1 Introduction

Natural hazards are becoming increasingly significant these days. It is not only that we are growing ever more aware of natural disasters thanks to the direct and almost complete coverage by the mass media, but also that exposure to catastrophes is constantly increasing. The factors responsible for this development are the increase in the world's population and settlement in areas that were previously avoided, as well as the development of highly sensitive technologies and their use in regions that are becoming more and more exposed. Added to this, there is the ever-growing concentration of economic values in large cities and industrial areas, which greatly increases the potential for catastrophes and gives rise to grave concern. Finally, the changes in the environment caused by man have already increased the danger even further at many locations around the world. More than ever before, there is a need for documentation that concisely presents the type and magnitude of natural hazards as an aid to political and economic decision making.

In recent decades, numerous maps showing the geographical distribution of natural hazards have been published. Most of these maps are limited to

- the description of individual types of hazard, so addressing but a part of the actual problem
- the description of just one area which makes worldwide comparisons impossible
- the indication or assessment of exposure on the basis of subjective criteria which means that results cannot be reduplicated or quantified

Our map is intended to avoid these and other deficiencies. In particular, exposure information has been stated, as far as possible, as numbers which can be checked and used directly in underwriting calculations. Exposure is a quantity that relates the occurrence/frequency and intensity of a hazard to a specific time interval and so is always expressed in terms of probability. Whenever possible, therefore, the hazard information on the Word Map has three essential components – intensity, frequency and reference period.

As a rule, the calculation of exposure is based on retrospective analysis, but its prime objective is an attempt to predict the future. The frequency of specific events in the past is extrapolated into the future under the assumption that there will be no or only minor changes in the frequency. This assumption is, of course, not always justified. We have all heard – today more than ever before – about changes in climate and the environment that have a considerable effect on a number of the hazards that have already been mentioned. Both at a local and a global level, earthquake phenomena exhibit periods of increased or reduced activity. Furthermore, reports on previous catastrophes are hardly applicable to current conditions and relate only to the regions that were populated at that time. On the other hand, it is precisely such historical reports that provide an indication of exposure in many areas. For this reason, the comprehensive catalogue of past natural catastrophes that has been compiled for the second part of the publication must be seen as an important source of information about the exposure in those countries and regions which can be used for an exposure analysis.

2 Description of natural hazards

The following hazards are depicted in the World Map of Natural Hazards

- Earthquakes
- Seismic sea waves (tsunamis)
- Volcanic eruptions
- Tropical cyclones
- Extratropical storms (winter storms)
- Tornadoes
- Regional storms, monsoon storms
- Storm surges
- High waves
- Heavy rain
- Hailstorms and lightning
- Pack ice and iceberg drift
- El Niño, climate change

A number of other hazards have been omitted because they cannot be shown satisfactorily on a world map as they are too localized or because adequate statistics are not available – this applies to inundations and landslides in particular. The list of major natural catastrophes of the past in the second part of the brochure which presents all natural hazards as comprehensively as possible is an attempt to rectify this deficiency.

A special mode of projection has been used to produce this map and provides a sensible compromise between the unavoidable distortion of shapes and the misrepresentation of distances. The separation between circles of latitude can be used to determine approximate distances as 10° to 10° (north to south) always represents 1.111 km. On the globe, the scale that has been provided can be used to read off all distances in a variety of units. As we wanted to emphasize the information on specific types of exposure, we decided to dispense with any kind of detailed geographical background information. Only coastlines, national borders and major cities and rivers have been indicated to give the reader a rough idea of the geographical location. The publication also presents the most frequently used earthquake, windstorm and tsunami scales and a wide range of other useful information.

2.1 Earthquakes

Earthquakes are generally regarded as the most destructive force of nature. While a long-term world-wide comparison shows that the number of deaths and the magnitude of economic losses caused by storms and floods by far exceed those by earthquakes, it is nevertheless true to say that no other natural phenomenon creates such a massive psychological shock. Since they are capable of causing severe damage over relatively large areas, earthquakes obviously have an enormous destructive potential. This was confirmed by the earthquakes in Northridge (California) in 1994 and in Kobe (Japan) in 1995. The losses were US$ 44 billion and US$ 100 billion respectively. The possible total cost of a major earthquake occurring today in California is estimated to be US$ 300 billion and in Tokyo even as high as US$ 1,000 to 3,000 billion. There are also a large number of regions with high concentrations of population and economic activity that are situated in zones of high seismic activity. For the insurance industry in particular, the problem of accumulated losses, which could threaten economic ruin, is therefore rapidly becoming a matter of great urgency. In view of this situation, it is essential to have an objective picture of the exposure to this hazard. Indeed, only on this basis can appropriate precautionary measures be taken – for example realistic premium calculations, accumulation control and the establishment of reserves or structural improvements to buildings and restrictions on land use.

Earthquakes and plate tectonics

More than 90% of earthquakes occur in regions where large tectonic plates meet. These plates are shown on auxiliary map 1, as is the direction in which the plates are drifting and their speed. The relative motion of the adjacent plates is used to define three types of plate boundary:

- Convergence zones: Here plates collide and the specifically heavier (generally the oceanic plate) is subducted under the lighter (generally the continental plate) Example the subduction of the Nazca plate under the South American continent
- Divergence zones: Here plates move apart as a result of the formation of new crust on oceanic ridges and the continental trench zones. Example: the Mid-Atlantic ridge.
- Transform faults Here plates move past each other horizontally Example the San Andreas fault in California

It seems self-evident that the most severe earthquakes should occur in convergence zones where there is a large variation in the stress profile Convergence zones are followed by transform faults and divergence zones

Auxiliary map 1 also shows the areas where volcanic activity occurs as an immediate consequence of plate movement. In this case too, there is a correlation with exposure Volcanic activity in convergence zones is explosive (ash and glowing clouds), but is effusive in divergence zones (lava streams).

