Knowledge series

Topics Geo
Natural catastrophes 2008
Analyses, assessments, positions

Münchener Rück
Munich Re Group

Contents

Cover:
The picture on the cover shows the city of Galveston on the coast of Texas on 9 September 2008 before Hurricane Ike made landfall.

Inside front cover:
This photo was taken on 15 September 2008 after Hurricane Ike had passed through. Apart from a few exceptions, the entire section of coast was razed to the ground.

Geo Risks Research think tank

Environment and market conditions are changing at breathtaking speed. Demand for new coverage concepts for complex risks is constantly increasing. This calls for experience and continual further development of our specialist knowledge. In addition, we are continually networking with external partners in economics and research and entering into business-related cooperative relationships with leading experts.

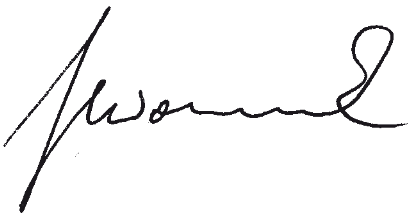
In this issue of Topics Geo we introduce you to some of our current scientific partnerships. Our intent is to pursue research into new and emerging areas of risk, to make them manageable and thus expand the frontiers of insurability. Our latest product in the field of geo risks research is the Globe of Natural Hazards, which documents the geoscientific data and findings we have accumulated over a period of more than 30 years. Since early 2009, the new version has been available as a printed map and in digital form on DVD. Besides providing you with information on the globe's most important innovations, this issue also contains the new fold-up World Map of Natural Hazards.

The natural catastrophe year of 2008 was one of the most devastating years on record. Two events alone, Cyclone Nargis, which devastated large parts of Myanmar in May, and the earthquake in Sichuan (China) on 12 May, claimed the lives of some 155,000 people. The number of persons reported missing is even now over 70,000. Losses of US$ 15bn made Hurricane Ike the costliest natural catastrophe for the insurance industry in 2008. Further catastrophe portraits deal with the exceptional snow losses in China at the beginning of 2008 and the storm series Hilal, which crossed much of Germany in late May. Hilal highlighted the need for improvements in the definition of loss occurrences. The storm series has prompted Munich Re to develop a transparent loss occurrence definition for natural hazards.

For our readers in the United States, Asia, and Australia, we have again prepared topics and statistics of local relevance; these are enclosed in the respective editions.

I hope you enjoy reading this issue of Topics Geo and that the information it contains will be of practical use in your work.

Munich, February 2009



Dr. Torsten Jeworrek

Member of the Board of Management and
Chairman of the Reinsurance Committee

In focus

In 2008, the United States was hit by six hurricanes in close successions – Dolly, Edouard, Fay, Gustav, Hanna, and Ike. Above all, Ike caused billion-dollar losses in the United States and the Caribbean.

Hurricane Ike destroyed almost all the buildings on the Bolivar peninsula in Texas. However, buildings erected in accordance with the guidelines issued by the Institute for Business and Home Safety withstood the winds and storm surge.

Hurricane Ike –The most expensive hurricane of the 2008 season

Ike was the most destructive hurricane of 2008. It was extremely difficult to estimate the loss in the immediate aftermath due to the sheer size of the area affected and the impact of the dramatic storm surge on coastal areas.

Following relatively moderate seasons in 2006 and 2007, 2008 proved to be another year of extremes, underlining the increased warm-phase activity in the western part of the North Atlantic since 1995. Of the 16 tropical storms that occurred in 2008 (including eight hurricanes), Ike was the one which stood out from the rest. With the lowest central pressure recorded in any hurricane that year and average wind speeds of more than 230 km/h, it caused widespread damage in the Caribbean, the USA, and Canada.

Its integrated kinetic energy (IKE) rating of 5.6 – on a scale of 1–6 – broke the record for Atlantic hurricanes. The IKE rating measures the combined destructive potential of wind and storm surge. For comparison purposes, Katrina measured 5.1 on the same scale in 2005. Overall losses from Ike were around US$ 38bn, of which US$ 15bn was insured. Thus, Ike ranks third, just behind Katrina (2005) and Andrew (1992), in terms of loss.

Meteorological development

From tropical disturbance to fully-fledged hurricane with destructive force: Ike had the people in the Caribbean, the USA, and Canada at its mercy for two weeks – with devastating consequences.

1 September – Ike classified as a tropical storm: Following moderate development in mid-Atlantic, the system was categorised first as a tropical depression 9 and, later the same day, as a tropical storm. Ike intensified in mid-Atlantic in the days that followed.

3–6 September – Ike reaches hurricane status: Owing to the lack of wind shear in the atmosphere, the storm virtually exploded, in a mere six hours, into a Category 4 hurricane, peaking on 4 September with a recorded wind speed of 230 km/h (one-minute average) and a central pressure of 935 hPa. Ike weakened to a Category 2 storm in the next few days, but was upgraded to Category 4 on the Saffir-Simpson Scale on 6 September, just before it passed over the Turks and Caicos Islands.

7–9 September – First landfall: On the morning of 7 September, Ike swept across the Turks and Caicos Islands with winds of 215 km/h. It made landfall near Cabo Lucrecia on the north coast of Cuba that evening as a Category 3 hurricane. After crossing the provinces of Holguín, Las Tunas, and Camagüey, it moved out over the Caribbean Sea to the south of the island.

On 8 September, Cuba's south coast was hit for a second time at Pinar del Río. Ike retained hurricane force, but weakened considerably in the mountainous terrain.

10 September – Ike refuels in the Gulf of Mexico: In the night of 9–10 September, Ike intensified sharply as it crossed the surface water of a warm current fed by the Caribbean. The result was a dramatic fall in central pressure from 963 to 944 hPa. However, there was no corresponding rise in maximum wind speeds at the centre, which increased from 140 to only 155 km/h. Instead, the cyclone's structure changed, as energy absorbed from the warm surface waters was distributed over a very large area, creating an enormous strong wind field.

During the next two days, Ike headed northwest towards Galveston and Houston, Texas. Just before landfall on the US coast, the area of hurricane-force winds (up to 118 km/h) had a diameter of nearly 400 km, and the area of tropical-storm winds (up to 64 km/h) almost 900 km. This compares with diameters of 350 km and 700 km respectively in the case of Katrina.

13 September – Severe storm surge as Ike hits US coast: Ike made landfall at 2.10 a.m. on the Texan coast at Galveston, with winds of over 200 km/h (Category 2–3 on the Saffir-Simpson Scale). It continued across the Bay of Galveston before making landfall a second time near Baytown (Texas).

Due to the enormous strong wind field and relatively low translation speeds, Ike triggered a severe storm surge in the Gulf of Mexico of the kind normally associated with a Category 4 hurricane. A band extending almost 500 km along the Gulf Coast between Louisiana and Texas was hit by a storm surge up to 2–4 m deep. Maximum storm surge levels of 6 m were recorded in the Bolivar Peninsula area, the Bay of Galveston, and south of Port Arthur.

Ike soon subsided to a tropical storm, passing Dallas 150 km to the east before changing course and heading northeast as a tropical depression.

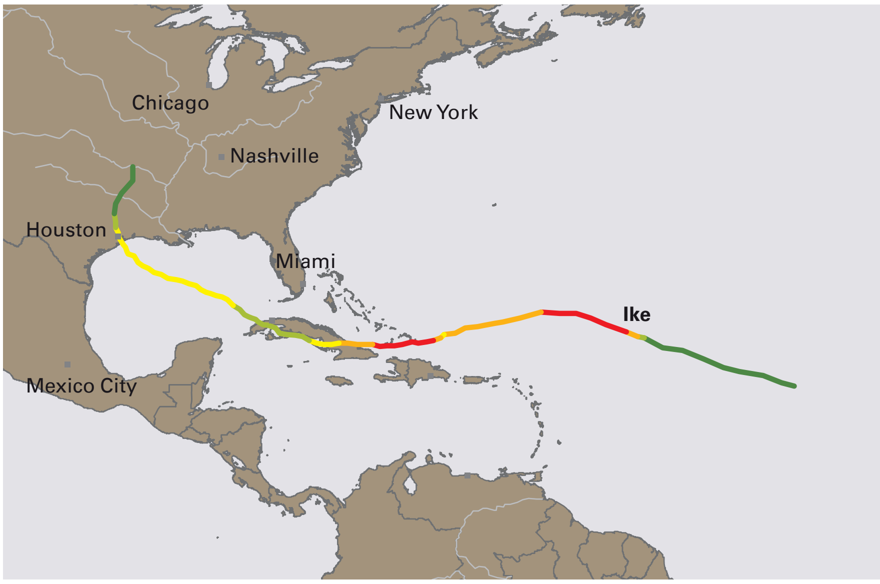
14 September – Ike weakens still further, encountering a cold front: Ike's remnants then merged with a cold front moving eastward across the USA. The ensuing low-pressure system brought heavy rain and gale-force winds to the Midwest, the East Coast, and parts of Canada on 14 and 15 September.

Impact and losses

Ike caused at least 168 deaths in the Caribbean and the USA, the countries worst affected being Haiti (74) and the USA (86).

Many people in the Galveston area of the Gulf Coast failed to evacuate the danger zone on time, despite stern warnings issued by the authorities. This had especially dire consequences on the Bolivar Peninsula. The storm surge struck several hours before the hurricane had been forecast to arrive, severing road links with the mainland. Many people had to be winched to safety by helicopter, but the flights were soon suspended as the wind strengthened. About 100 people were forced to stay behind.

Hurricane Ike's track



Wind speeds in km/h
(SS: Saffir-Simpson Hurricane Scale)
- Tropical storm (63–117 km/h)
- SS 1 (118–153 km/h)
- SS 2 (154–177 km/h)
- SS 3 (178–209 km/h)
- SS 4 (210–249 km/h)
- SS 5 (≥ 250 km/h)

Source: UNISYS

In spite of a robust concrete design, the foundations of many buildings erected directly on the coast suffered severe damage.

Caribbean losses: Worst affected of the Turks and Caicos Islands were Grand Turk, North Caicos, and Middle Caicos. Very few buildings escaped damage, and one third of homes sustained severe losses. A number of businesses and warehouses were totally destroyed. Overall losses on the islands were around US$ 500m.
There was severe flooding on Haiti, where Hurricanes Fay, Hanna, and Gustav had already caused floods and landslides. The Caribbean island was battered by four hurricanes over a three-week period, resulting in a humanitarian catastrophe, in which nearly 800 people were killed, over 300 reported missing, and about a million left homeless. Cuba, hit by the record number of three extensive (Category 3 or more) hurricanes in one year, reported losses in the billions. More than two million Cubans had to be evacuated.

US losses: According to PCS (Property Claim Services) estimates, insured losses in the USA were US$ 11bn. This figure excludes losses covered under the federal National Flood Insurance Program (NFIP) and damage to offshore facilities. In all, over a million private household claims were submitted, 600,000 in Texas alone, where private household claims amounted to US$ 5bn. Although Texas was worst hit, Ike left its mark over an area extending as far as New Orleans, which was swept by 80-km/h gusts. The floodgates on the city's canals were closed, and coastal communities evacuated. Parts of Louisiana were under more than half a metre of water. Apart from damage to buildings, more than two million people were without electricity, many power lines and distribution systems having been damaged or destroyed. The two utility companies worst affected reported that more than 90% of their customers were without electricity during the storm. Supplies were not fully restored until early October.

Texan Gulf Coast losses: Worst hit on the Texan Gulf Coast were Galveston, the Bolivar Peninsula, and the Port Arthur area. Galveston, population 60,000, had been hit by Category 4 hurricanes in 1900 and 1915. The town was protected from the full force of the waves by a sea wall constructed after the 1900 hurricane (cf. page 8, "Hurricane in Galveston, 1900"). Even so, there was flooding of up to 2 m in places, the storm surge hitting the island's exposed rear flank from the Bay of Galveston. The storm had a major impact on roofs and façades, whilst ground-floor flooding caused slight structural damage but severe damage to contents. In particular, many buildings located outside the sea wall or on the Gulf Coast itself were badly affected either due to their being of wooden construction or, in the case of more resistant, concrete structures, due to undermining of the foundations.

The Bolivar Peninsula was a scene of total destruction. Over 90% of the buildings disappeared or were a total loss. The exceptions were those built to IBHS (Institute for Business and Home Safety) standards, which withstood the storm surge and Ike's strongest winds. The region around Port Arthur adjoining the northern Bolivar Peninsula was also badly hit. A large number of petrochemical facilities are located here and several of these industrial risks suffered heavy losses.

Oil platforms were damaged as Ike whipped up waves up to 18 m high. In all, 50 out of 3,800 platforms were destroyed. At least 35 reported severe damage, and a further 60 minor damage. Oil and gas pipelines were also hit. At least 17 oil refineries had to be shut down temporarily.

Losses in Houston: Although the winds were not as strong in the Houston area as on the coast itself, the sheer size attained by Ike was an important factor there, since Ike extended further inland than is usually the case with minor storms. In Houston, façades and roofs, sign boards, satellite dishes, and other non-structural elements suffered slight to moderate damage. The extent of the damage was largely determined by the quality and age of the buildings. However, in the city centre itself, the glazed façades of a number of tower blocks suffered considerable damage. The most notable example was the JPMorgan Chase Tower, on which almost all the lower windows on one side of the building were destroyed. The fact that the damage was confined to a relatively limited area may have been due to the funnel-like effect produced by the lines of tower blocks or to roof tiles dislodged from surrounding buildings and projected like missiles.

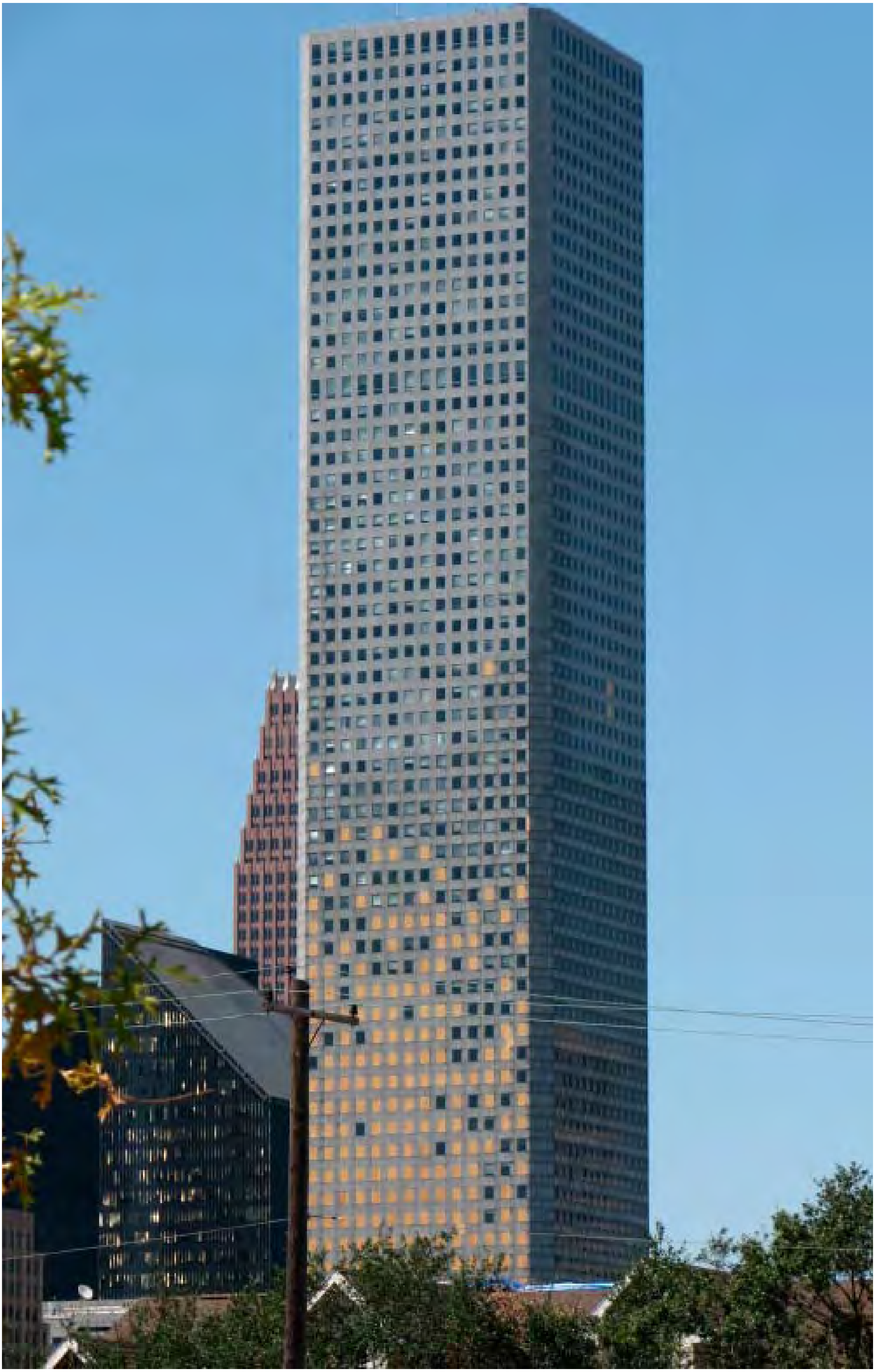
Downtown Houston was hit particularly badly. This photo is of the JPMorgan Chase Tower, on which a large proportion of the window panes were destroyed. The brown windows have been temporarily sealed with wooden panels and are awaiting replacements.

