide examples of such a policy.

Extreme natural disasters

What are "extreme natural disasters"? A strict definition is difficult as there is a smooth transition from "normal" and "big" disasters to exceptional ones. For practical considerations and from an insurance perspective, we classify as extreme disasters those events whose occurrence probability is well below once in 1,000 years and is usually more in the region of once in 10,000 years or more.

The South Asian tsunami of 26 December 2004 – A wake-up call

In terms of human losses, the South Asian earthquake and tsunami disaster, with about 230,000 victims, was the biggest natural disaster since the Tangshan earthquake in China in 1976. Total material losses amounted to approximately US$ 10bn, whilst insured losses were below US$ 1bn. The national economies of the various countries were affected in different degrees. The Maldives, which depend almost entirely on the tourism industry, and Sri Lanka, again largely dependent on tourism and fishing, were the most severely hit. But in spite of the staggering death toll, the impact on Indonesia's GDP was only nominal, and in Thailand too, the economy was not affected to a really significant extent. In summary, there was an enormous death toll, but the financial impact of this gigantic human disaster was insignificant on a global and partially even on a national scale.

Notwithstanding the small volume of insured losses and the fact that the South Asian tsunami was not a truly rare event in a worldwide context, it increased the sensitivity for extreme natural disasters. First and foremost, the question was raised as to what the loss potential of similar events in other ocean basins (see fig. 5) may be, and also the widespread media coverage of a possible flank collapse at the Cumbre Vieja volcano on La Palma received renewed attention within the financial sector. The sheer extent of the affected region was unprecedented as far as the insurance industry was concerned – past ocean-wide tsunamis, such as the 1964 and 1960 events in the Pacific basin, occurred too early to be of real concern to insurance. Losses occurred not only in the countries directly affected but also in countries located far away, where the event brought suffering and death to several thousand tourists. The bulk of the losses were in property insurance but personal lines – life, health, workers compensation, personal accident, travel insurance – were also affected. The complexity of the loss had much in common with the hitherto greatest insurance event, the terrorist attack to the World Trade Center on 11 September 2001.

The challenge of extreme natural events

Regarding the risk management of extreme disasters, the same principles and procedures can be applied as those specified in the foregoing section in the context of "classical" natural hazards. This means that the hazards have to be identified and the related risks evaluated. Then, the potential losses have to be controlled, and prevented and mitigated as far as possible. The particular challenge of very rare, extreme events lies in the fact that such disasters have not yet been experienced in documented human history. Therefore, their effects must be reconstructed on the basis of geological and geomorphological investigations and theoretical modelling of the physical processes involved. Both these undertakings are fraught with considerable uncertainties. It is only partially possible to draw analogies from known events in the recent past. For instance, the South Asian tsunami of 26 December 2004 may well serve as a blueprint for damage patterns of similar future events in other regions. Another example is Hurricane Katrina of August 2005: the degree of destruction it inflicted on the US Gulf Coast would probably not be exceeded even by a strong tsunami. But, as the Boxing Day 2004 tsunami in South Asia demonstrated, the length of coastline could be greater.

There now follows a brief summary of knowns and unknowns and the description of a rational approach to treating extreme events in accordance with the risk management process presented in section 1.

Hazard identification

A wide range of extreme natural events are a threat to the insurance industry. Such events include among others:

- Submarine landslides on continental slopes: The best-documented cases are the Storegga slides west of Norway, the last of which occurred 7,000 years ago. Its volume was about 2500 km^3.
- Flank collapses of volcanic islands in the ocean or on coasts. In principle, every volcano in the ocean is an unstable edifice whose over-steepened slopes collapse from time to time in catastrophic slides or slides series. About 20 such catastrophic episodes have been documented for the Canary Islands within the last two million years and more for others as e.g. the Cape Verdes, Reunion and the Hawaiian Islands, and
- a consequential effect common to both of these: tsunami generation.

Another, less well-known event, which may be mentioned here, is the sudden release of methane hydrates buried under the ocean bottom. Such an event may have caused the Storegga slide mentioned above.

Risk assessment

Risk assessment involves a (probabilistic) assessment of the hazard and combining the hazard with data on the vulnerability of objects. The challenges of hazard assessment are discussed below in more detail taking the example of tsunamis. Regarding vulnerability, there is – over and beyond the lack or scarcity of empirical loss data – a further complicating effect: losses from extreme natural events are often the end result of a combination of primary and secondary hazards in event chains. Furthermore, losses can accumulate from many countries and from different lines of business. To some extent, this was demonstrated by the Sumatra earthquake and the ensuing tsunami, where losses occurred in all sorts of insurance classes. Identification of all possible loss agents is of prime importance in order to avoid hidden accumulations.