Exposure grading

The earthquake risk is graded according to the intensity that is to be expected once in a period of 475 years. In a period of 50 years, which corresponds to the mean service life of modern buildings, the probability that this value will be exceeded is 10%. This definition of risk has been chosen in line with the most frequently used international probability level in anti-seismic building design codes. For shorter or longer periods, the probability that this value will be exceeded is correspondingly smaller or larger as the following table shows:

Period	Probability of being exceeded
years	%
10	2
25	5
50	10
100	19
250	41
500	65
1.000	88

The earthquake intensity is expressed in terms of the 1956 version of the Modified Mercalli Scale (MM). The new European macroseismic scale (EMS-92) is only applicable to Central and Northern Europe. This and other common scales are presented in the sequel. An approximate correlation with the maximum horizontal ground acceleration as defined by Medvedev and Sponheuer is also stated. The advantage of intensity is that it describes the effect of earthquakes at the surface of the earth and integrates a number of parameters such as ground acceleration, earthquake duration and subsoil effects. EMS-92 is an attempt to find a uniform definition of the various grades of intensity which provides for better quantification and so easier comparison. Even though there is a degree of subjectivity that cannot be eliminated, intensity is the only way of including historical earthquake reports in risk analysis and so extending the period over which statistical analysis can be conducted. Earthquake exposure is classified using five zones.

Zone	Probable maximum intensity (MM) once in 50 years (probability of being exceeded: 10%)
0	V or below
1	VI
2	VII
3	VIII
4	IX or above

Generally, the intensity values refer to average subsoil conditions (firm sediments). Local subsoil conditions may result in exposure differences in areas too small to be visible on a world map. The following table states the mean change in intensity for various subsoil conditions These changes only apply to particular sites. If used for larger areas, they should be reduced according to the type of subsoil generally found in the area

Subsoil	Mean change in intensity
Rock (e g. granite, gneiss, basalt)	−1
Firm sediments	0
Loose sediments (sand, alluvial deposits)	+1
Wet sediments, artificially filled ground	+2

The intensification effect of soft subsoil is partially due to a shift in ground motion to longer oscillations which are potentially more destructive in relation to buildings. This effect is greater further away from the epicentre than it is close to it Depending on the thickness of the sediment layer, there may be resonance effects which amplify ground movements several times within a narrow frequency spectrum (well-known example: Mexico City).

A special symbol is used to indicate large cities where resonance effects of this kind have been observed, or are probable, because of the combination of subsoil conditions and very distant, large earthquakes. Usually, taking this resonance effect and other secondary ground effects (e.g. liquefaction, faults and ground settlements, landslides) would require detailed local investigations.

2.2 Seismic sea waves (tsunamis)
Seismic sea waves, generally referred to by the Japanese word "tsunami", occur after strong seaquakes or large submarine landslides often induced by earthquakes or volcanic eruptions in the sea or on the coast (see 2.3). These waves spread out in all directions at a great speed which depends on the depth of the water. In the great oceanic basins, the mean speed is about 700 km/h. Although the waves are hardly noticeable in the open sea, they reach gigantic proportions in deep coastal waters, especially in narrow bays (in shallow waters they die away before they even reach the coast). In Hawaii and Japan, for example, waves of this kind suddenly hitting the coastline have been known to reach 30 m in height, destroying long sections of the coast. As the waves can travel 10.000 km or more without much attenuation, regions that have not experienced any direct earthquake effects can be affected (e.g. Japan by the Chile earthquake in 1960) This is why a tsunami early warning service has been set up for the whole circumpacific zone. The World Map indicates those coasts known from experience to be exposed to tsunamis Exposure is limited to regions directly on the coast, but under worst case conditions may extend about 1 km inland With a rapidly increasing number of major industrial areas and large hotels being built along coastal regions, the tsunami risk has become considerably higher

2.3 Volcanic eruptions

The World Map shows all volcanoes with known eruption dates within the last 10,000 years. There are three classes of volcano.

Class 1: Last eruption before 1800 AD
Class 2: Last eruption after 1800 AD
Class 3: Volcanoes which are categorized as particularly dangerous by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI).

Class 1 volcanoes are often commonly held to be extinct, but to assess volcanic activity periods as long as hundreds or even thousands of years are required. An example that illustrates this is the eruption of Pinatubo on the Philippines. Before the eruption in 1991, the last time it became active was 600 years previously. The volcano El Chichon in Mexico was considered to be totally extinct before it erupted in 1983.

There are several risk factors associated with volcanoes, the principal being:

- Ashfalls
- Tidal waves
- Lava and mud flows
- Glowing clouds
- Volcanic earthquakes

These phenomena vary from volcano to volcano. Whereas ashfalls and tidal waves can cause damage over relatively large areas, the other phenomena only present a danger to the area in the immediate vicinity of the volcano and so are easier to record. The spread of ash depends on the direction and force of the wind and so the risk for regions further afield is difficult to estimate. The impact of tidal waves, caused by volcanic eruptions under lakes, seas and on the coast is comparable with that of seismic sea waves. All the phenomena that have been referred to have a great potential to cause damage as the history of natural catastrophes tells us (see the catalogue of catastrophes).