Losses in the Midwest, on the East Coast, and in Canada: Ike weakened to a tropical depression and then merged with a cold front extending deep into the Midwest and subsequently as far as the East Coast and Canada. The frontal system intensified due to the arrival of warm, moist air from the south. This produced high winds and torrential rain and led to storm damage, power cuts, and flooding in Arkansas, Illinois, Indiana, Kentucky, Missouri, Ohio, Pennsylvania, and parts of New York. Ohio, Kentucky, and Indiana suffered the heaviest losses. In Ohio alone, nearly two million people were without electricity for several days. In Canada, the provinces of Ontario and Quebec were affected, record precipitation causing local flooding. Winds of up to 80 km/h tore down trees and power lines, causing power failures in the St. Lawrence River area, including Montreal.

Hurricane in Galveston, 1900: Hurricane Ike was a reminder of the scenes of desolation witnessed over a hundred years ago

For the city of Galveston, Hurricane Ike was a hundred-year event in the worst sense of the term. When it was devastated in 1900 by a Category 4 hurricane with a track similar to Ike's, Galveston was one of the largest ports on the Gulf of Mexico. Over 6,000 people (unofficial estimates put the figure much higher) lost their lives, many through drowning. Fortunately, this prompted the authorities to take decisive action. They commissioned the building of what was then a vast undertaking: the construction of the Galveston Seawall. The Wall prevented another disaster when a similar hurricane struck in 1915 and it was also instrumental in warding off the worst of the storm surges in 2008. Although, unlike the 1900 hurricane, Ike did not cause a major catastrophe, it is nevertheless a sobering reminder, not just to the people of Galveston, of what could be in store in the near future.

Galveston 1900



Post-event loss estimates

Due to Ike's unusual nature, it was difficult to estimate losses in the immediate aftermath. Although initial market loss estimates were roughly in line with the real figures (at least at the upper end of the scale), the losses incurred by a number of portfolios concentrating on commercial and industrial business were drastically underestimated. What were the reasons for this, and what made Ike so different?

The sheer extent of Ike was underrated: The area with high wind speeds extended a long way inland. Moreover, reconstruction of the wind field was open to considerable interpretation due to the lack of reliable wind readings.

The area of coast affected by the storm surge was underestimated: A characteristic of Ike was the vast area of strong winds that extended over the sea. This resulted in a stronger storm surge than would normally have been expected for a hurricane of that intensity. Due to the special topographic conditions in the Galveston area, apart from the storm surge from the open sea, Galveston Island was also overrun by water from the lagoon to its rear.

Reinforced frontal system – Separate event? Wind speeds had already dropped, but reintensified when Ike's final remnants merged with a frontal system. Does a reinforced frontal system constitute a separate event?

What proportion of overall losses will consist of business interruption claims is not yet certain. Even at the time of writing, it is not possible to gauge the extent to which losses are due to exceptionally heavy business interruption claims caused by utility failures, non-availability of the work force, or denial of access.

Loss surveys carried out immediately after the hurricane concentrated on locations at the centre: They failed to take into account the huge area in which slight to moderate damage was incurred. Even in the central area, the extent of loss seems not to have been fully appreciated or registered. Further, many of the losses reported were actually caused by Ike's precursor, Hurricane Gustav.

Overall commercial and industrial losses were driven up by high individual risk amounts: This appears to be typical of this sector with events of a certain scale, and not peculiar to Ike. The models clearly fail to adequately reflect the fact that the loss span is much broader in this sector than in personal lines.

Loss statistics for commercial and industrial risks are relatively inadequate: The corresponding loss functions are less reliable than in the case of private dwellings, for example. This is particularly true of offshore energy risks.

Although it may seem paradoxical, it is actually more difficult to accurately estimate the loss from a single event than to calculate the aggregate PML (probable maximum loss) curve. The PML denotes the occurrence probability of losses of various sizes and PML curves are calculated by simulating tens to hundreds of thousands of events (event set). In this way, the characteristics of the individual scenarios balance each other out, provided there is no systematic miscalculation in loss functions or occurrence frequencies, for example.

The experience from the estimates for Hurricane Ike highlights the need to further improve the quality of the risk models for post-event loss estimates. Traditional estimates have been based on a selection of similar events from the event set of a risk model. They do not, however, reflect all the characteristics of the individual event in detail. The question is whether it is in anyone's interests to have quantitative loss estimates delivered in record time if they are not reliable. A rapid qualitative appraisal is needed for the immediate aftermath and the deployment of loss adjusters. However, the reputations of insurance companies and modelling firms are at stake when loss figures backed by insufficient data are published precipitately, so that it would be better to announce the estimates later, on the basis of actual losses reported, rather than race to publish.

Conclusion

Ike confirmed that all major hurricanes have their own characteristics. However, it also raised a number of general issues and renewed a number of messages.

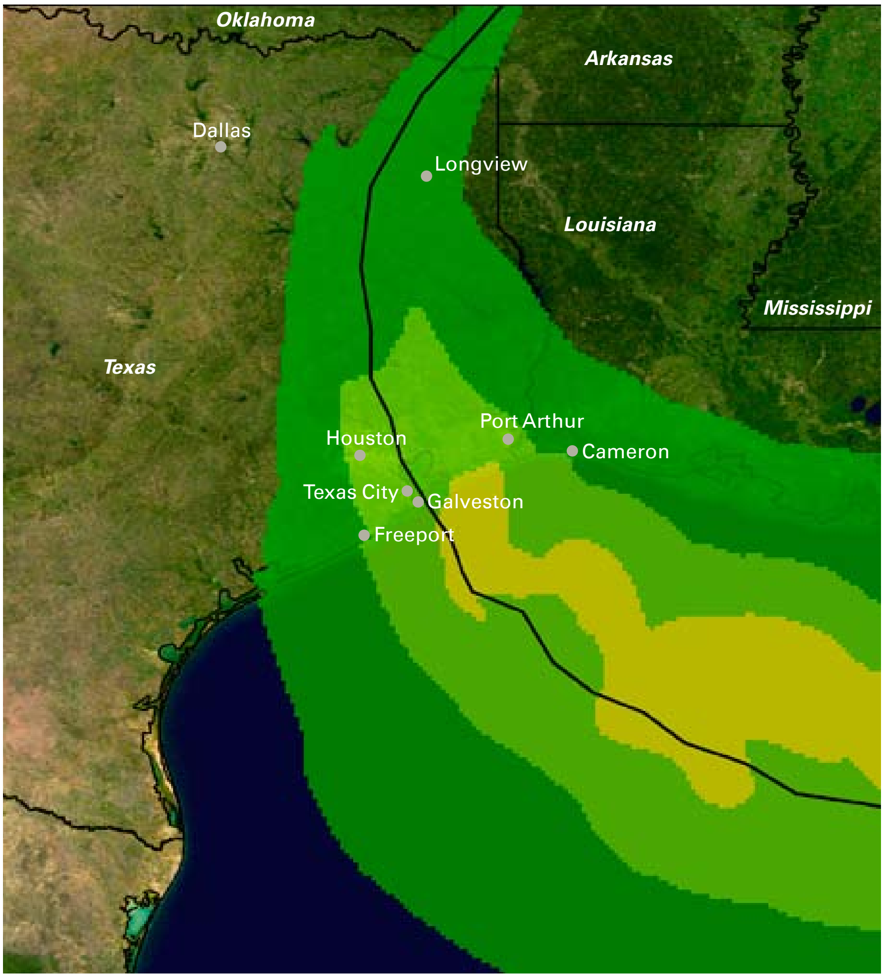
Storm surge: More attention has to be focused on storm surge loss potential. Clearly, the situation varies according to coastal topography, but storm surge is quite likely to be a major loss factor in hurricane scenarios involving Tampa, Florida, or New York.

Low wind speeds: As with Wilma in 2005, damage to tower block façades was surprisingly heavy in view of the relatively low wind speeds. This is a key starting point when considering loss prevention measures, especially for business quarters in major cities.

Building codes: Significant improvements were made to Florida's building codes following Hurricane Andrew (1992), and all new buildings now meet the relevant standards. Other states (e.g. Texas, but especially Louisiana and Mississippi) lag behind, average building standards having been changed very little, despite the 2005 hurricane season. It is essential that the authorities be involved to proactively raise construction standards, and implement land-use regulations that will prevent loss of human life, and minimise material damage.

The insurance industry can play its part in limiting the risk by implementing measures such as appropriate premiums, clear wordings, adequate deductibles, and high-resolution risk and location data, especially where high sums insured are involved. As well as underwriting instruments, more active loss prevention is required, not least because the effects of climate change and the migration of people and values are likely to bring heavier loss burdens in highly exposed coastal regions.

Hurricane Ike's wind field



Ike's wind field extended over a huge area. The storm moved a long way inland with high wind speeds.

Wind speeds in km/h
(SS: Saffir-Simpson Hurricane Scale)
- Tropical storm (63–117 km/h)
- SS 1 (118–153 km/h)
- SS 2 (154–177 km/h)

Source: NOAA, ESRI ArcWeb Services: Digital Globe (MDA EarthSat)

The tropical storms and hurricanes of the 2008 season destroyed hundreds of thousands of buildings in the Caribbean, the United States, and Mexico. Overall losses came to over US$ 50bn, of which some US$ 20bn was insured. The overall death toll was nearly 1,000. This is a photo of Hurricane Dolly, which raged in the border area between Mexico and the United States with wind speeds of 160 km/h.

North Atlantic hurricane activity in 2008

The 2008 hurricane season, with 16 tropical storms including eight hurricanes, was well above the 1950–2007 long-term average (10.3 tropical storms and 6.2 Atlantic hurricanes). This increased activity was also reflected in the number of tropical storms and hurricanes that made landfall on the US coast. For the first time on record, six consecutive tropical storms (Dolly, Edouard, Fay, Gustav, Hanna, and Ike) made landfall. Three of them were Category 3 hurricanes (Dolly, Gustav, and Ike), the long-term average being only two. Cuba was hit for the first time in one season by three major hurricanes (Category 3 and above).

There were five major hurricanes (Category 3–5 on the Saffir-Simpson Scale) in 2008, again well above the long-term average (2.7).

The 2008 season was slightly above the average of the warm phase that began in 1995: just slightly in the case of tropical storms (1995–2007: 14.6) and hurricane-force storms (1995–2007: 7.9) but more distinctly in the case of major hurricanes (1995–2007: 3.8). Apart from June and September, each of the individual months of the hurricane season (up to and including November) produced a figure that was at least equivalent to the rounded average of the current warm phase.

Overall losses in the 2008 season losses exceeded US$ 50bn, insured losses totalling some US$ 20bn. This makes 2008 one of the most expensive hurricane years ever for the insurance industry. An elevated hurricane loss potential must continue to be expected in the continuing warm phase.

The following factors have contributed to increased hurricane activity and intensity:

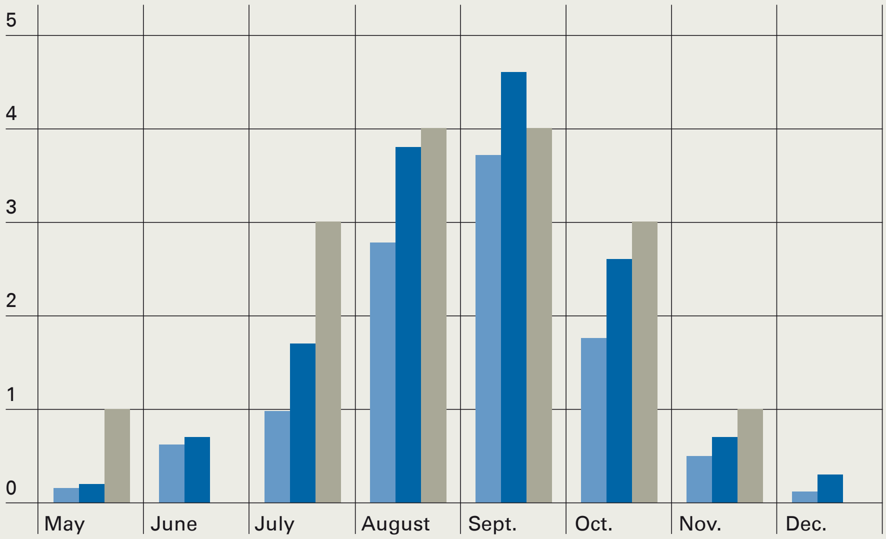
– The Atlantic Multidecadal Oscillation (AMO) observed in the North Atlantic since 1995, which also accounts for a deviation in (July–October) sea surface temperatures of up to +1.3°C over the long-term average in the main development region of cyclones;

– Lower than average atmospheric pressure at sea level from August–October in the main development region. Low pressure implies a tendency towards a less stable atmosphere with higher humidity in the lower area, creating conditions that favour convective processes as encountered in tropical cyclones.

– Compared with the long-term average, much lower vertical wind shear (vertical difference in wind force and/or direction) at the mid-August/mid-September height of the hurricane season. High vertical wind shear prevents or at least hinders the formation of tropical cyclones. Conversely, low shear is conducive to their formation.

– The failure of an El Niño event to materialise in the Pacific in the late summer. This would have tended to impede hurricane activity. On the contrary, conditions were, on the whole, neutral.

Number of named tropical storms in the North Atlantic



May–December monthly averages for 1950–2007, 1995–2007, and values for 2008

Average for 1950–2007
Average for 1995–2007
2008

Source: NOAA, UNISYS

Catastrophe portraits

Asia was hit by several major catastrophes in 2008: snow and ice brought parts of China to a standstill in January, whilst in May many livelihoods were wrecked in a matter of seconds when Sichuan was struck by a severe earthquake. In Myanmar, tens of thousands were killed by a cyclone.

China was caught in the grip of a severe cold spell in January and February 2008. In all, 18 provinces were hit by heavy snow and freezing rain. Many areas suffered power cuts as a result of damage to electricity pylons and transformers.