Risk control

There is a common misperception about extreme natural disasters that control and prevention measures would be useless because of the sheer size of such events. Such an attitude denies the fact that there is a smooth transition from classical to extreme hazards. Furthermore, it has been demonstrated by Ward and Asphaug (2000) that the risk of meteorite impact is dominated by objects with a diameter of some 200-300m, i.e. just big enough to survive the plunge into the upper atmosphere. This principle can also claim validity in respect of other hazards such as large volcanic eruptions and is dictated by the exponential decrease in frequency with increasing event size.

The list of measures for risk control presented in section 1 is also suited to handling extreme events, but with somewhat differing weights regarding the various possible choices. As to calculating technical rates, extreme events are so rare that calculating an insurance rate ends up in values close to zero. They are, however, the ultimate expression of low-probability/ high-consequence events, and it is therefore absolutely imperative to limit the liability arising from them. This implies the need for exact knowledge of what is covered under existing insurance contracts. However trivial this may sound, it is very important because unclear and misleading terms are not unusual in insurance policy wordings.

As risk assessment is fraught with high uncertainties, a general exclusion from coverage may turn out to be the *ultima ratio* for such events, at least given the present state of knowledge. But drawing a line between what at first sight appears to be an insurable peril, e.g. a volcanic eruption, and what could become an uninsurable one once it develops into a massive flank collapse and generates a tsunami is a problem that has not yet been considered systematically – let alone solved – by the insurance industry.

And what about prevention, which plays such an important role in connection with "classical" natural perils? Whereas it seems hardly possible to design measures specifically designed for rare extreme events, many prevention measures which work in the case of earthquakes or for coastal protection, will also have a positive effect on tsunami, for example.

The case of tsunami

Indeed, tsunami is the peril which deserves most urgent attention. This derives from the fairly high frequencies caused by the variety of causative phenomena. In decreasing order of frequency, tsunami are caused by earthquakes - often in combination with concurrent submarine slides -, by submarine slides on their own, by volcanic eruptions and by meteorite impact. Geomorphological field work on several coasts has documented prehistoric and even historic tsunamis of unknown origin within the last 10,000 years whose force must have been stronger than that observed in the South Asian tsunami of 2004. This can be deduced from the huge boulders displaced on higher ground and inland by the tsunami. Interestingly, various observations relate to regions which are not exposed to earthquake tsunami, e.g. the Bahamas, the ABC islands in the South Caribbean and Majorca (Scheffers & Kelletat 2003). But this also used to apply to the Thai coast – before the 2004 tsunami. In the case of Majorca, the coastal region of North Algeria provides an earthquake source, as demonstrated in the Boumerdes earthquake of 2003, but prehistoric tsunamis at about 500 B.P. and earlier must have been much bigger than would be expected from the typical size of earthquakes offshore Algeria.

In principle, constructing a global probabilistic tsunami hazard map for earthquake tsunami appears feasible. But converting the available data into a probabilistic hazard assessment requires a great deal of additional effort. A straightforward and logical approach is presented by Ward & Asphaug (2000) for meteorite tsunami, irrespective of the fact that the base assumptions on the underlying physical processes they use in their modelling are partially doubtful. The procedure as such is derived from the well-established probabilistic seismic hazard assessment method (PSHA) and can safely be transferred to earthquake tsunami modelling. The origin and propagation of earthquake tsunamis is fairly well understood. For local applications, the main problem lies in modelling the run-up heights. There again, the physical process causing run-up is well-known, but the crucial data on offshore coastal topography only exist for a small section of coastal regions globally. A further problem in global earthquake tsunami modelling is the fact that it is sometimes difficult to distinguish between earthquake-generated and slide-generated tsunamis which often occur concurrently with true earthquake tsunamis. Prominent examples are the Aleutian earthquake of 1946 and the Alaska earthquake of 1964, both of which produced earthquake-induced, ocean-wide tsunamis and consequential slide-induced, local tsunamis as well.

Earthquake tsunamis have extended sources. Other tsunami causes such as slides and meteorites can be considered point sources. This constitutes an important difference regarding wave propagation, as point sources tend to produce comparatively shorter wavelengths which are dispersed more quickly with increasing distance than the longer waves generated by extended sources. Whereas the earlier model of the La Palma slide by Ward and Day (2001) failed to address this effect correctly, in the meanwhile more sophisticated codes, such as the SAGE code developed at the Los Alamos National Laboratory (Gisler et al. 2005) have become available which allow these effects to be handled more adequately. The modelling uncertainty already starts, however, with the assumptions on the slide mechanism as such – a single block slide as opposed to slide series – and on slide velocity, and it continues with the way in which the slide energy is transformed into tsunami waves. More observational data on slide mechanisms and velocities and their coupling to wave generation are urgently needed in order to constrain the assumptions which go into the modelling process.