It is, however, very difficult to assess and, as is the case with earthquakes, classify the actual exposure. On the one hand, eruptions are usually too rare for reliable statistical analysis and on the other classification in terms of intensity would scarcely seem possible. However, the use of the latest instruments to make short and medium term predictions would seem to be considerably more promising than the same approach with earthquakes as a few successful cases (Rabaul, Montserrat) show.

2.4 Windstorms

In terms of frequency of damage and total area affected, storms are, world-wide, the most significant of all natural hazards. This applies particularly to losses covered by insurers who in recent years have had to pay out unprecedented amounts for storm damage. Over the period 1988 to 1997, two thirds of the claim payments (US$ 130 billion) for natural catastrophes were occasioned by storms. The World Map shows the areas exposed to the most significant types of storm. Storm force is reached when the wind speed is at least 8 on the Beaufort scale, i.e. 62 km/h. The main map shows the regions endan-gered by tropical storms (hurricanes, typhoons, cyclones) and extratropical storms (winter storms).

Auxiliary map 3 "Regional Storms, Monsoon Storms, Tornadoes, Hailstorms" gives an overview of types of storm which may only affect less extensive regions but still cause an enormous amount of damage.

Auxiliary map 2 covers risks posed by heavy rain and lightning. The exposure zones indicated depict regions with heavy rainfall and high thunderstorm activity. Rain and thunderstorms are often associated with strong gusts. In the tropics, the monsoon months indicate the seasonal distribution.

2.4.1 Tropical cyclones

When tropical storms reach 12 on the Beaufort scale, they are called "hurricanes" in the Atlantic and Northeast Pacific, "cyclones" in the Indian Ocean and in the seas around Australia and in the South Pacific and "typhoons" in the Northwest Pacific. If the wind speed is below hurricane force, i.e. 62 to 117 km/h (Beaufort 8 to 11), they are referred to as "tropical storms".

The particular hazard presented by these storms is their ability to hit large areas with wind speeds of up to 250 km/h, in some cases even over 300 km/h. The diameter of the hurricane area is usually 100 to 200 km, while the storm area may be 200 to 500 km wide. Coastal regions and islands are particularly exposed as they are affected not only by the direct impact of the storm but also by the additional hazards of storm surges and the surf. The intensity of a storm rapidly decreases as it moves inland because of the increase in friction above the surface of the earth and a reduction in the supply of energy (primarily from water vapour) to the storm system. On the other hand, this also causes huge amounts of rain-fall – especially on the windward side of mountains, frequently resulting in extremely severe floods.

For many coastal regions which have a high economic potential and recreational value and so encourage migration, tropical cyclones have an extraordinary catastrophe potential.

On the World Map, the degree of exposure is represented by the 5-level Saffir-Simpson scale SS (to hurricane force) which is basically the storm intensity that can be expected once in 100 years.

Zone 1:	SS 1 (118 to 153 km/h)
Zone 2:	SS 2 (154 to 177 km/h)
Zone 3:	SS 3 (178 to 209 km/h)
Zone 4:	SS 4 (210 to 249 km/h)
Zone 5:	SS 5 (≥ 250 km/h)

Example: South Florida, USA (zone 4): In this region, the 100 year wind speed is 210 km/h or above.

Apart from the storm risk which is indicated by green areas, the Map also shows the main tracks of the tropical cyclones. On a case by case basis, there are wide variations but the mean tracks indicate the usual direction from which danger threatens. This is also important because in the northern hemisphere the speed of rotation and forward movement are added on the right-hand side of the track and in the southern hemisphere on the left – so that the highest wind speeds occur on these sides in each case.

2.4.2 Extratropical storms (winter storms)

Extratropical storms differ from tropical cyclones not only in terms of the areas in which they occur and the tracks they follow, but also, and above all, with regard to the physical processes by which they are generated. There are also substantial differences in intensity and geographical coverage. Extratropical storms are created in the transition region between subtropical and polar climatic zones, i.e. in the latitudes between about 35° and 70°. In these regions, cold polar air masses collide with warm subtropical air masses, forming extensive low-pressure eddies. The intensity of the storm areas within these eddies is proportional to the difference in temperature between the two air masses and is, therefore, at its greatest in late autumn and winter when the oceans are still warm but the polar atmosphere is already cold. This is why extratropical storms are also referred to as winter storms. The maximum wind speed of extratropical storms is approximately 140 to 200 km/h and under extreme conditions may reach 250 km/h. The storm areas can be up to 2,000 km wide. Over land these values are considerably modified by topographical effects. In general, the wind speed increases with height above sea level and at the same time there are horizontal and vertical deflection, blocking, jet and lee effects.

Blizzards and ice storms are variants of this type of storm and their potential for causing damage is often underestimated. In January 1998 an ice storm covered large areas of East Canada and the North East of the USA with a layer of ice that was several centimetres thick and caused total damage that was estimated at over US$ 1 billion. The largest geographical area to be covered this century was in all probability an enormous region from the New England states to Texas. This occurred in 1951, 28th January to 4th February, when an ice storm left a layer of ice that was 10 cm thick in some places.

Extratropical storms cannot be shown in detail on the World Map because of the strong influence local topographical effects have on storm exposure. A special shading is used to indicate those areas that are at an increased risk and also the main tracks of the storm lows are shown by arrows (see main map).

2.4.3 Tornadoes

As with tropical cyclones, a number of names are used in conjunction with tornadoes. Often it is only the common regional designation, for example "tatsumaki" in Japan or "Trombe" where German is spoken. A tornado that occurs over water is referred to as a "waterspout".