January: Winter damage in China

For weeks, China was caught in the grip of a severe cold snap, the extent of the catastrophe revealing the vulnerability of the country's power supplies. The winter loss potential had clearly been underestimated.

Meteorological causes and background

In January 2008, the weather situation was dominated by a particularly intense high pressure system over Siberia, which brought a steady stream of cold air to China and triggered the cold spell. Cold air remained over continental China due to a strong, subtropical zone of high pressure located further south, in the Northwest Pacific. At the same time, warm, moist air masses arrived in the country from the Bay of Bengal. Freezing rain occurs in wintertime when rain produced in a warm air mass falls through a cold air mass at a lower level, subsequently freezing on contact with the ground, power lines, and other cold surfaces. This freezing rain transformed roads in China into skating rinks, whilst a thick layer of ice completely covered roofs and the ground.

The catastrophe began on 10 January 2008. Freezing rain instantly covered the ground in a sheet of ice, which failed to thaw due to the persistent cold spell. This, combined with heavy snow that fell in an area extending over approximately 1.3 million km^2, left much of Central and Southern China covered in a thick layer of ice and snow for a period of several weeks. Guizhou, Hunan, and Jiangxi, which do not normally experience prolonged periods with temperatures around freezing, were severely affected, the 2008 winter breaking all previous records.

Overall losses

People in the southern regions were virtually unprepared for freezing rain and heavy snowfall. The death toll in the 18 provinces concerned rose to 129, many the victims of road accidents caused by the icy conditions. More than 1.6 million people had to be evacuated. Around 800,000 waited for several days at Guangzhou Station in the hope they would be able to see in the Chinese New Year at home. Collapsed electricity pylons and interruptions in coal supplies to power stations brought frequent power cuts. In the extreme conditions, more than 480,000 homes were destroyed and 12 million hectares of farmland damaged.

Insured losses

The event caused insured losses of the order of US$ 1.2bn, mainly in the utilities sector.

Electricity pylons and transformers were damaged and power lines collapsed under the weight of ice and snow. Industry was also badly hit. Factory and warehouse roofs caved in, the standard lightweight metal constructions found in the region being unable to bear the weight of snow, although it was only 20 cm deep in some cases. As a result, stock and machinery suffered water damage. Losses under business interruption, agricultural, and residential covers were minor.

Underwriting aspects: Definition of loss occurrence
Most wordings stipulate that individual losses due to the same cause are to be aggregated. However, it is very difficult to establish a common cause where the loss is due to the weight of snow or ice. Has the loss been caused by the last snowfall, the aggregate winter snowfall or the general weather pattern? Some wordings further stipulate that individual losses with the same cause shall also be due to one and the same event. However, this also leaves room for interpretation. Does a prolonged winter constitute a single event?

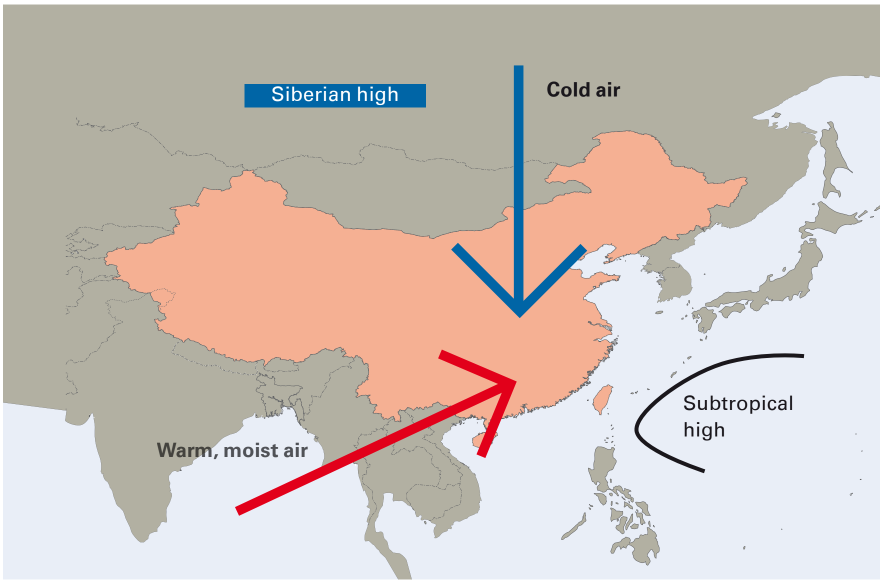
If the last snowfall is held to trigger the loss occurrence, this gets round the problem of having to determine what weather situation constitutes an event. Accordingly, each roof collapse would be ascribed to a particular event. However, this assumes losses can be attributed to a particular snowfall, which is only possible if comprehensive meteorological data are available. From a scientific perspective, it is the aggregate snow load, which may have accumulated from several snowfalls, that causes a roof to collapse, irrespective of number and chronology.

Reinsurance for losses caused by snow and ice load is generally provided under programmes containing standard occurrence definitions: hours clauses. However, such wordings are not always suitable in practice because they may not clearly circumscribe the loss. Further alternatives may be considered such as winter aggregate excess of loss coverage or an extension of the loss occurrence clause.

Underwriting aspects: High-voltage transmission lines
The widespread physical distribution of power lines makes them highly susceptible to natural hazard losses, particularly windstorms (typhoons) and ice. Overhead lines harbour major loss accumulation potential. Exposure and vulnerability largely depend on the age of the network, the quality of maintenance, and the standard of design (distance between pylons, method of construction, materials used). With regard to the underwriting of transmission and distribution (T&D) lines, special care must exercised in respect of risk definition, risk quality, and sum insured. The January 2008 event showed that underwriting and claims practice are not always in line with the special requirements of T&D risks, with in some cases an arbitrary definition of risk.

– T&D sums insured under policies issued several years ago have not always been adjusted to take account of the current situation. In order to meet higher quality standards, T&D lines have been largely upgraded in recent years. As a result many policyholders are under-insured.

Atmospheric conditions



An area of high pressure over Siberia gave rise to a constant stream of cold air from the north (blue), whilst warm, humid air flowed into southern China from the south (red).

– Policies have not provided for increased reconstruction costs that arise due to the urgent need to restore power.

– Apart from natural hazards, other factors also have a significant impact on T&D line risks. For instance, other providers may be able to act as a back-up network, minimising downtimes.

Due consideration must be given to all these factors in order to obtain adequate terms and premiums and optimise claims handling.

From the reinsurer's perspective, high-risk T&D lines should be included in treaties only if certain restrictions are applied: in general, T&D lines should only be covered up to a distance of 1,000 m from the insured power plant. Standalone coverage should not be granted unless risk, coverage, and losses are absolutely clear on both insurance and reinsurance side.

Loss assessment
In terms of insured losses, this event in China ranks as the third most expensive winter event of all time, behind the 1993 winter damage and the 1998 ice storm in the USA and Canada.

For the Chinese economy, the 2008 winter was one of the costliest weather-related natural catastrophes on record, surpassed only by the major floods in 1996 and 1998. Industrial and commercial insurance density in China remains very low. Only 3–5% of risks are insured although, in the utilities sector, the density of T&D insurance is high.

The loss potential of winter events in China is enormous. If industrial and commercial insurance density increases and, as expected, sums insured are adjusted to reflect the current values of T&D lines, losses due to similar events could be much higher in the future. The 2008 event clearly shows that winter loss potential has been seriously underestimated.

The three most costly winter events worldwide (1980–2008)

Year	Event	Overall losses (US$m, 2008 values)	Insured losses	Fatalities
1993	Blizzard, United States and Canada	7,300	2,880	270
1998	Ice storm, United States and Canada	3,750	1,500	45
2008	Winter damage, China	21,000	1,200	129

2008 winter damage in China: Regions affected

Vast areas of the country (beige shading) experienced exceptionally low temperatures, heavy snow and freezing rain, a number of provinces being severely hit (red shading).

- Regions severely affected
- Regions affected
- ○ Heavy snow
- × Freezing rain

May: Cyclone Nargis, Myanmar

Cyclone Nargis hit Myanmar on 2 May 2008. The storm claimed over 85,000 lives, made hundreds of thousands homeless, and caused devastation in vast areas. Insurance protection is not available in Myanmar at present, but microinsurance solutions are under discussion.

Scientific aspects

Nargis was the first cyclone of the Indian Ocean's 2008 season. In late April, a Category 2 storm developed in the Bay of Bengal. After initially weakening, it gained in strength again as it headed towards the coast. Nargis attained its highest wind speeds (Category 4) just as it reached the Irrawaddy Delta. Its strength diminished slowly as it proceeded along the coast because roughly half of the storm was still over the Andaman Sea, from which it continued to draw energy. Nargis struck the city of Rangoon (and its population of several million) with wind speeds exceeding 130 km/h; it rapidly weakened as it approached the mountainous border region between Myanmar and Thailand, subsiding completely on 3 May.

As the cyclone swept across the Irrawaddy Delta with high wind speeds, it triggered a storm surge with heights of over 3 m. The situation was made worse by record rainfall and severe floods. Satellite images show that an area of some 14,000 km² was flooded.

Scale of damage

Cyclone Nargis is the worst storm in Myanmar's history in terms of human losses. It is thought to have claimed more than 130,000 lives: the official figure is 85,000 deaths, with 54,000 missing. The disaster left over a million people homeless.

The Myanmar government declared five regions as disaster areas: Rangoon, Ayeyarwady, Bago, Mon, and Kayin. The Irrawaddy (Ayeyarwady) Delta was worst hit, virtually all homes being destroyed there. The delta lies on average only 1–2 m above sea level. High wind speed forced seawater into the river's distributary channels. Due to the very flat landscape and sparse vegetation, the storm surge was able to penetrate almost unhindered up to 40 kilometres inland.

Overall losses from Nargis are estimated to be more than US$ 4bn. Insurance cover is not available in Myanmar due to the current political climate.

Microinsurance – Solutions under discussion

Experts are looking into ways of using microinsurance to make good the lack of insurance cover for losses caused by events like Nargis. Although it will be far from easy to find microinsurance solutions that cover losses caused by cyclones and other large-scale weather-related perils, every effort is being made to develop corresponding products.

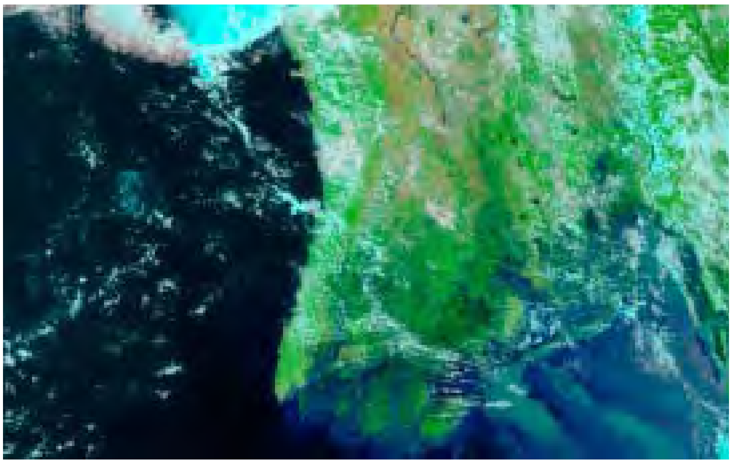
Analysis

Nargis was an exceptional event as far as Mynamar is concerned, since cyclone-force storms are by no means an annual occurrence there. The analysis of historic events indicates that a Nargis-type cyclone has a return period of approximately 20 years.

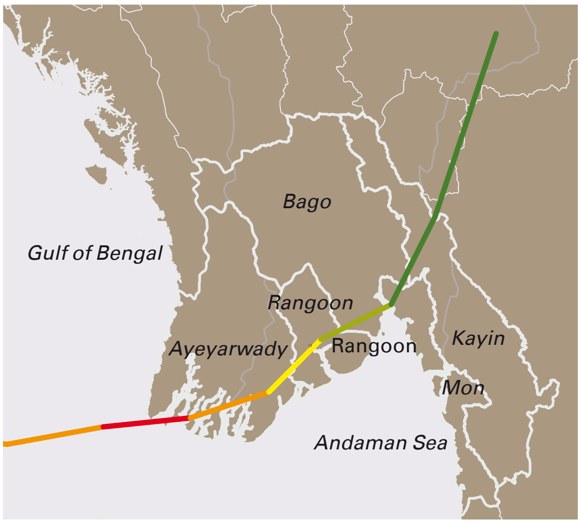
Loss figures

450,000	Buildings destroyed
350,000	Buildings damaged
6,000 km²	Crop area and fish farms destroyed
> 150,000	Livestock killed

These are satellite images of Myanmar on 15 April 2008 before Cyclone Nargis (top) and on 5 May 2008 after its departure (bottom). Large parts of the country were swamped by record rainfall and a storm surge that reached heights of over 3 m (marked blue in the lower image).

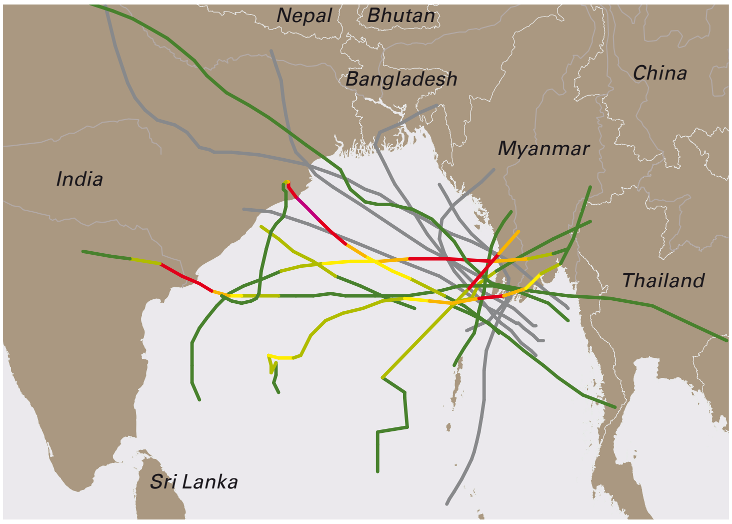


Track of Cyclone Nargis, 2008



The map on the left shows the track of Cyclone Nargis in May 2008. The map on the right shows the cyclones that have been registered in the Gulf of Bengal since 1948.

Cyclones in the Gulf of Bengal, 1948–2008 (selection)



Wind speeds in km/h
(SS: Saffir-Simpson Hurricane Scale)

- Tropical storm (63–117 km/h)
- SS 1 (118–153 km/h)
- SS 2 (154–177 km/h)
- SS 3 (178–209 km/h)
- SS 4 (210–249 km/h)
- SS 5 (≥ 250 km/h)

Source: UNISYS

May: Earthquake in Sichuan, China

On 12 May 2008, the province of Sichuan was struck by a strong earthquake. At least 70,000 people died even though no major city was directly affected. The earthquake claimed the highest death toll of any natural catastrophe in China since the Tangshan earthquake in July 1976.

Scientific aspects and features

The magnitude 8.0 earthquake occurred along the Longmenshan range in the west of Sichuan at 2.28 p.m. local time. The rupture extended northwestwards from the epicentre near the city of Dujiangyan over a distance of more than 200 km. The Longmenshan fault zone does not manifest itself as an obvious, single, clear fault line at the surface. GPS data had indicated almost no movement along the fault. Strong earthquakes had been reported in recent centuries along adjacent systems to the north and south but not directly along this fault system. The most recent earthquake in the region occurred in August 1976, when the city of Songpan, some 100 km further north, was struck by two magnitude 7.2 tremors. The 1933 Diexi earthquake in the same region also caused significant damage.