To assess the risk in terms of expected losses, hazard assessment has to be supplemented by vulnerability data, which are, again, scarce. For example, along the affected Thai coast, the Boxing Day 2004 tsunami produced an average loss of about 4% of the total exposed values in the stricken municipalities. Whereas this may seem surprisingly low, the fact must be taken into account that the damage was heavily concentrated in the first row of buildings and that the average figure includes a large number of unaffected structures farther inland. Using the 4% figure and assuming a recurrence period of 1,000 years – not unreasonable for the Thai coast – this translates into a net rate of 0.04 ‰, which gives a very rough idea on the required average insurance rate for this most frequent type of extreme event. Clearly this average figure would be higher along the northwest coast of Sumatra and probably also the east coast of Sri Lanka, and should be differentiated according to location, distance from the coast and construction type.

Earthquake tsunamis cannot be considered uninsurable, with the usual policy or treaty limits in force, even for the most serious scenarios. Such scenarios could be, for example, a repetition of the earthquake offshore Portugal in 1755, when the ensuing tsunami not only destroyed nearby coasts but even affected the Lesser Antilles and the east coast of North America. Another example would be a tsunami triggered by a magnitude 8 earthquake on the Aegean subduction zone, which could affect a large portion of the coasts in the eastern Mediterranean, or a more local tsunami caused by an earthquake on the Nankaido trough south of central Honshu. In respect of earthquake tsunamis, assessing the hazard and loss potential is a problem for which a solution is usually possible. This also applies to volcanic eruptions as a causative mechanism, but with a somewhat higher uncertainty regarding event frequencies and propagation of the tsunami waves. As discussed above, submarine slides and meteorite impacts are a different matter. This is due not only to a lack of research but also to the fact that some tsunamis – including the 2004 event – do not leave long-lasting traces which would be amenable to later geological research. In addition, there is great uncertainty about the propagation of tsunamis caused by point sources such as submarine slides, volcanic flank collapses or oceani metorite impacts. Therefore, estimates of tsunami height on the east coast of the US in the wake of the hotly debated case of a flank collapse on La Palma in the Canary Islands vary from a few centimetres to 25m – an intolerable solution for any decision-maker. As long as such enormous disparities exist, the insurability of non–earthquake-generated tsunamis is an open issue.

Conclusions

The well-known risk management approach which consists of the consecutive steps of identifying the hazard, assessing the risk and eventually defining and taking measures to control and reduce the risk is also suitable for the discussion of extreme natural events. Nevertheless, extreme events present particular challenges and requirements, which are summarised below:

Hazard and risk assessment: A quantitative, probabilistic assessment of the hazard suffers from the lack of reliable and cross-checked event catalogues. The situation is best for earthquake- and volcano-induced tsunamis (NGDC online), but there is room for improvement even here. This applies to a clearly higher degree to volcanic flank collapses in ocean islands and to submarine slides. Much more geological and geophysical field work is needed in order to improve the existing inventories of events. The new technique of side-scan SONAR for mapping oceanic topography has great potential for enhancing inventories of past submarine slides. More observational data are also needed to constrain the input parameters for modelling the tsunami hazard from slide-generated tsunamis. These data have to obtained by the meticulous investigation of events which often happened far in the geological past.

Risk assessment/vulnerability: Although direct empirical evidence of vulnerability is usually lacking due to the rare occurrence of extreme events, it is possible to draw analogies from smaller-sized or similar events. The South Asian tsunami in 2004 offers a unique chance to collect empirical loss data, but sufficiently reliable statistical data have so far only become available for the Thai coast.

Risk control: Compared to the risk of more common disasters as earthquakes, windstorms and floods, which can by and large be controlled by introducing policy or treaty limits, complete exclusions from the coverage have probably to play a greater role for extreme hazards. An important first step is to identify and eliminate ambiguous policy wordings which may produce hidden accumulations. An example is the term "tidal wave", which could lead to unintentional tsunami coverage under flood policies. As regards proactive risk prevention, nothing specific can be achieved over and beyond the measures used for the more common risks. The unique feature that some or even ample warning time will usually be available does not mean much in terms of reducing and preventing material losses. A systematic discussion on how the insurance sector should handle the risk of extreme disasters has not yet taken place, and is indeed overdue.

In conclusion, one could argue that submarine slides as such would not represent a great challenge for the insurance industry - unless great and high-value installations of the oil and gas industry were affected. But what is very dangerous for well developed coastal areas are the tsunamis which unavoidably follow after, although there are signs that the far-field threat of slide generated tsunamis has been overstated by some authors in the past. Even so, the remaining threat is great enough to justify increased efforts aimed at improving global event databases, hazard assessment and scenario-based risk assessment.

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