This type of storm can be described as follows. Compared with tropical cyclones and extratropical storms, tornadoes are very localized but extremely intense. The mean diameter of the typical tornado funnel is about 100 m, the mean track but a few kilometres long. However, tornadoes that have been more than 1,000 m wide and with tracks of up to 300 km in length have been observed. The maximum wind speed at the edge of the funnel is estimated to be over 500 km/h; most tornadoes however only have wind speeds slightly in excess of 100 km/h. The direct damage caused by the high wind speeds is exacerbated by the sharp drop in air pressure (10% or more) at the centre of the funnel, which causes windows with tight seals (e.g. in air-conditioned buildings) to "explode".

Tornadoes occur worldwide at latitudes between 20° and 60°, but are most frequent by far in the USA in spring and summer. Tornadoes also reach their greatest intensity in the Mid West of the USA owing to the particularly violent nature of thunderstorm cells. However, in general, it can be said that this type of storm can be observed throughout the whole of the year – in other words even sometimes in the winter. The greatest tornado loss so far occurred in the USA in April 1974 when 93 tornadoes were observed within 2 days. They caused an estimated total damage of US$ 1,000 million, approximately US$ 430 million of which was insured.

However, even single tornadoes can cause damage amounting to several hundred million US dollars. Significant losses have also been caused by tornadoes in Europe, India, Japan, South America, South Africa and Australia.

The World Map (auxiliary map 3) has 5 exposure zones based on the mean annual number of tornadoes per 10,000 km^2

	Tornadoes/10,000 km^2/year
Zone 1	0.01 to 0.1
Zone 2	0.1 to 0.5
Zone 3	0.5 to 2
Zone 4	2 to 10
Zone 5	> 10

As in many regions – particularly thinly populated ones – complete tornado records cannot be compiled, this exposure map cannot provide a complete global overview. Rather it is intended as a first step to providing exposure information comparable to the earthquake and cyclone zones which the insurance professional can use to determine premiums and identify possible damage potential. Regions with scattered but significant tornado events in the past – outside the stated exposure zones – have, therefore, been marked with a special symbol (e.g. in South America, Russia, Australia).

The Fujita tornado scale describes the intensity of a tornado in terms of its maximum wind speed. The currently common form covers a speed range from 62 km/h to over 400 km/h and has six levels from F 0 to F 5. Newer estimates suggest that the introduction of a further level F 6 (> 493 km/h) would be sensible.

2.4.4 Regional storms, monsoon storms

Most of the storms marked on auxiliary map 3 "Regional Storms, Monsoons, Tornadoes, Hailstorms" with arrows can from the meteorological point of view be clearly classified as orographic storms. Their common feature is that they arise on the lee side of mountains if the air at the windward side is colder than that at the lee side. Then, the cold air, because of its great weight, can only tumble down into the valleys below from the mountain ridge and high passes. The greater the temperature difference and the height, the greater the velocities. If these downward currents are superimposed by a large-area air-stream travelling in the same direction, wind speeds of up to 200 km/h can be reached.

The best known examples are the Bora on the Dalmatian Adriatic coast, the Föhn in the Alps, the Mistral in the Lower Rhone valley and the Chinook in the Rocky Mountains. However, these downwinds can be observed in every mountainous region of the world – in particular on the edges of the moderate climate zones. The creation of storms of this kind is so dependent on topography that they always occur at the same locations or in the same valleys and with the same wind direction. Because the cold air often plummets down like large drops, the air stream is generally very gusty; this is particularly hazardous for shipping in coastal waters near mountain ranges.

The monsoon storms which occur regularly and with great persistence in early summer around the Horn of Africa are an independent storm phenomenon of regional significance which considerably jeopardize and hinder shipping in that area. The isolines shown on the map reflect the high frequency of storm hours in June.

2.5 Storm surges

Storm surges continue to claim an extraordinary number of lives. They also have an immense potential to cause damage. Almost all the coast lines of the world's large oceans, and inland seas and large lakes are exposed to storm surges to a greater or lesser extent.

Depending on the type of coast, the danger is inundation and wave impact on the one hand and beach erosion on the other. The special aggressiveness of the saltwater must also be considered in this context. The high damage potential of storm surges lies in the high concentration of economic values along the coasts.

Storm surges only occur when the normal tide level along the coast is raised considerably by the following effects:

- Astronomical tide
- Run-up
- Low pressure
- Surface waves

The amplitude of astronomical tides depends essentially on the geometry of the local coasts. It can be as high as 12 m. The run-up effect is influenced by the direction, strength, duration and fetch of the wind. A further increase in sea level of up to 1 m can be caused by low atmospheric pressure which allows the water surface to rise. Furthermore, surface waves can cause sea water to lap over protective dams and walls. High waves and the resulting breakers can exert enormous mechanical forces which erode beaches and protective dikes as well as cliffs. In addition to the tide and the meteorological factors, the coast geometry plays a decisive role. Storm surges can cause a very high water level where water is piled up by the wind and cannot escape to the side or below. Gulf-like, flat seas, funnel-like estuaries and long lakes are particularly susceptible.

The regions that are most exposed to storm surges, therefore, are the Gulf of Bengal, the South China coast, various bays in Japan, the coasts of the Gulf of Mexico, the American East coast, the Rio de la Plata in South America and the North Sea Coast in Europe. The Great Lakes of North America, the Baltic Sea and Lake Baikal are also exposed to increased risk from storm surges.