Shaking during the Sichuan earthquake exceeded the maximum assumed in China's official building code map by a factor of 4–6. Comparison of average slip rate along the fault with offset during the earthquake, and paleoseismic analysis indicate a return period of more than 1,000 years for an earthquake of this strength along the fault zone. Earthquake hazard in the area is therefore still considered moderate.

Losses

Losses were largely concentrated in a long, narrow belt along the fault area in the transition zone between the Tibetan Plateau and the Sichuan Basin. Many severely damaged villages and towns were located on valley bottoms, having been built on the saturated sediments of the rivers that had formed the valleys. These sediments amplified the destructive power of the shaking.

Hundreds of "quake lakes" resulted in the immediate aftermath, landslides forming natural but unstable dams that impounded the waters of the rivers. Enormous efforts were made to prevent an uncontrolled breach of the Tangjiashan quake lake, which was threatening more than a million people downstream. However, this meant inundating cities already devastated and evacuated, such as Beichuan. Quake lakes caused by landslides continue to be a very real threat. Just how dangerous the temporary lakes can be was shown by an earthquake that occurred in Sichuan Province in 1786, when a landslide dam burst killing more than 100,000 people.

Sichuan earthquake confirms past experience

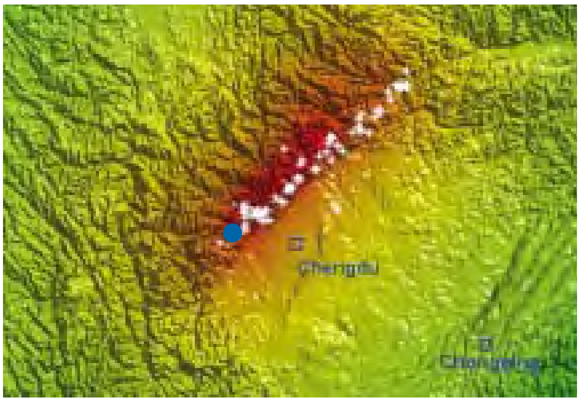
- Although the shaking exceeded the maximum assumed in China's official building code, buildings that met code standards were in many cases better able to withstand the earthquake. Even in the worst affected areas, many well-built constructions suffered only minor cracks.

- The implementation of a stringent building code for new structures has not been supplemented by measures for reinforcing older structures. This had previously been identified as a serious problem, especially in economically under-developed regions.

Loss figures

Fatalities	70,000
Missing	18,000
Injured	374,000
Buildings (total loss)	5.3 million
Buildings (damaged)	21 million
Direct overall losses	US$ 85,000m
Insured losses	US$ 300m

Earthquake on 12 May 2008 and aftershocks: Intensity field model



The map shows the location of the epicentre (blue) and the intensity field. Aftershocks (up to 12 September 2008) of intensity V or more are shown in white.

Intensity:
low high

Epicentre
Aftershocks

– Many soft-storey constructions collapsed because the lower floors were not rigid enough to withstand horizontal earthquake loads.

– Most of the destruction, however, can be attributed to unregulated, non-engineered structures. Many buildings were constructed with simple means and materials, generally consisting of unreinforced concrete blocks, loosely connected with mortar, with a wooden-frame structure and a light shingle roof, thus offering little lateral resistance. Widespread destruction of this kind of construction was observed and contributed significantly to the devastation.

Conclusion
The Sichuan earthquake was a rare and extreme event. Nevertheless, it is duly represented in Munich Re's probabilistic earthquake model for China, which translates the direct and indirect effects of more than 250,000 stochastic earthquakes into losses for the individual client portfolios.

The estimates of insured losses were largely unreliable due to the need for subjective assumptions to complement the limited exposure information available. Spatial resolution was inadequate and there was not even minimal information on the types of risk covered. Often, it was not even clear exactly what the cover included. Insurers had gathered far too little information about the risks and had communicated even less to reinsurers and brokers.

The Sichuan earthquake is a clarion call for the insurance industry. In consequence, clear data standards for risk management and reporting between insurers and reinsurers have to be defined – already common practice in other countries. This clearly includes accumulation assessment zones (CRESTA zones) for natural hazards. Current province-level reporting has proved inadequate. Four-digit or six-digit postcode zones would provide far more realistic risk assessments.

In the last few years, due to intense competition, insurers have often included earthquake extensions at no extra charge as a way of attracting business. This was in line with long-term experience. Since 1976, there had been no truly catastrophic earthquakes, most natural catastrophe losses having resulted from typhoons and flooding. The May 2008 disaster showed that the earthquake risk, contrary to widespread perception, is far from negligible. Significant losses can and do arise from this peril. This has to be adequately reflected in the price of cover.

Due to Sichuan's very low insurance density, the insurance industry did not significantly contribute to financial compensation of the losses. Earthquake coverage has hardly been offered to private homeowners up to now. One approach being tested in the field is to provide minimum natural hazards' cover. As in other regions that have suffered comparable events (for example following earthquakes in Taiwan and Turkey in 1999) the answer may well be to establish a pool providing basic natural catastrophe coverage.

May/June: Storm series Hilal, Germany

A series of thunderstorms swept over Germany from the end of May to the beginning of June 2008. Hilal highlighted above all the problems involved in distinguishing between different loss occurrences – a clear-cut and transparent definition is in the process of being developed.

Meteorological background and chronology
The storms formed along a stationary air mass boundary separating warm, moist Mediterranean air in the southwest from dry air in the northeast. There was a convergence zone between high pressure over Scandinavia and low pressure over France and Southern Germany. In such a situation, air masses from various directions flow towards one another and are forced to rise. This enables very large thunderclouds to form, with heights sometimes reaching 12–14 km. Temperatures at these altitudes can be as low as -65°C, conditions that are perfect for the generation of large hailstones.

On the evening of 28 May, the storm series named after the low-pressure system Hilal began with thunderstorms, hail, and local flooding in the west of Germany, particularly in the Dortmund area. In the early hours of the following day, storms caused flooding in Luxembourg, the Rhineland-Palatinate, and North Rhine-Westphalia.

On the morning of 30 May, severe hail swept over many parts of North Rhine-Westphalia. Hailstones of up to 5 cm caused severe losses in Düsseldorf, Detmold, and Krefeld. Tens of thousands of cars were damaged in Krefeld alone.

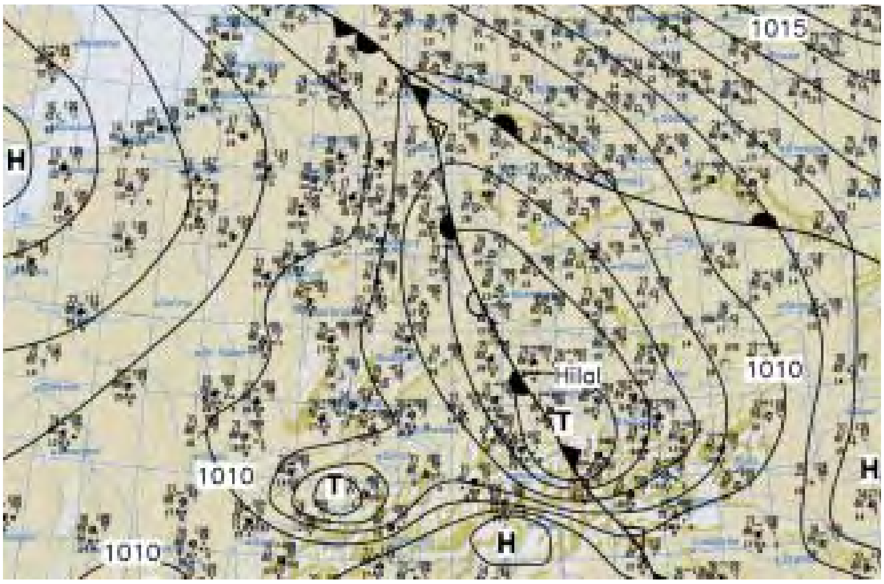
Over the next few days, further storms caused heavy losses in eastern Germany. On the evening of 2 June, torrential storms led to flash flooding and inundation in Baden-Württemberg. One of the worst hit areas was the Killertal in southwest Germany, where three people died in flash floods.

Loss occurrence definition
Owing to the meteorological situation encountered during Hilal, the loss occurrence definition acquires particular importance. The terms and conditions of individual contracts incorporate standard natural hazard loss occurrence clauses, which commonly take one of the following three definitions as a basis for windstorm and flood events.

Loss figures

Overall losses	US$ 1,500m
	€1,100m
Insured losses	US$ 1,100m
	€800m

Surface pressure chart for 30 May 2008



Severe thunderstorms formed along a stationary air mass boundary separating warm, moist Mediterranean air in the southwest from dry air in the northeast.

Source: Verein Berliner Wetterkarte

This photo was taken at the Bad Kissingen recreational airfield. Strong gusts from Hilal lifted the white powered glider ten metres into the air and dropped it unceremoniously onto a light aircraft. The insured loss was €55,000.

Losses are aggregated if they
– evolve from a single overall weather pattern,
– or can be attributed to what is considered in meteorological terms a single storm and/or hailstorm event,
– or evolve from a single atmospheric disturbance.

The feature common to all three definitions is that the occurrence is limited to a maximum of 72 hours. Flood losses can be aggregated if they occur within periods ranging from 168 to, in some cases, 504 hours. However, losses can only be aggregated in a contiguous area of flooding. This restriction is not always explicitly applied to storm or hail events. What matters is that the pricing and accumulation loss models should be based on the same hours clauses. On closer examination, the common occurrence clauses – and their often quite different wordings – are inadequate when meteorological conditions like those of Hilal are to be factored into the contracts. We will now look in detail at the different wordings and their impact on the loss occurrence definition, taking the example of Hilal as a basis.

"One and the same general weather pattern"

According to the definition used by the German Weather Service, a "general weather pattern" is an "average distribution of pressure at sea level and in the mid-troposphere over a wide area (e.g. Europe and parts of the North Atlantic) lasting for a period of at least three days". The general weather pattern determines the essential character of a weather period, whereas the weather itself may change due to small-scale pressure systems whose tracks follow a similar course. Consequently, an occurrence clause based on this definition will not precisely correspond to an event as it actually occurs. This is because losses are not caused by general weather patterns prevailing over the entire continent but by air pressure systems crossing an area and – on an even smaller scale – by individual storms, torrential downpours, and hailstorms.

Loss events are thus only indirectly attributable to the general weather pattern, which, though increasing the occurrence probability of storms and thunderstorms, has only a limited influence on their location, time, and duration.

For this reason, the losses from the winter storm series in 1990 and 1999 were not aggregated on the basis of the general weather pattern prevailing in each case – although this certainly made their occurrence more likely – but on the basis of the respective local pressure systems, e.g. Lothar and Martin in 1990 and Vivian and Wiebke in 1999.

In the summer of 2007, floods in the United Kingdom coincided with severe losses in Germany's Middle Franconia due to heavy rain associated with a thunderstorm. In theory, it would have been possible to aggregate the losses from these two events as long as the occurrence definition did not require a geographical connection between them.

The same applies to Hilal. The series of severe weather events formed along an air mass boundary that lasted from 28 May to 4 June approximately. However, the German Weather Service reported two distinct general weather patterns in Europe during this period – a southeast cyclonic pattern from 28–31 May followed by a high North Sea-Fennoscandian cyclonic pattern lasting until 7 June.

Accordingly, all losses occurring during the two periods would have to be aggregated separately, even though the pressure system (the air mass boundary) was the same. One moot point, however, is the geographical connection between the events. This is not easy to resolve since large thunderstorm systems move slowly over a long period of time.

On 1 June 2008, the roof of a DIY market collapsed in Schwarzenberg (Saxony).

All the established models used in the market, for instance, take individual pressure systems in the case of winter storms or individual hailstorms as the basis for defining loss occurrences. Consequently, these models are not directly applicable to contracts that aggregate all losses occurring during a single general weather pattern into one single loss occurrence. Applying the model results to this loss occurrence definition is an extremely precarious undertaking.

"A storm and/or hailstorm to be considered one event in meteorological terms"

The advantage of this definition lies in the attempt to define occurrences on the basis of actual causal relationship. In practice, however, the formulation "storm and/or hailstorm to be considered one event in meteorological terms" is not unproblematic. Strict application of this definition would mean in the case of Hilal, for instance, that each individual thunderstorm cell and the ensuing hailstorm would count as a separate occurrence. Whilst this may appear at first sight desirable for risk assessment and pricing purposes, it is impossible to make such a fine distinction between loss occurrences both in spatial terms, given present-day meteorological measuring techniques, and in temporal terms, given the fact that it is difficult to determine the time and place of losses with the precision needed to allocate ensuing claims to, for example, one of two thunderstorms occurring in quick succession.

On the other hand, however, risk assessment is also based on such imprecise loss occurrence definitions because there is no better way of collecting data from past events. Moreover, with no clear-cut definition of what "in the meteorological sense" means, the terms "storm" and "hail" are so widely open to interpretation that lawyers would speak of a "vague legal concept".

"One and the same atmospheric disturbance"

Similarly, "atmospheric disturbance" is not clearly defined in meteorological science and thus requires interpretation. If „atmospheric disturbance" is deemed equivalent to a "high-pressure or low-pressure system", the clause initially provides a relatively conclusive framework for the majority of hazard situations. Winter storm events are thus defined as individual occurrences, whereas a number of thunderstorms can be aggregated into one occurrence provided they have formed within the same pressure system.

In the case of Hilal, this means that all events occurring within a period of 72 hours are to be aggregated. However, this reveals one of the drawbacks of this definition. As described above, the natural hazard models commonly used in the market attempt to separate all events, including thunderstorms. If cover is provided on an occurrence basis, this can lead to imprecision in the evaluation. One way of addressing this issue and maintaining pricing consistency would be to introduce a 24-hour clause for thunderstorm and hail events. These are determined to a large extent by the sun's diurnal movement – even if the pressure remains stable over a period of several days, as was the case with Hilal – and can therefore be separated into individual events using a daily mode of observation.

Flood losses

Summer thunderstorms are often associated with heavy rain that results in flash floods and local inundation. The standard clauses allow losses to be aggregated if they occur within periods ranging from 168 to 504 hours. This may be eminently appropriate in the case of widespread river flooding, in which the gradual progression of the flood wave over a considerable period can lead to individual losses at different locations. However, there is no argument in its favour in the case of flash floods, which are confined to a specific area and last for only a short time. A clearer distinction needs to be drawn between the various flood types.

Conclusion

In recent years, the market has developed many different definitions, based essentially on specific aspects of atmospheric perils, i.e. windstorm, hail, heavy rain – often to the detriment of the requisite transparency in risk assessment and modelling. Hilal in particular showed that using a general weather pattern to define an occurrence is open to criticism. But all the other standard clauses also lack a completely convincing loss occurrence definition that can be applied to all possible event types.

A loss occurrence definition that is acceptable to the insurance industry has to meet the following criteria: The definition

– must be coherent in scientific terms, as transparent as possible, and unambiguous;

– must be compatible with risk assessment techniques and models and thus with pricing;

– must also enable practical loss settlements between insurer and reinsurer.

Last summer's severe weather events have prompted Munich Re to develop a clear-cut loss occurrence definition for natural hazards in Germany. The definition will take account of all the issues and requirements described in this article, the aim being to establish greater clarity and transparency in the processes of risk assessment and claims settlement.

Storm series Hilal: heavy rain, hail, and tornadoes from 28 May to 4 June 2008:

The data from the ESWD (European Severe Weather Database) provide a good indication of the places where tornadoes, large hail (≥2 cm), and heavy rain were recorded during the storm series. The criteria applied in the case of rainfall were large volumes of precipitation that were unusual for the location or produced losses.

● Torrential rain
▼ Tornado
▲ Large hail

Source: European Severe Weather Database

Climate and climate change

Extreme weather-related events and the resulting losses continue to increase. The year 2008 was marked by temperature extremes, record precipitation, and one of the highest levels of tornado activity ever registered in the United States.

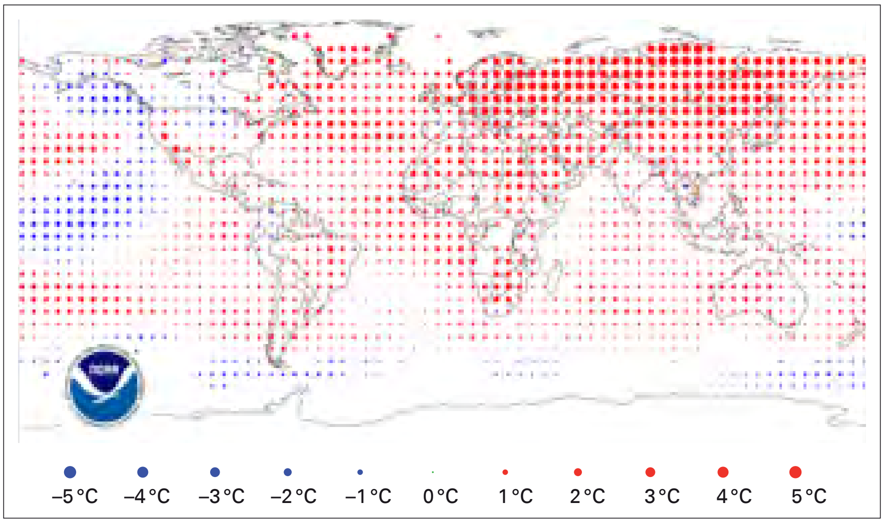
The Arctic sea ice extent in 2008 was the second lowest on record. For the first time ever, the Northwest and Northeast Passages were navigable simultaneously. The photo shows blocks of iceberg falling into the sea.

Data, facts, background

The World Meteorological Organisation (WMO) classifies 2008 as the tenth warmest year since recordings began in 1850. Ten of the warmest years in the statistical series have occurred in the last twelve years.

The global mean surface air temperature in 2008 was 0.31°C above the average of the period 1961–1990, in which the value was 14.00°C (Hadley Centre). The La Niña phase that lasted from September 2007 to May 2008 had a cooling influence in the equatorial Pacific. This region remained in the cool-neutral range of the El Niño-La Niña oscillation beyond mid-year. The mean global temperature in 2008 deviates negatively from the temperature level of past years – particularly due to La Niña. In the north, however, large parts of Scandinavia recorded their warmest ever winter in 2007/08, with temperature anomalies of more than +7 °C in some places. The winter was also exceptionally warm in northwestern Siberia.

Regional deviations of mean annual temperature in 2008 from the 1961–1990 mean



Positive temperature anomalies are shown as red dots, negative anomalies as blue dots, their size reflecting the degree of variation. There is a distinctive warming trend. Strong positive temperature anomalies in the northern latitudes are clear to see, particularly in Eurasia.

Source: National Climatic Data Center/ NES-DIS/NOAA. http://www.ncdc.noaa.gov/ oa/climate/research/2008/ann/global.html

Melting of Arctic sea ice

The high temperatures in Arctic latitudes in association with changes in atmospheric current patterns resulted in a minimum Arctic sea ice extent of 4.7 million km^2 in September 2008, thus almost reaching the previous year's record of 4.3 million km^2. On account of the heavy thaw, the Arctic Northeast and Northwest Passages were – for the first time ever – simultaneously navigable. The 6,500-km Northeast Passage, which leads along the coast of Siberia, makes the journey between Hamburg and Japan 40% shorter than the route leading through the Suez Canal. If the Northeast and Northwest Passages were to be used more frequently in the coming decades, it would be necessary to establish new ports and facilities for processing raw materials along the coasts of Siberia and Canada respectively. More exploration and exploitation of resources in the Arctic region would increase the demand for technological infrastructure along the neighbouring coasts. Along the Arctic sea routes and in the coastal areas, new risks would emerge in connection with the construction of facilities and transportation.

Data and facts on the climate in 2008

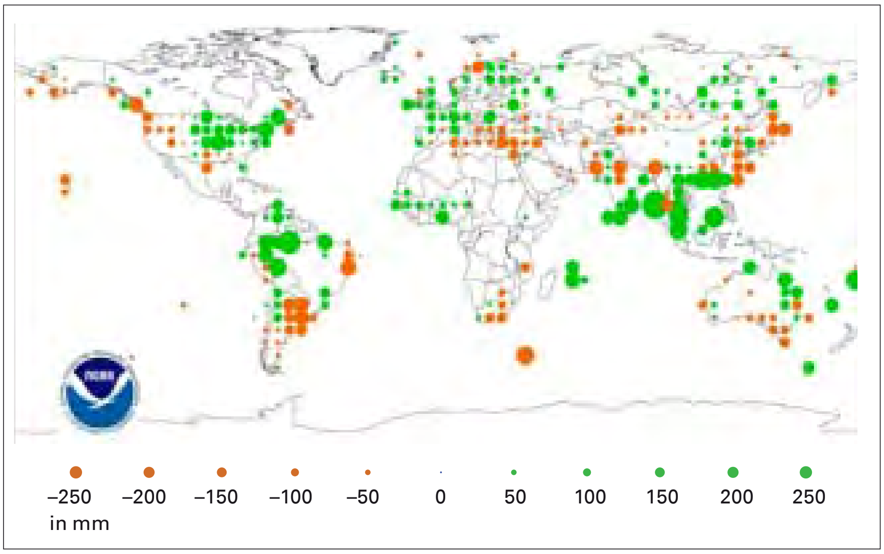
Global temperature extremes

There were heatwaves in such regions as Australia, southeastern Europe, and Argentina. A drought in the southeast of Australia caused substantial crop losses in the Murray-Darling Basin, a major agricultural region. A prolonged dry spell in California was one of the causes of devastating wildland fires. It is probable that the gradual spread of aridity in the southwest of North America is already linked to anthropogenic climate change. Parts of Argentina, Paraguay, and Uruguay suffered their worst droughts in five centuries, resulting in severe losses in the agricultural sector. Southern China, on the other hand, experienced an extreme cold spell in January, with snowfalls and ice formation producing major losses.

Record rainfalls

Particularly heavy rain was recorded in the monsoon regions of South and Southeast Asia. Thousands of people were killed in India, Pakistan, and Vietnam, whilst more than ten thousand were made homeless. More than 300,000 were affected by heavy rain and floods in the West African monsoon. In the United States, extreme precipitation brought heavy flooding to the Midwest. In the last ten days of November, extreme rainfall in Southern Brazil caused floods and landslides – with more than 1.5 million people affected and about 80,000 made homeless. Europe, particularly southern and central France, had to cope with floods from late October until early November. During this time, some places recorded 500 mm of rain.

Regional deviations of mean annual precipitation in 2008 from the 1961–1990 mean



Green dots represent positive anomalies, orange dots negative anomalies, their size reflecting the degree of variation.
Positive anomalies are very prominent in South and Southeast Asia as well as in the north of South America. There are precipitation deficits in the Mediterranean area, southern Australia, and parts of South America.

Source: National Climatic Data Center/ NES-DIS/NOAA. http://www.ncdc.noaa.gov/ oa/climate/research/2008/ann/global.html

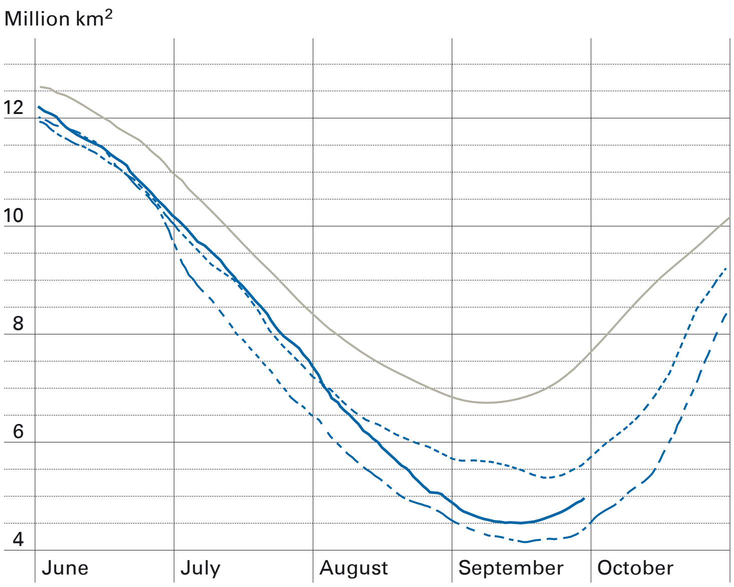
During the winter of 2007/08, Canada had to contend with extreme volumes of snow, reaching depths of 5.5 m in some places (Quebec) and causing the roofs of many houses to collapse. At the same time, the meagre extent of the northern hemisphere snow cover in the spring of 2008 – with a negative anomaly of more than 7 million km² in respect of the average of the last 40 years – confirmed the long-term negative trend.

Tornado records
The United States registered a period of tornado activity that was one of the most intense since the first reliable records began in 1953. Almost 1,500 tornadoes swept over the country between January and August, an absolute record in tornado activity for this time of year. For the year as a whole, the number of confirmed tornado events will probably be some 1,700, which is much higher than the average of the last ten years, 1,270, and just below the previous record of 1,817 set in 2004.

Anomalous activity characteristics observed in a single season cannot in themselves be attributed to climate change. On the other hand, a recent climate model study (Trapp, R.J. et al., 2009, GRL36) shows that during the simulation period 1950–2099, with greenhouse gas concentrations increasing in the United States, there are likely to be more and more days in the year on which there is a potential for severe thunderstorms with wind gusts, hail, heavy rain, and tornadoes.

Conclusion
Observations made in the year 2008 confirm the persisting trend of anthropogenic warming. As in the previous year, the striking decline in the Arctic sea ice extent provided clear evidence of increased warming in the higher latitudes. Of particular relevance for the insurance industry were the extreme weather events that occurred in the year 2008, including heavy rain, windstorms, and severe local storms.

Annual development of Arctic sea ice extent



This graph presents a comparison of the Arctic sea ice extent in the years 2005, 2007, and 2008, and the annual mean in 1979–2000. The strong decrease in the minimum over time is plain to see.

2008
2007
2005
1979–2000 mean

Source: National Snow and Ice Data Center

NatCatSERVICE

With more than 26,000 entries, Munich Re's NatCatSERVICE database is one of the world's most comprehensive sources of information on natural catastrophes. It is supplemented every year by about 800 new events which are analysed and documented.

The latest analyses, charts, and statistics are available for downloading free of charge at our website www.munichre.com/geo.

The year in figures

Tropical cyclones and the earthquake in Sichuan (China) made 2008 one of the most devastating years on record. Overall losses from 750 natural catastrophes came to US$ 200bn (2007: US$ 82bn). Insured losses totalled US$ 45bn (2007: US$ 30bn).

Number of events

The percentage breakdown of events into the various types of natural hazard was in line with the long-term average. In 2008, we analysed and documented 750 loss events, including 78 earthquakes, 10 volcanic eruptions, 282 windstorms, and 292 floods and landslides. A further 88 loss events were caused by heatwaves, droughts, forest and wildland fires, and frost or winter damage.

Fatalities

At least 163,000 people died as a result of natural catastrophes in 2008. More than 85,000 people were killed alone by Cyclone Nargis, which crossed Myanmar at the beginning of May. 54,000 people are still missing, whilst over a million were made homeless. A strong earthquake in the Chinese province of Sichuan – also in May – claimed the lives of at least 70,000 according to the authorities, and a further 18,000 are still missing.

Overall losses and insured losses

On the basis of figures adjusted for inflation, 2008 was the third most expensive year on record. Overall losses came to US$ 200bn, a figure exceeded only in the hurricane year of 2005 and in 1995, the year of the Kobe earthquake in Japan.

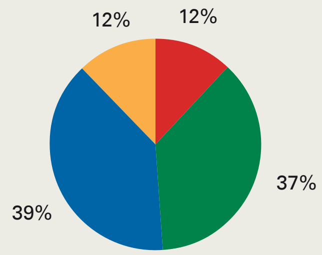
The most expensive catastrophe in macroeconomic terms was the earthquake in Sichuan, with direct losses of at least US$ 85bn. The costliest windstorm was Hurricane Ike, which in September devastated parts of the Caribbean and caused severe damage in the US states of Texas and Louisiana. Overall losses came to US$ 38bn.

Insured losses totalled US$ 45bn. The costliest event was Hurricane Ike, which caused losses in the US$ 15bn range, making it the third most expensive hurricane in US history, surpassed only by Hurricane Katrina in 2005 with losses topping US$ 66bn and Andrew with losses at US$ 30bn (both in current values).

In Europe, the costliest natural catastrophe was Emma, a winter storm that crossed large parts of Europe at the beginning of March with wind speeds of over 150 km/h, causing insured losses of US$ 1.5bn and overall losses of US$ 2bn.

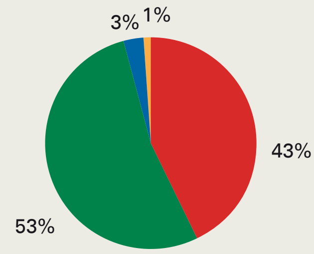
* Not including missing persons:
Cyclone Nargis: 54,000
Sichuan earthquake: 18,000

750 events



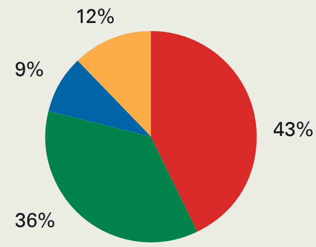
Percentage distribution worldwide

163,000 fatalities*



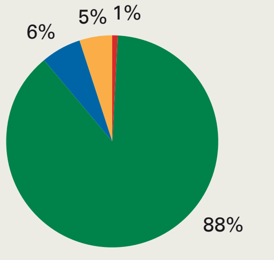
Percentage distribution worldwide

Overall losses: US$ 200bn



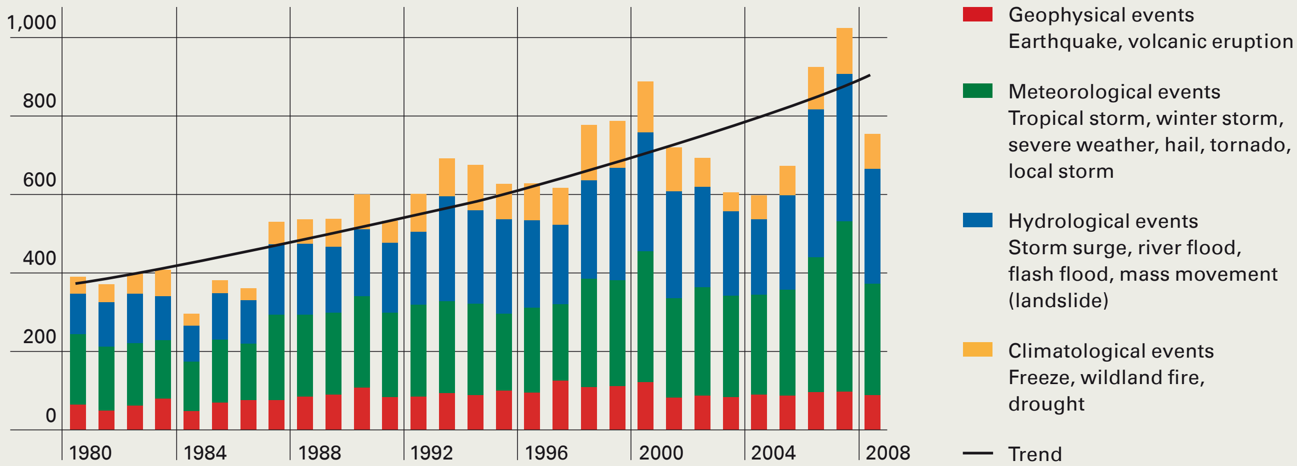
Percentage distribution worldwide

Insured losses: US$ 45bn



Percentage distribution worldwide

Number of natural catastrophes 1980–2008



Pictures of the year

10 January–13 February
Winter damage: China
Overall losses: US$ 21,100m
Insured losses: US$ 1,200m
Fatalities: 129

14–31 January
Floods: Australia
Overall losses: US$ 600m
Insured losses: US$ 450m