On the World Map, coasts which are threatened by flooding from storm surges are marked with a line parallel to the coast. A graduation of the level of risk is not possible as, in general, the differences are highly localized. Even coasts that are only threatened by erosion are not marked (e.g. Californian Cliffs).

The obvious global rise in sea level increases the risk of storm surges. The frequency of flooding will increase along badly protected coasts (e.g. Bangladesh), and on well protected coasts (e.g. around the North Sea) the probability of failure of sea defences will increase (see auxiliary map 4).

2.6 High waves

For many decades, the heights of waves have been measured by ships and buoys. Now, satellites are able to provide wave height data continuously and with full coverage even from the most remote sea areas. Particularly dangerous are freak waves – rarely occurring waves of extreme size which may arrive unexpectedly from almost any quarter. They are produced by the superimposition of a number of different waves or by the influence of sea currents.

Regions where wave heights in excess of 5 metres have a probability of occurrence of 10% p.a. (10 year waves) are shown on the World Map. Waves of this height can be a hazard for medium-sized ships. It is precisely when ships' cargoes are sensitive that problems can occur at the loading hatches and considerable damage may result if the cargo is not secured properly.

High waves mostly occur during the winter storm season, i.e. in the northern hemisphere from December to February and from June to August in the southern hemisphere. Tropical cyclones also produce extremely high waves.

2.7 Heavy rain

The annual precipitation rate varies widely from region to region. In the North East of India the rainfall is more than 10,000 mm (10 m!), in the Atacama Desert in Chile less than 10 mm. The global mean annual rainfall level is about 1,000 mm, equivalent to 1,000 l/m^2.

The map showing exposure to heavy rain (auxiliary map 2) indicates the global distribution of the observed maximum values for 24-hour rainfall. These locally measured rainfall values are an important indicator for flash floods, particularly when the values are high in comparison with the monthly total (or even the annual total) for the region in question.

The highest values occur, as would be expected, in the tropics. In central and higher latitudes, the daily total drops considerably. However, even values of around 100 mm can cause extensive local flash floods, particularly when they occur in what would otherwise be low-rain (arid) regions.

In a number of insurance lines, heavy rainfall can lead to considerable claims. In these lines, extra information should be obtained to aid risk assessment. The Roman numbers indicate marked rainy seasons and the key months in which increased caution is advisable.

2.8 Hailstorms and lightning

Thunderstorms are one of the most impressive natural phenomena. Since time immemorial they have fascinated and terrified mankind. At any one time, about 1,500 thunderstorms are taking place all over the world with hardly any region being unaffected. Thunderstorms often lead to adverse weather with intense lightning, hail, rain and wind (see also chapters 2.4 and 2.7).

Lightning strikes are the main cause of natural fires which can destroy whole forests and often buildings. In many regions, lightning strikes cause more fatalities and injuries per year than any other natural hazard. Air traffic avoids thunderstorms because of strikes to aircraft which can be critical especially at the take-off or landing stage.

Another significant source of potential damage is lightning induced overvoltages in electrical equipment and in electronic function or control units in particular. Power grids and transformer stations are frequently being damaged by strikes and the result is business interruptions.

Since 1995 lightning activity has been recorded worldwide by satellites. This data is the basis for our presentation of the lightning risk (see auxiliary map 2), as well as the observation data from ground based lightning measurement networks.

The map shows areas with > 2 lightning strikes per square kilometre per annum and > 6 lightning strikes per square kilometre per annum. The first level roughly corresponds to the lightning strike risk in Central Europe, the second to regions with a very high lightning strike density (e.g. Florida). The proportion of lightning strikes that reach the ground as a global mean is below 50% and may be as low as 10% for tropical thunder clouds. Most lightning strikes are dissipated between the clouds over the continents.

Hailstorms cause extensive damage to agriculture and also to buildings and vehicles. If extreme hailstorms occur over large conurbations, the economic and insured damage can run to billions.

Heavy hailstorms are usually triggered by wide cold fronts. By contrast, local hot-weather thunderstorms, produced as a result of intense insolation over land or mountain slopes, as a rule only lead to weaker localized hailstorms.

An important precondition for hailstorms is a sharp decrease in temperature with altitude (unstable layers). This gives rising air at ground level a strong uplift and results in a high upwind zone with powerful cloud formations (cumulonimbus with typical anvil form). In an upwind zone of this kind, hail particles are suspended in the upper section of the cloud so that water droplets and ice crystals cling on to them and the hail stones grow in layers. When the weight of the hail stones becomes too great or the upwind weakens, the ice seeds fall from the cloud and it begins to hail. Isolated, heavy hail tracks, which accompany large thunderstorm systems (super cells) may be over 10 km wide and several hundreds of kilometres long. They can often bring heavy rain, lightning strikes and stormy gusts with them, which also increase the extent of the damage.

The map showing hailstorm exposure (see auxiliary map 3) provides the following information.

- The marked areas indicate regions where > 1 and > 3 hail days per year occur. No indication of the intensity of the hail is given.
- Special symbols indicate the regions exposed to hail hazards and which in the past have suffered extensive damage from hailstorms. In regions marked with these symbols, heavy hail must occasionally be expected.

2.9 Pack ice and iceberg drift

Pack ice and iceberg drift, for the most part, affects sea traffic and so has a bearing on marine insurance. Iceberg drift is almost as unpredictable today as it was in the past when there was a number of spectacular disasters. Nowadays, ice phenomena seem more significant economically because sea traffic can be obstructed to a great extent. Pack ice can even make major seaways impassable for long periods.