27 February
Earthquake: United Kingdom
Overall losses: US$ 40m
Insured losses: US$ 30m

1–2 March
Winter Storm Emma: Europe
Overall losses: US$ 2,000m
Insured losses: US$ 1,500m
Fatalities: 14

28 April
Severe storm, tornadoes: USA
Overall losses: US$ 110m
Insured losses: US$ 80m

2–5 May
Cyclone Nargis: Myanmar
Overall losses: US$ 4,000m
Fatalities: 85,000
Missing: 54,000

12 May
Earthquake: China
Overall losses: US$ 85,000m
Insured losses: US$ 300m
Fatalities: 70,000
Missing: 18,000

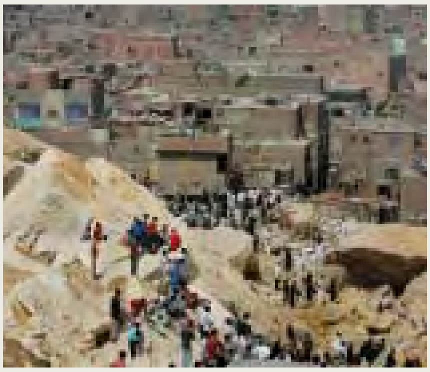
June
Floods: USA
Overall losses: US$ 10,000m
Insured losses: US$ 500m
Fatalities: 24

22 July–7 August
Floods: Ukraine, Moldova, Romania
Overall losses: US$ 800m
Fatalities: 38

19–22 August
Tropical Storm Nuri: Hong Kong, China, Philippines
Overall losses: US$ 40m
Fatalities: 8

18 August–11 September
Floods: India, Nepal, Bangladesh
Overall losses: US$ 240m
Fatalities: 635

21 August–3 September
Hurricane Gustav: USA, Caribbean
Overall losses: US$ 10,000m
Insured losses: US$ 3,500m
Fatalities: 139



6. September
Rockslide: Egypt
Fatalities: 101

7–14 September
Hurricane Ike: USA, Caribbean
Overall losses: US$ 38,000m
Insured losses: US$ 15,000m
Fatalities: 168

12 October–24 November
Wildfires: USA
Overall losses: US$ 2,000m
Insured losses: US$ 600m
Fatalities: 2

28–29 October
Earthquake: Pakistan
Overall losses: US$10m
Fatalities: 300

October–December
Floods: Brazil
Overall losses: US$ 750m
Insured losses: US$ 470m
Fatalities: 131

1–15 December
Floods: Italy
Overall losses: US$ 160m
Fatalities: 8

Great natural catastrophes 1950–2008

In the year 2008, there were 750 loss occurrences, compared with 960 in the previous year. When classified by catastrophe category, however, the drop is noticeable only in the minor events in categories 1 and 2. In categories 3 and 4 (severe and major catastrophes), the number of occurrences was more or less the same in both years. A completely different picture is presented by category 5, which relates to devastating catastrophes with overall losses exceeding US$ 500m in today's values and more than 500 fatalities. Here, a constant upward trend is clearly discernible. In 2008, there were 41 such catastrophes – the highest number ever recorded in this category.

These included

– Hurricane Gustav, which swept over the Caribbean towards the United States, claiming hundreds of lives in Cuba, Haiti, and the Dominican Republic. Gustav caused overall losses totalling more than US$ 10bn.

– Monsoon floods in August and September in India, Bangladesh, and Nepal with thousands of fatalities.

– Typhoon Fengshen, which caused widespread devastation particularly in the Philippines. The toll: over 300,000 damaged or destroyed buildings, more than 550 fatalities, overall losses amounting to US$ 220m.

Great natural catastrophes – Category 6

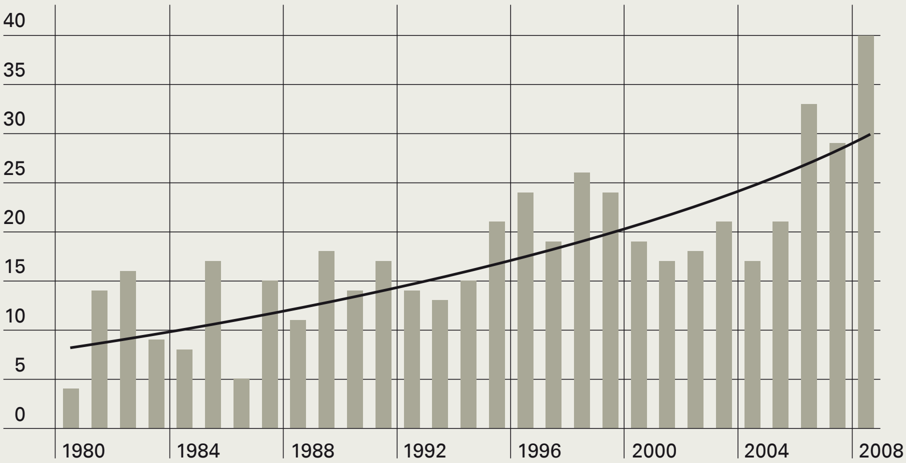
The number and effects of great natural catastrophes in category 6 serve as important criteria for long-term analyses. In line with United Nations definitions, natural catastrophes are classified as great if the affected region's ability to help itself is clearly overstretched and supraregional or international assistance is required. As a rule, this is the case when there are thousands of fatalities, when hundreds of thousands of people are left homeless, and/or when overall losses – considering the economic circumstances of the country concerned – and/or insured losses are of exceptional proportions.

Four catastrophes complied with this definition in 2008: the winter damage in China in January and February, the earthquake in Sichuan (China) on 12 May, Cyclone Nargis, which hit Myanmar in May; and Hurricane Ike, which caused havoc in the Caribbean and the United States. More than 150,000 people lost their lives in these four great natural catastrophes. Overall losses came to US$ 148bn, of which some US$ 17bn was insured.

Outlook

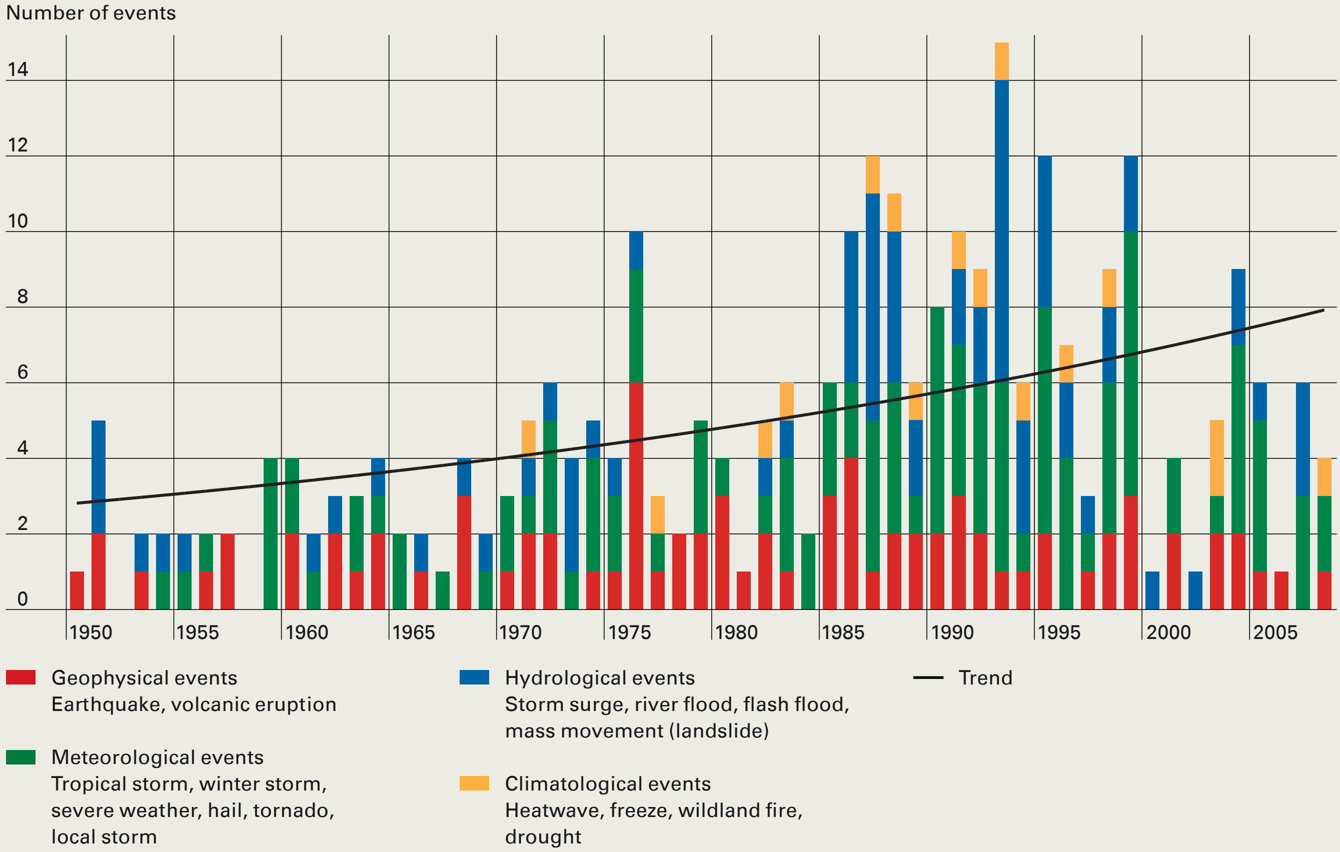
The long-term analysis of great natural catastrophes confirms a rising loss trend. The reasons for this are, to a large extent, socio-economic developments, such as increasing concentrations of values, rising population figures, and the settlement and industrialisation of exposed areas. Climate change and the increase in major weather-related natural catastrophes that is to be expected as a result are not to be neglected as an essential driver of this loss development in the future.

Number of "devastating natural catastrophes" (Category 5) 1980–2008

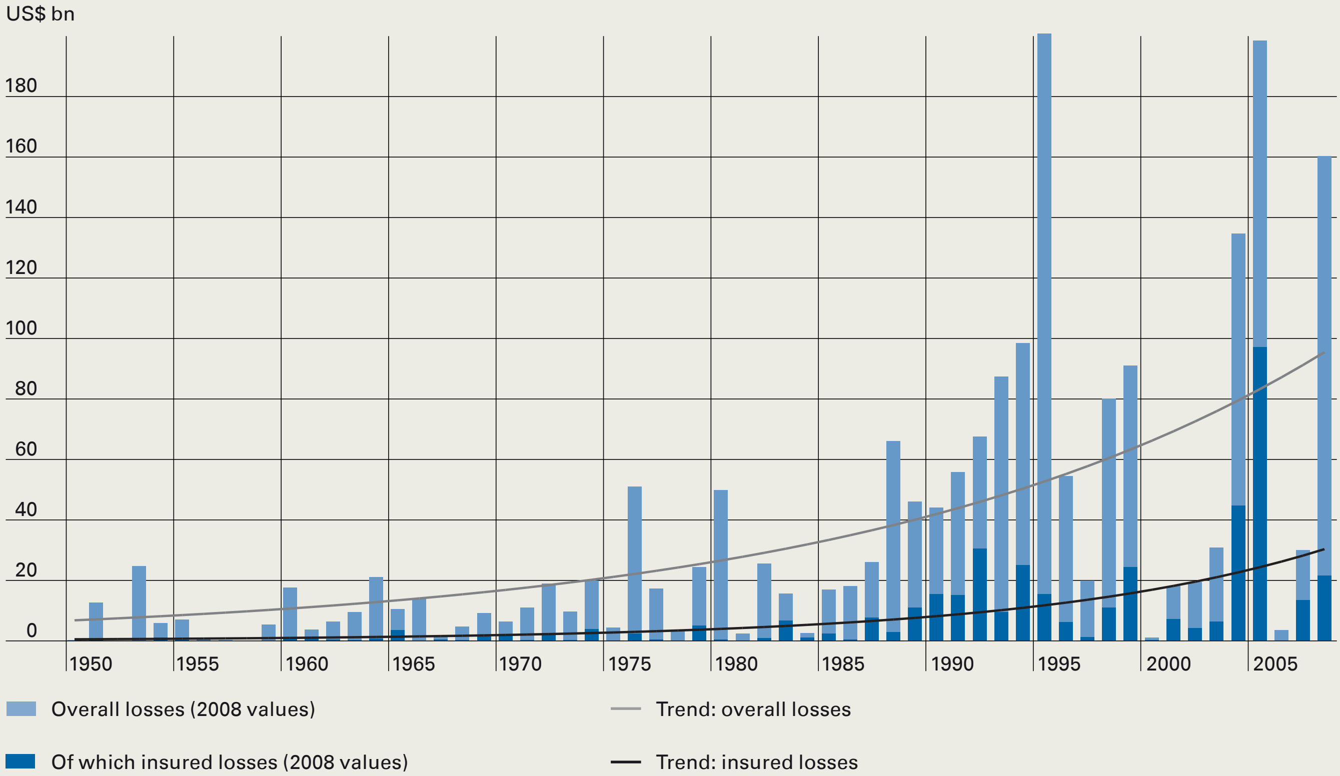


Category 1 Small-scale loss event
1–9 deaths and/or minor and small-scale damage
Category 2 Moderate loss event
10–19 deaths and/or damage to buildings and other property damage
Category 3 Severe catastrophe
More than 20 deaths and/or overall loss of more than US$ 50m
Category 4 Major catastrophe
More than 100 deaths and/or overall loss of more than US$ 200m
Category 5 Devastating catastrophe
More than 500 deaths and/or overall wwloss of more than US$ 500m
Category 6 Great natural catastrophe
(cf. above definition)

Number of "great natural catastrophes", 1950–2008
The chart shows for each year the number of great natural catastrophes (Category 6), divided up by type of event.



Overall losses and insured losses from "great natural catastrophes", 1950–2008
The chart presents the overall losses and insured losses – adjusted to present values. The trend curves verify the increase in Category 6 catastrophe losses since 1950.



Insurance sector think tank – Corporate agreements will generate valuable expertise

Environment and market conditions are changing at breathtaking speed. Demand for innovative concepts to cover complex risks is constantly increasing. We are enhancing our expertise in the field of natural hazards and climate change impacts by engaging with first-class partners, thus laying the foundations for innovative solutions and products.

Munich Re, founding corporate partner of the Centre for Climate Change Economics and Policy at the London School of Economics (LSE)
Since October 2008, Munich Re has been collaborating with the renowned London School of Economics and Political Science. Munich Re is a founding corporate partner of the Centre for Climate Change Economics and Policy, chaired by Professor Lord Nicholas Stern within the new Grantham Research Institute. Our ambitious objective is to quantify and assess the economic impact of climate change, together with the new technologies and market mechanisms, e.g. emissions trading, developed in response to it. The agreement has been concluded for an initial period of five years. Munich Re's five projects will analyse issues such as the impact of climate change on economic development in the BRIC states (Brazil, Russia, India, and China), how best to organise the emissions trading system, and what business potential can be derived from it. The results will be fed into Munich Re's strategic business planning to improve risk management and develop new climate change business segments.

Risk research in collaboration with Risk Management Solutions (RMS)
Risk markets are in a constant state of flux. Consequently, risk modelling, especially accumulation risk modelling, faces many challenges. Munich Re has entered into a long-term agreement with Risk Management Solutions (RMS) that involves identifying and researching new, difficult risk complexes. Founded in 1988, RMS is now the leading provider of products, services, and expertise in the field of catastrophe risk quantification and management. We have concluded this non-exclusive cooperation agreement in order to increase accumulation risk transparency, identify the drivers of modelling uncertainties, optimise risk management, and support the development of innovative risk transfer solutions for clients.

Global Earthquake Model (GEM) – New standard for calculating and communicating earthquake risks
Currently, there is no standard earthquake exposure model. The Global Earthquake Model (GEM) is about to change this. Initiated by the OECD's Global Science Forum, the project will pool the expertise of hundreds of well-known earthquake experts worldwide. It will last for five years. The aim is to establish the Global Earthquake Model as an independent standard that will improve earthquake risk calculations, promote risk awareness, and thus improve loss prevention particularly in the less-developed regions. In the medium term, we believe the work will have a positive effect on insurability of the earthquake peril throughout the world. GEM is an open-source model, i.e. the data and results will be available not just to the scientific community but also to the commercial sector, and any other interested parties.

Globe of Natural Hazards – The interactive reference work for risk communication

When Munich Re's geoscientists first published the World Map of Natural Hazards in 1978, they laid the foundations for what was to become a standard reference work for the identification and risk management of natural hazards.
Now, at the beginning of 2009, the fourth version of the work has appeared as a wall map, a fold-up map, and in digital form.
Since publishing the CD-ROM version, World of Natural Hazards, in 2000, Munich Re has made 80,000 copies available to clients, media representatives, and the public.

What is new in the 2009 version?

The latest version, Globe of Natural Hazards, opens a new avenue in risk communication. The global natural hazard maps are presented on this multimedia DVD against the background of a satellite image globe. New features include the representation of the hazard complexes of hailstorms, tornadoes, winter storms, and coastal hazards. Flood risk is visualised for the first time in selected countries, which has not been possible before due to its enormous complexity. For easier orientation, the user can zoom in on any point in the world or search in a comprehensive database with more than 800,000 locations and cities.

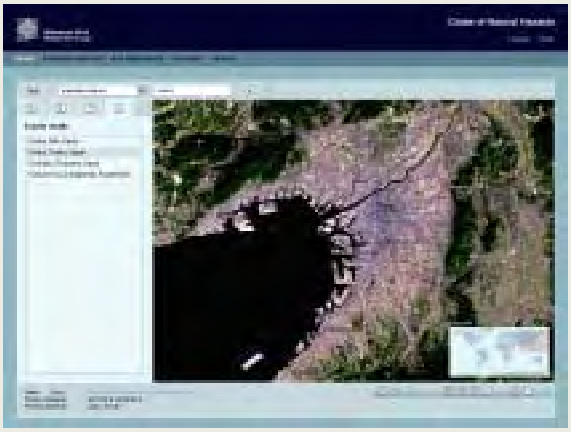
Natural hazards and climate

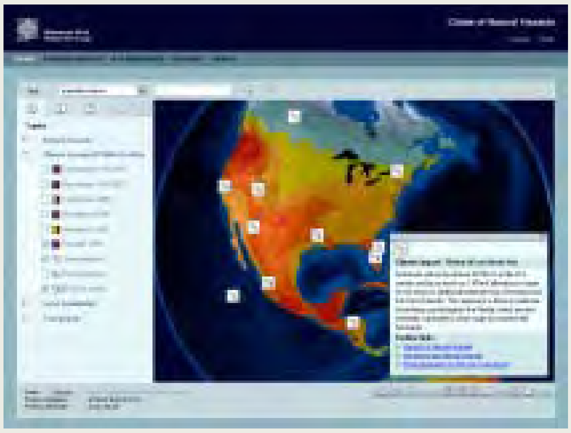
The incorporation of the topic areas of climate change and El Niño/La Niña is another completely new feature, with various climate change maps (precipitation, temperature, heatwaves, droughts) and climate projections integrated for the first time in the globe mode. Knowledge points also indicate the regions of the world in which the risk situation is likely to change in the future.

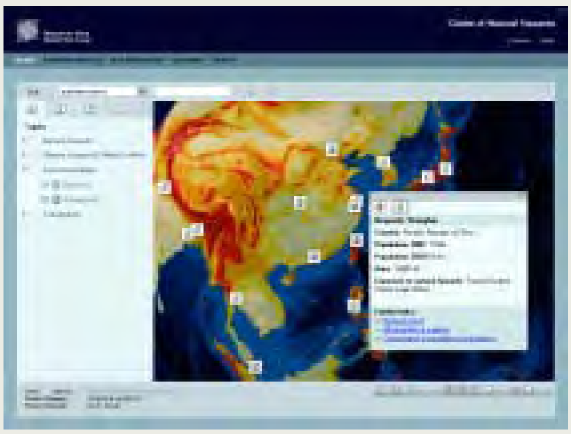
Interlinked and geocoded knowledge

The DVD contains other knowledge components besides climatological information. Under the heading "Local knowledge", it offers a wealth of detail on megacities and other informative topics, ranging from population development to technological risks (e.g. buildings and renewable energy sources). This is an area in which the principle of interlinked knowledge based on geographical-spatial structures can be applied very effectively.

Munich Re's historical Catalogue of Natural Catastrophes (basis: NatCatSERVICE) is linked to the natural hazard and climate maps in this way, too. After a country and period have been selected, the interactive catalogue shows the distribution of historical events and provides information on the associated losses. In the case of exceptional catastrophes, further details are provided by special printable reports.







Power function: Hazard Pointer

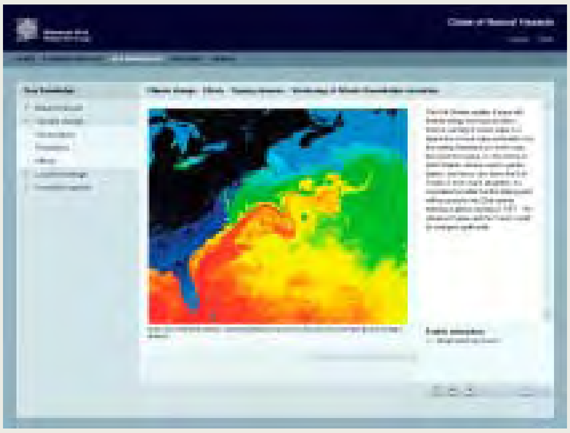
The Hazard Pointer is a special feature that makes it possible to identify the hazard potential at any place on earth with a single click. The systematic classification of the risk provides an objective picture of the hazard. The readable presentation of the results enables the user to make a quick and simple comparison of the exposures at different locations and can be printed in the form of a report. Natural hazards and climatic effects can be assessed jointly for the first time.

More modules – More knowledge

The important background information in the modules Country Profile, Geo Knowledge, Glossary, and Scales make the Globe of Natural Hazards an all-round risk management tool. The Country Profile provides a quick impression of each country, with a list of natural hazards to which it is exposed, information on its geography, together with facts and figures on its administration, population, transportation, and trade and industry. The extensive Geo Knowledge module presents important basic knowledge on all natural hazards and climate change and discusses their interaction with the insurance industry. Numerous diagrams, video clips, and animated sequences supplement the textual content and help non-experts to quickly assimilate complex subject matter. The meaning of specialist terms that are unfamiliar to the user can be found in the Glossary. The various hazard levels in use internationally are listed in the Scales module, which also explains in graphical manner the impact of the various magnitudes and intensities of events.

Risk transparency

Earth's exposure to extreme natural hazards will continue to increase. The interactive Globe of Natural Hazards is a powerful tool for natural hazard risk management – because only with the help of reliable and readily comprehensible information will it be possible to deal effectively with the challenges of the future.



Munich Re offers the following products, which can be ordered from the publications portal on our website (www.munichre.com):

Order numbers
English:

302-05913	DVD – Globe of Natural Hazards
302-05912	Wall map – World Map of Natural Hazards
302-05972	Folding map – World Map of Natural Hazards

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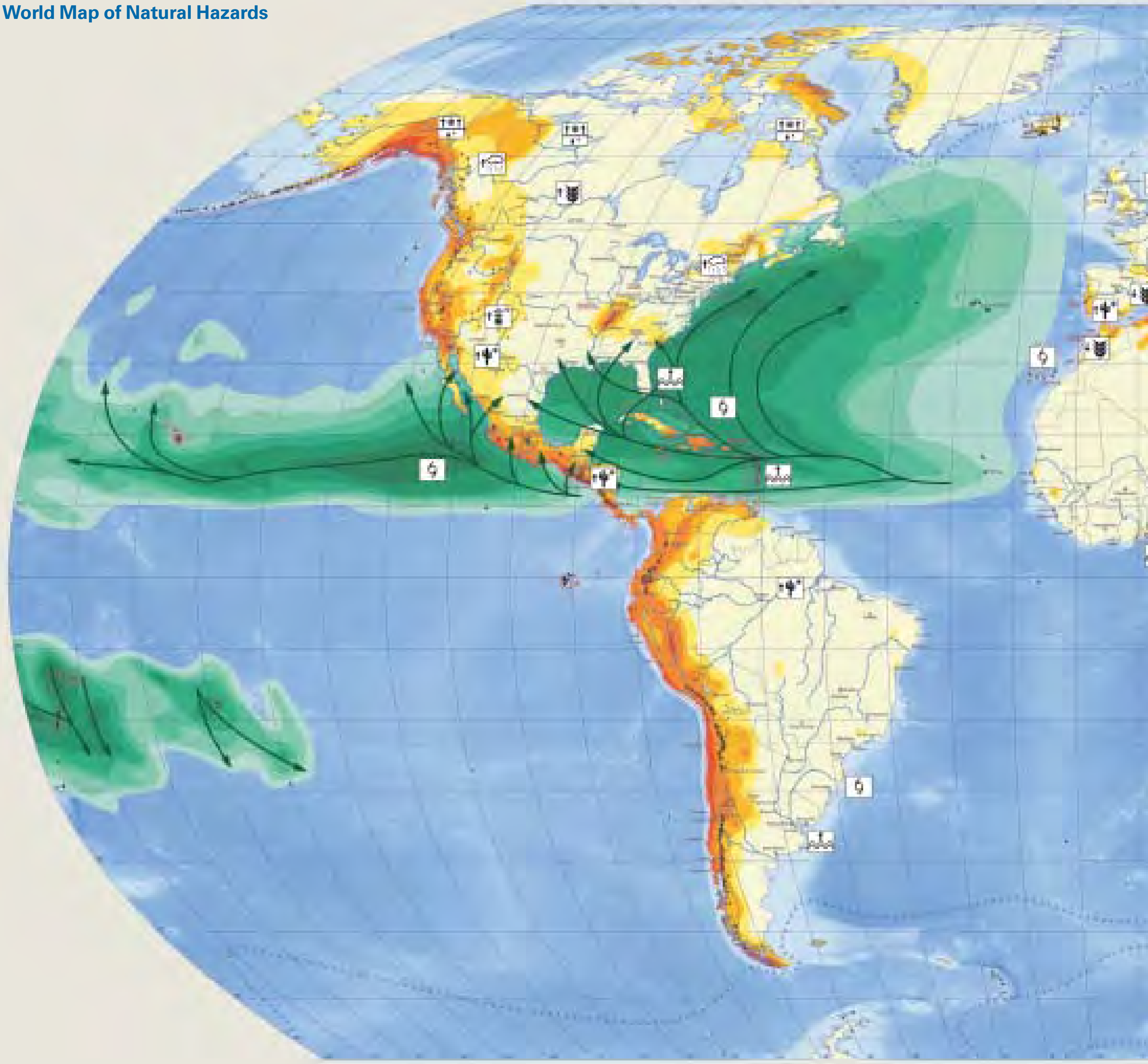
World Map of Natural Hazards



Earthquakes

- Zone 0: MM V and below
- Zone 1: MM VI
- Zone 2: MM VII
- Zone 3: MM VIII
- Zone 4: MM IX and above

Probable maximum intensity (MM: Modified Mercalli scale) with an exceedance probability of 10% in 50 years (equivalent to a return period of 475 years) for medium subsoil conditions.

Ōsaka Large city with "Mexico City effect"

Tropical cyclones

Peak wind speeds*

- Zone 0: 76–141 km/h
- Zone 1: 142–184 km/h
- Zone 2: 185–212 km/h
- Zone 3: 213–251 km/h
- Zone 4: 252–299 km/h
- Zone 5: ≥ 300 km/h

* Probable maximum intensity with an exceedance probability of 10% in 10 years (equivalent to a return period of 100 years).

Typical track directions

Volcanoes

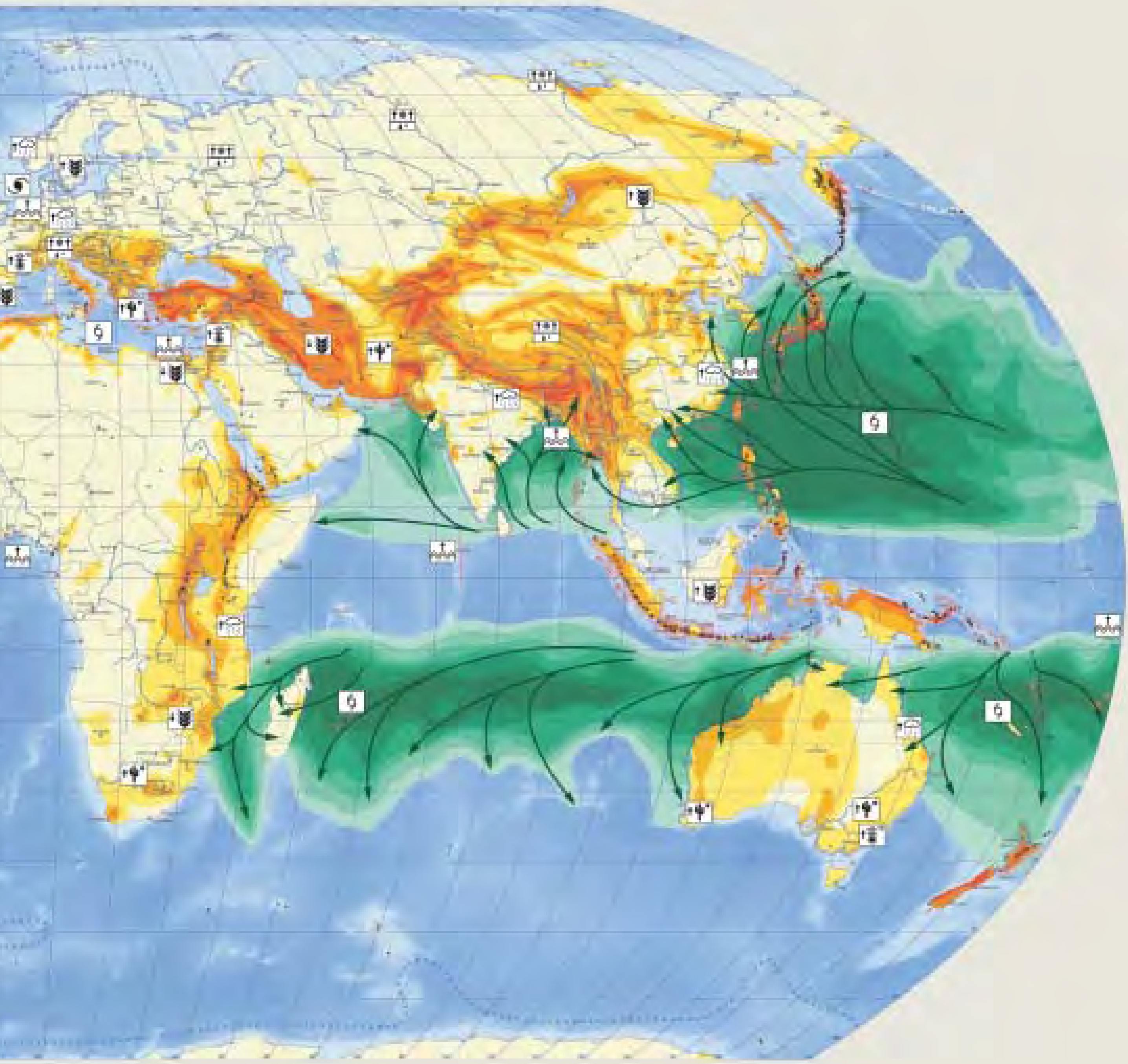
- △ Last eruption before 1800 AD
- ▲ Last eruption after 1800 AD
- ▲ Particularly hazardous volcanoes