The high speeds that are reached, say, by modern container ships and the limited manoeuvrability of, say, supertankers also increase the risk. Numerous recent accidents demonstrate this. The increase in the transportation of hazardous goods and the value of the cargo also contribute to the risk for owners and insurers.

The World Map shows the maximum extent of the pack ice over the year (winter/spring) by means of a spotted pattern in the appropriate regions. Around these regions is the line of iceberg drift which gives the limits within which icebergs have been observed in the past.

2.10 El Niño, climate change

Auxiliary map 4 provides information about the El Niño phenomenon (natural climate fluctuation) and the emerging worldwide change in climate due to additional greenhouse gas emissions (anthropogenic climate change). Both have an effect on the weather and the climate and so consequently on natural hazards associated with the atmosphere. They change the risk profile and in some regions of the globe this will be considerable.

El Niño

El Niño is the name for a relatively rapid warming of the equatorial Pacific by around 1° to 5° C within a few weeks. Maximum warming occurs around Christmas (hence the name "the Christ Child"). Strong El Niño effects are, however, observed beyond December and they may persist for many months and in some cases years. The temperature increase involves the uppermost 100 to 400 m of the East Pacific in particular between about 10° S and 10° N. The cause of the warming is assumed to be a temporary reduction in the trade winds where the warm surface water that builds up in the west "laps back" to the east and floats on the cold upwelling waters along the South American Pacific coast. It is an interaction between atmospheric and oceanic anomalies and this is why scientists refer to it as the El Niño Southern Oscillation Phenomenon (ENSO).

Every El Niño event is sui generis and in the regions affected may sometimes be stronger and sometimes weaker.

The effects of natural hazards which are shown on the map are now considered to be well verified:

- Extreme rainfall, flooding and storms along the Pacific coast of North and South America and in East Africa

- Strong increase in cyclone activity in the Mid and Eastern Pacific and a reduction in the hurricane activity in the North Atlantic including the Caribbean

- Extraordinary dryness with high risk of drought and forest fires on the western side of the Pacific from Australia past Indonesia and along to the Philippines, presumably also on the Indian subcontinent, in South Africa, in the Sahel zone and in north eastern South America

Various lines of the insurance business will be affected in a number of ways and the insurance industry would be well advised to take El Niño into account in its premium and acceptance policies Because of the random nature of major and worst-case catastrophes, the insurance industry will not necessarily be under more strain due to natural catastrophes in the El Niño years than in the opposite situation (La Niña – cooling of the equatorial Pacific).

Anthropogenic climate change
The emerging man-made warming of the atmosphere oceans and continents is caused by the release of climate-influencing trace gases into the atmosphere – in particular carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs)

Below are some effects relating to natural hazards that have already been observed or that are expected to appear in the next century

- Since the middle of the 19th century, the mean global temperature has risen by about 0.5 to 0 7°C By the end of the 21st century, the mean global temperature will have gone up by a further 1 to 3°C. The zones in auxiliary map 4 show that the geographical distribution of warming is very differentiated and there is even cooling at a few locations.

- The majority of mountain glaciers are melting as are parts of the Arctic and Antarctic (in a few regions growth is observed). The map indicates the appropriate regions

- The sea level is rising faster and faster (melting of glaciers, thermal expansion of sea water) and will be 20 to 80 cm higher in the next century. Critical regions (endangered islands, deltas and sections of coast) are indicated on the map.

- The map also shows the retreat of the permafrost limit in the polar regions. Permafrost occurs frequently in the polar regions and around high mountains. Melting affects the stability of the mountain slopes and landslides are the result. Also, methane is released, which further increases the greenhouse effect

- The warmer atmosphere can absorb more water vapour and intensify convection processes. Therefore, more heavy rain, flash floods and landslides, thunderstorms, hailstorms and lightning strikes as well as an increase in tornadoes are a likely result. Possibly not only will the frequency and intensity of tropical cyclones increase but also the seasons and regions in which they occur could expand markedly. The extratropical storm lows could also become more intense and penetrate further into the continents.

- The seasonal and regional precipitation patterns will also change. On the one hand this will increase the risk of floods and on the other hand that of dry periods and droughts.

The insurance industry is well advised to keep an eye on these developments so as to be able to initiate appropriate underwriting measures at an early date. As a result of climate change, it is possible that there will be new extreme values for a large number of parameters that are of relevance to the insurance business in almost all regions of the world which will presage natural catastrophes of unknown intensity and frequency.

Classical rating methods cannot be applied to natural hazards because these events occur so rarely. To nevertheless obtain premium rates commensurate with the actual risk, attempts must be made to simulate the claims experience which cannot be obtained in the real world. The following three steps are essential:

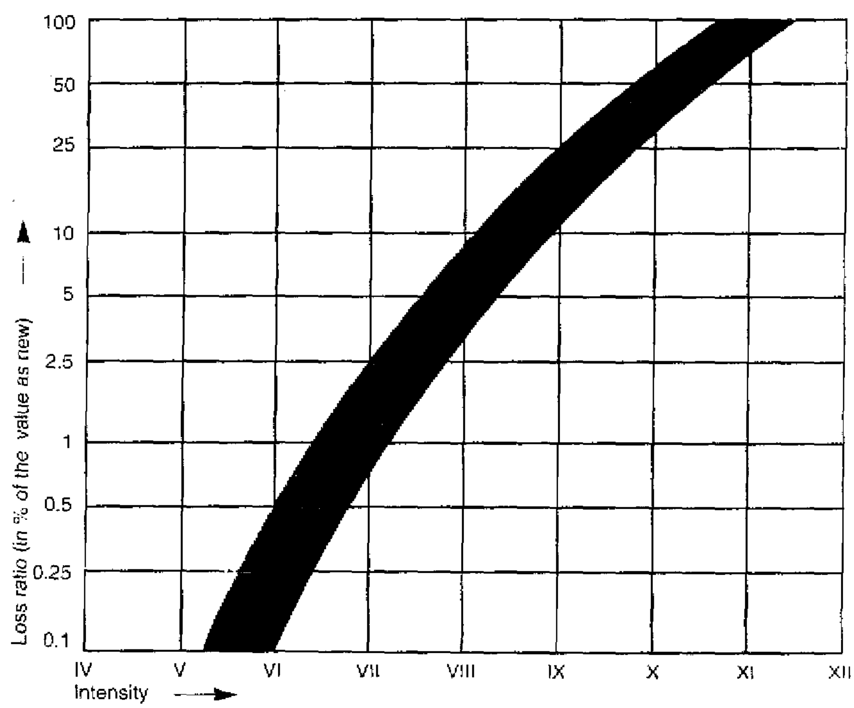
- Determining the event frequency: This is effected on the basis of data from instruments or descriptions of historical events. The historical data which is often available for large-scale events can be used to estimate the probability of smaller events. However, the opposite approach can also be scientifically valid. Seismology uses the frequency of low-magnitude earthquakes to derive the probabilities of major earthquakes. The event frequency, however, says nothing about damage frequency. For this it would be necessary that the geographical distribution of the risks to be insured and their individual damage susceptibility are known.

- Assessment of the risk location: The geographical location of an object has a considerable influence on the risk premium rates. When covering earthquakes, it is, above all, the closeness to the nearest seismic faults and the local subsoil conditions at the risk location that determine the technical premium. In the case of storms, it is the local topographical conditions and with floods the difference in altitude between the risk location and bodies of water in the vicinity. The development of geographical information systems (GIS) has provided insurers with modern IT-supported analysis systems which can perform a detailed exposure assessment of the risk location by linking data on event frequency with individual local risk factors. Also, the geographical distribution of risks when covering whole portfolios can be taken into account in a technically correct way.

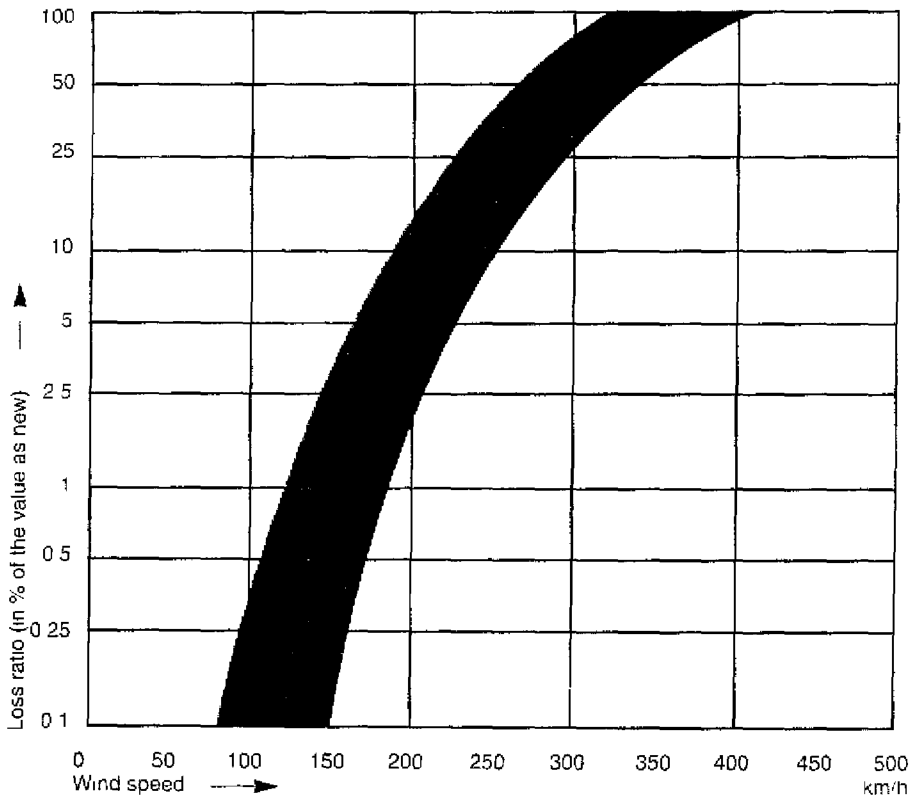
- Susceptibility to damage: The transition to damage frequency is performed in the third step by correlating the expected event intensity with the risk-specific loss ratio. It was precisely the major, high-loss natural catastrophes that took place in the mid 80s (earthquakes in Chile and Mexico in 1985, in Northridge in 1994, in Kobe in 1995, winter storms in Europe in 1990, Typhoon Mireille in 1991, Hurricane Andrew in 1992, etc.) that have considerably expanded the sparse data of the past and have helped correct many risk estimates (often in a positive sense).

Diagram "Earthquake losses": Expected earthquake loss ratios (in percent of value as new) as a function of the local event intensity on the Mercalli scale. The coloured region describes the spread of the expected damage as a function of the different susceptibility to damage for various types of use, assuming average building quality.

Earthquake losses



Windstorm losses



Expected storm loss ratios (in percent of value as new) as a function of wind speed. The coloured region shows the range of types of construction, roof type and shape, materials used, etc and their effect on the expected damage.