Tsunamis and storm surges

- Tsunami hazard (seismic sea-wave)
- Storm surge hazard
- Tsunami and storm surge hazard

Iceberg drifts

△ △ △ △ Extent of observed iceberg drifts



Climate impacts

Main impacts of climate change already observed and/or expected to increase in the future

- Change in tropical cyclone activity
- Intensification of extratropical storms
- Increase in heavy rain
- Increase in heatwaves
- Increase in droughts
- Threat of sea level rise
- Permafrost thaw
- Improved agricultural conditions
- Unfavourable agricultural conditions

Political borders

- State border
- State border controversial (political borders not binding)

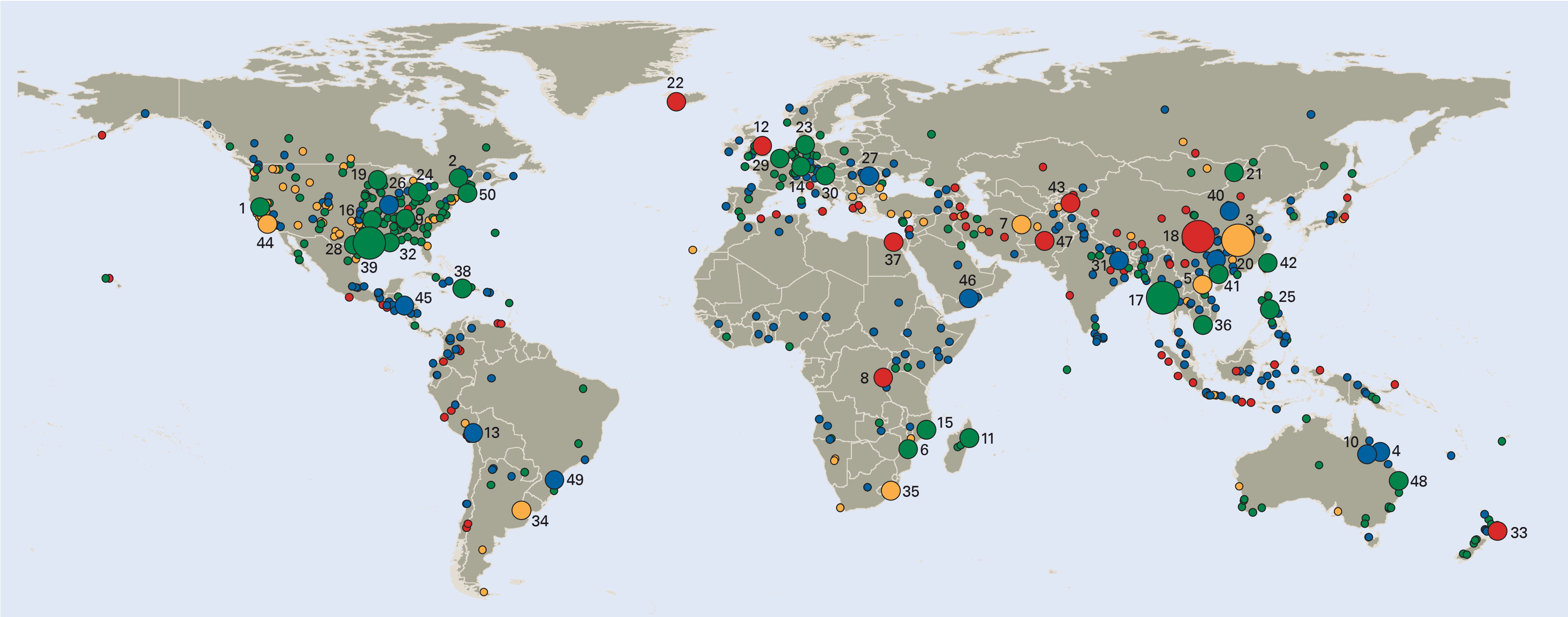
Cities

◻	Denver	> 1 million inhabitants
⊙	San Juan	100,000 to 1 million inhabitants
∘	Maun	< 100,000 inhabitants
■ ● •	Berlin	Capital city
◻	Melbourne	Munich Re office

Data resources

Bathymetry: Amante, C. and B. W. Eakins, ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis, National Geophysical Data Center, NESDIS, NOAA, U.S. Department of Commerce, Boulder, CO, August 2008. **Extratropical storms:** KNMI (Royal Netherlands Meteorological Institute). **Lightning strokes:** NASA LIS/OTD Science Team, NASA/MSFC/GHRC. **Temperature/Precipitation 1978–2007:** Climatic Research Unit, University of East Anglia, Norwich.

Topics Geo World map of natural catastrophes 2008



750 natural hazard losses

- 50 significant loss events (selection)
- 4 great natural catastrophes

- **Geophysical events:** Earthquake, volcanic eruption
- **Meteorological events:** Tropical storm, winter storm, severe weather, hail, tornado, local storm
- **Hydrological events:** Storm surge, river flood, flash flood, mass movement (landslide)
- **Climatological events:** Freeze, wildland fire, drought

Great natural catastrophes 2008

No.	Date	Region	Loss event	Fatalities	Overall losses (US$ m)	Insured losses (US$ m)
3	10.1.–13.2.	China	Winter damage	129	21,000	1,200
17	2.–5.5.	Myanmar	Cyclone Nargis	85,000	4,000	
18	12.5.	China	Earthquake	70,000	85,000	300
39	7.–14.9.	Caribbean.USA	Hurricane Ike	168	38,000	15,000

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Topics Geo Significant natural catastrophes in 2008

No.	Date	Loss event	Region	Fatal-ities	Overall losses US$ m	Insured losses US$ m	Explanations, descriptions
1	4–9.1	Winter storm	USA: esp. CA, MI	12	1,000	745	Wind speeds up to 175 km/h, tornadoes, heavy rain, hail. Thousands of houses, vehicles and businesses damaged.
2	7–9.1	Severe storm, flash floods	Canada		80	50	Wind speeds up to 100 km/h. Houses, vehicles damaged.
3	10.1–13.2	Winter damage	China	129	21,000	1,200	485,000 houses damaged/destroyed. 2,100 greenhouses collapsed. Severe losses to agriculture, 118,600 km² of crops affected/damaged.
4	14–31.1	Floods	Australia		600	450	Heavy monsoon rains, flash floods. Hundreds of houses flooded/damaged. Crops destroyed, livestock killed. Losses to mines.
5	Jan–Feb	Winter damage	Vietnam		36		Severe losses to agriculture. 1,500 km² of rice fields destroyed. 60,000 cattle killed.
6	Jan–Feb	Cyclone Fame	Mozambique	20	100		Torrential rain. Rivers burst their banks. Houses flooded. Losses to agriculture.
7	Jan–Feb	Cold wave, avalanches	Afghanistan, Kyrgyzstan	1,000			Heavy snowfall. >800 houses destroyed. 150,000 head of livestock killed.
8	3–4.2	Earthquake	DR of Congo	7	7		Mw 5.9. 3,400 houses, public buildings damaged.
9	5–6.2	Tornadoes, severe storm	USA: esp. KY,TN	50	1,300	955	Wind speeds >300 km/h, thunderstorms, large hail. Thousands of houses and cars damaged/destroyed. Losses to agriculture.
10	11–18.2	Floods	Australia	2	1,100	890	Thunderstorms, high wind speeds, flash floods. 2,000 houses, 100 businesses flooded/damaged. Losses to mines.
11	17–19.2	Cyclone Ivan	Madagascar	93	60		Wind speeds up to 230 km/h, heavy rain, floods. >130,000 houses, bridges damaged/destroyed. 500 km² of crops destroyed, livestock killed.
12	27.2	Earthquake	Great Britain		40	30	Mb 4.8. Buildings, vehicles damaged.
13	Feb–March	Floods, landslides	Peru, Bolivia, Ecuador	50	175		Torrential rain. >62,500 houses damaged/destroyed. Roads, bridges destroyed. Losses to crops. Oil pipeline damaged, oil spilled.
14	1–2.3	Winter Storm Emma	Europe	14	2,000	1,500	Wind speeds up to 150 km/h, thunderstorms, tornadoes, heavy rain, snowfall. Houses, vehicles damaged. Losses to industry and communication facilities.
15	5–10.3	Tropical Cyclone Jokwe	Mozambique	17	20		Wind speeds up to 200 km/h, heavy rain. 20,000 buildings damaged/destroyed. >110 fishing boats damaged/destroyed. Bridge collapsed.
16	9–11.4	Severe storm	USA: esp. AR,TX	3	1,100	800	Wind speeds up to 110 km/h, torrential rain, hail, flash floods. Thousands of houses and businesses damaged. >50,000 people without electricity.
17	2–5.5	Cyclone Nargis	Myanmar	85,000	4,000		Wind speeds up to 215 km/h. 450,000 houses destroyed, 350,000 damaged. Crops destroyed, 156,000 head of livestock killed. Major losses to infrastructure. Missing: 54,000.
18	12.5	Earthquake	China	70,000	85,000	300	Mw 7.9. Landslides, rockslides. >5 million houses destroyed, >21 million damaged. 50,000 greenhouses damaged/destroyed, 12,5 million head of livestock killed. Missing: 18,000.
19	22–26.5	Severe storm, tornadoes	USA: esp. CO, MN	12	1,600	1,325	Wind speeds up to 260 km/h, thunderstorms, hail. Thousands of houses, businesses and vehicles damaged. Electricity and communication facilities interrupted.
20	23.5–23.6	Floods	China	170	2,100		Torrential rain, landslides, rockfall. 3,000 schools, 140,000 houses damaged/destroyed. 530 km² of crops destroyed.
21	26–29.5	Snowstorm	Mongolia	44			Wind speeds up to 145 km/h. Buildings damaged. Several hundred head of livestock killed.
22	29.5	Earthquake	Iceland		80	75	M 6.2. Rockslides. Houses, roads damaged/destroyed. Livestock killed.
23	29.5–2.6	Severe Storm Hilal	Germany	3	1,500	1,100	Thousands of houses, vehicles damaged. Hail damage to cars and vineyards. Losses to infrastructure.
24	5–8.6	Severe storm, tornadoes, floods	USA: esp. MI,WI	24	1,500	725	Thunderstorms, wind speeds up to 130 km/h, hail, flash floods. Thousands of buildings damaged/destroyed.
25	18–25.6	Typhoon Fengshen	Philippines. China	560	220		Wind speeds up to 140 km/h, flash floods, landslides. >85,000 houses destroyed, 270,000 damaged.
26	June	Floods	USA: esp. KS,WI	24	10,000	500	>5,000 buildings damaged/destroyed. Crops destroyed, livestock killed. Losses to infrastructure.
27	22.7–7.8	Floods	Eastern Europe	38	800		Thunderstorms, heavy rain, landslides. 50,000 houses damaged. Crops destroyed.
28	23–25.7	Hurricane Dolly	Mexico. USA	3	1,050	525	Wind speeds up to 160 km/h, heavy rain, flash floods, storm surge. Hundreds of houses damaged. Damage to oil platforms. Business interruption.
29	4.8	Tornado	France	3	80	60	Wind speeds up to 215 km/h. 1,000 houses damaged/destroyed.
30	15.8	Hailstorm	Slovenia		200	190	Thunderstorms, hail up to 6 cm in diameter. Houses, vehicles damaged. Losses to crops.
31	Aug–Sept	Floods	India, Nepal, Bangladesh	635	200		Torrential rain, landslides. 800,000 houses damaged/destroyed. Severe losses to agriculture. Evacuated: >10 million. Displaced: 3 million.
32	21.8–3.9	Hurricane Gustav	Caribbean. USA	139	10,000	3,500	Wind speeds up to 240 km/h, tornadoes, heavy rain, flood. >140,000 houses damaged/destroyed. Losses to oil platforms. Evacuated/displaced: >3 million.
33	25.8	Earthquake	New Zealand		5	0.5	M 5.9/5.5. Property damage
34	Summer	Drought	Argentina		700		Severe losses to agriculture.
35	30.8–11.9	Bush fire	South Africa	34	430		Wind speeds up to 100 km/h. 330 km² of forest burnt. Property damage.
36	August	Tropical Storm Kammuri	China, Vietnam	211	160		Wind speeds up to 95 km/h, flash floods, landslides. >4,000 houses destroyed, 18,000 damaged. Losses to agriculture and livestock. Affected: 125 million.
37	6.9	Rockslide	Egypt	101			Massive rockfall. 30 houses buried.
38	6–8.9	Tropical Storm Hanna	Haiti, USA, Canada	540	150	80	Wind speeds up to 95 km/h, heavy rain, flash floods. Hundreds of buildings damaged. 200,000 people without electricity.
39	7–14.9	Hurricane Ike	Caribbean. USA	168	38,000	15,000	Storm surge. Hundreds of thousands of houses and vehicles damaged/destroyed. Losses to oil platforms. >2 million people without electricity.
40	8.9	Rockslide, mudslide	China	277			Thousand of houses damaged/destroyed.
41	20–30.9	Typhoon Hagupit	China, Philippines, Taiwan, Vietnam	80	1,000	100	Wind speeds up to 220 km/h, torrential rain, flash floods, landslides. 30,000 houses damaged/destroyed.
42	28.9	Typhoon Jangmi	Taiwan	2	90	65	Wind speeds up to 155 km/h. 86,000 households without electricity. Losses to agriculture.
43	5.10	Earthquake	Kyrgyzstan, China	85			Mw 6.6. >520 houses damaged/destroyed. Village destroyed.
44	12.10–24.11	Wildfire	USA: esp. CA	2	2,000	600	Santa Ana winds, gusts up to 110 km/h. 1,000 houses destroyed. 87 km² of forest burnt.
45	15–23.10	Floods, landslides	Honduras, Nicaragua, Guatemala	43			Tropical depression. Mudslides. Thousands of houses destroyed, >11,000 damaged.
46	24–25.10	Flood	Yemen	185	400		Thousands of houses damaged/destroyed. Losses to infrastructure.
47	28/29.10	Earthquakes	Pakistan	300	10		Mw 6.4. Landslides. >2,000 houses destroyed.
48	15–21.11	Severe storms, floods	Australia	2	450	200	Gusts up to 130 km/h, large hail, flash floods, landslides. >4,000 houses damaged/destroyed. >200,000 houses flooded.
49	Oct–Nov	Flood, landslides	Brazil	131	750	470	80% of Santa Catarina flooded. Thousands of houses damaged.
50	11–22.12	Winter storms, ice storms	USA: esp. MA, NY	5	360	275	Wind speeds up to 100 km/h, heavy rain, floods, snow and ice. Houses, businesses and vehicles damaged.

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