The stated loss ratios vary strongly as a function of the type of use (residential, commercial, industrial) and characteristic parameters like the age of the building, height and type of construction A further important criterion is the general standard of building (building specifications, quality and monitoring) in the region in question

By collating the three types of risk information mentioned above (event frequency, risk location and susceptibility to damage) the appropriate premium can be found for covering a particular natural hazard.

If key data for calculating the risk premium is too sparse or no suitable computational models are available, a rough estimate can often be made with an approximation method. Example earthquakes: Making simplifying assumptions, the risk premium P (= net premium required as a percentage of the sum insured) can be expressed as the sum of the loss ratios L per intensity class (Mercalli scale) divided by the return period N_j (in years) of the respective intensity:

$$P = \frac{L_{VI}}{N_{VI}} + \frac{L_{VII}}{N_{VII}} + \frac{L_{VIII}}{N_{VIII}} + \frac{L_{IX}}{N_{IX}} + \frac{L_{X}}{N_{X}}$$

The Munich Re has developed a number of computer models to calculate risk premiums and to determine the cumulative damage potential of natural hazards. Within the framework of the MRCatPMLService (see Chapter 5), we can calculate for our customers the probable maximum loss using their individual liability data and advise them on their optimal insurance strategy.

4 Munich Re services and natural hazards

Since its formation, Munich Re has thought of itself as a customer-oriented partner in the international insurance business. A Geoscience Research Group was set up as early as in the early 70s to analyse the coverage of natural hazards. Now the group includes scientists from almost all areas, from meteorology and climatology through seismology, geology, geophysics and geography to hydrology as well as experts on geographical information systems (GIS).

Therefore, not only can we provide support on matters relating to insurance, but we are also in a position to offer information and advice on historical damage and possible future damage due to natural catastrophes.

MRNatCat*SERVICE*
Munich Re's Geoscience Research Group has been gathering information about natural events and catastrophes all over the world systematically for about 25 years. In addition to the basic data such as event location, date and duration, short descriptions containing relevant information that gives a rapid overview of the magnitude of the events is also compiled. If appropriate information is available, damage to or destruction of buildings, the effect on infrastructure, damage to utilities and agriculture, etc. are noted. The effect on the population (fatalities, injured, homeless, missing persons, etc.) is also listed. Finally, the economic and insurance losses are recorded. This data is crucial for analysis and determining trends.

Customers who make use of the NatCat*SERVICE* will also receive important auxiliary information in addition to a concise and precise description of the event:

- Lists of damage
  according to country or event type. These allow a rapid overview of the more recent history of damage and allows an initial assessment of the exposure in a particular region.

- Comments
  on particular events which are analysed regarding the probability of occurrence (return period) and the magnitude of damage (for example in comparison with other catastrophes).

To obtain information about events of recent months, simply contact the Munich Re directly or use the Reuters Insurance Briefing (RIB), a comprehensive on-line information service run by the Reuters news agency. Concise reports can be called up under "NatCat" (as source or search key).

MRCatPML*SERVICE*
This is the name of Munich Re's product that performs loss accumulation potential damage analyses for earthquakes, storms and floods (only a few countries) on the basis of liability information categorized geographically and according to risk (CRESTA system). Depending on customer requirements, particular historical or hypothetical catastrophe scenarios can be simulated and their effects on individual portfolios estimated (deterministic analysis). Probabilistic analyses can also be performed. In this case, we calculate the probabilities that damage will occur for specific liability situations using our own simulation models. Part of the MRCatPML*Service* is to advise our customers on tailor-made reinsurance strategies.

5 Catalogue of major catastrophes

Natural catastrophes are the best proof of the dangers inherent in nature Every year, all around the world, there are many hundreds of instances of major damage by natural phenomena Earthquakes storms and floods are the most significant events, other natural hazards (cold spells droughts, forest fires, landslides etc.) usually play a subordinate role – apart from a few exceptional cases. The following are the results of an analysis of the worldwide frequency and distribution of events of the last 10 years.

- As far as number is concerned, storms and floods dominate Together they make up almost two thirds of the 6,000 events that were recorded all over the world Earthquakes accounted for about 15% and other events for about 20%.

- Since 1900 natural catastrophes have taken the lives of 10 million people and in the last 10 years there have been about 390.000 fatalities – the striking feature however, is that 58% of the victims were claimed by floods. Earthquakes in particular are also responsible for a consistently high level of victims

- Economic damage is fairly uniformly distributed over the main types of event – earthquakes, storms and floods (about 30% for each) Other natural hazards were hardly significant (10%)

- In the case of insured damage, storms clearly dominated (two thirds) because there is maximum insurance density for this natural hazard all over the world. Earthquakes followed at a considerably lower level (approx. 20%) Worldwide, the role of floods (8%) and other events (6%) is (as yet) not significant.

The catalogue for the World Map lists the most significant historical natural catastrophes (from 1,000 AD to April 1998) under the following headings

- Earthquake
- Volcanic eruption
- Storm
- Flood
- Other natural catastrophes

The events are listed according to continent in chronological order. Additional information is also provided – particularly in relation to the number of fatalities and, whenever possible. the economic loss (value in US$ at that time) When risk is assessed subjectively, the major natural catastrophes are often intuitively considered to be highly significant. However, historical reports often contain gaps, are contradictory on certain matters and usually are difficult to relate to current conditions Nevertheless, they have an important role to play in risk analysis because they considerably extend the period that can be used for statistical evaluation. In a number of cases, it is only through historical reports that one becomes aware of a natural hazard