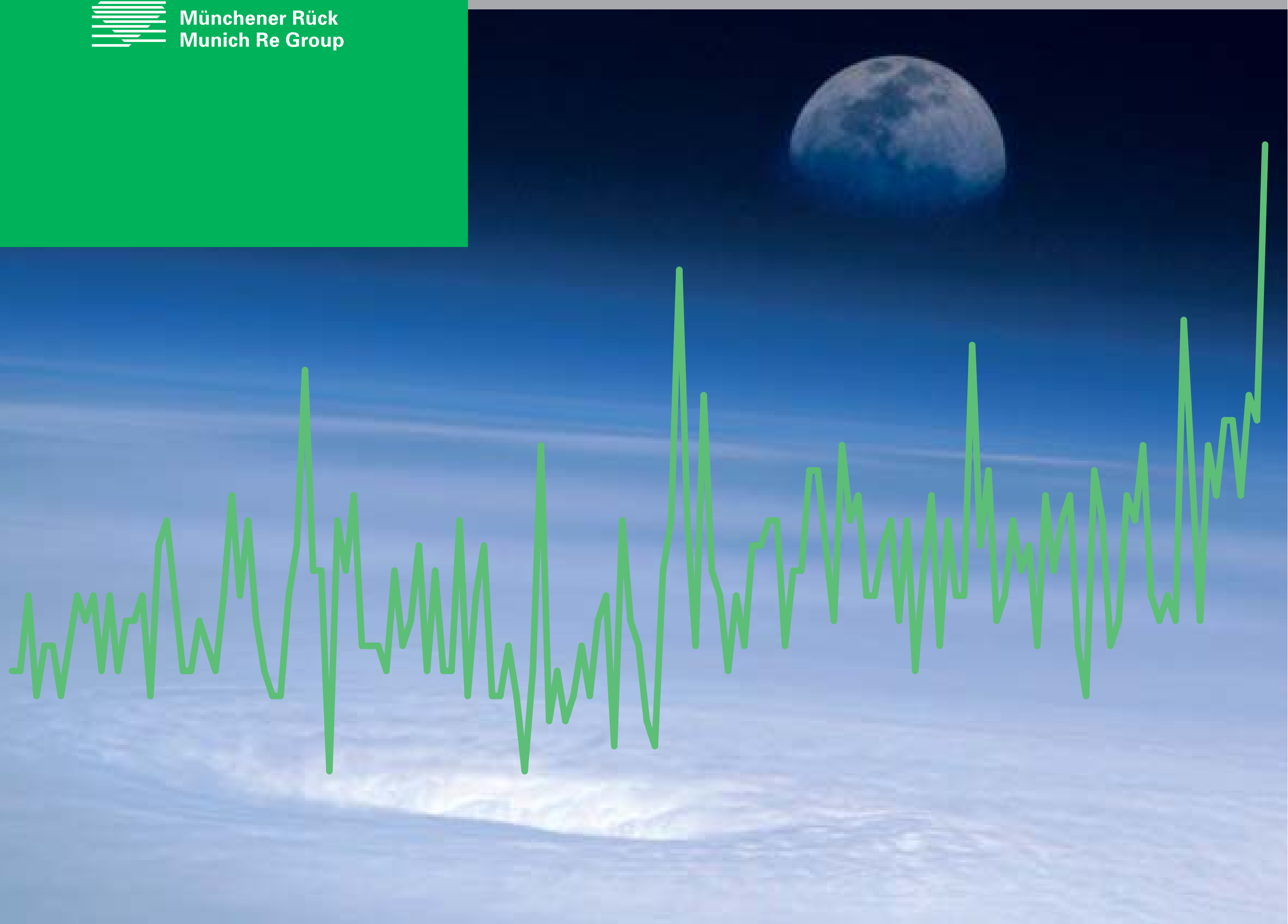
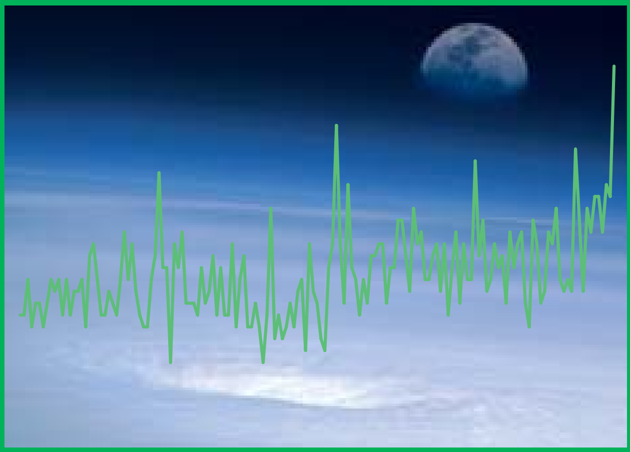
Knowledge series

Hurricanes – More intense, more frequent, more expensive

Insurance in a time of changing risks

Münchener Rück
Munich Re Group





Tropical cyclones in the North Atlantic
Annual frequency of named storms from 1851 to 2005.
Data source: NOAA.

Background:
Hurricane Emily, image from the ISS space station.
Image source: NOAA.

Introduction

This publication on the 2005 hurricane season is a joint product of Munich Re and American Re.

In 2005, the hurricanes in the Atlantic broke all meteorological and monetary records – one more reason to examine the risk in even greater detail in the future.

Our particular focus is on the North Atlantic. Professional risk management has long ceased to be just a matter of simply looking at the historical claims statistics for tropical cyclones. This was underlined again by the characteristic patterns of the losses in 2004 and 2005.

The higher frequency of intense storms and indications of a systematic change in the hazard are not only a worry to the people in the regions immediately affected. They are also a challenge to the insurance industry. The current situation is marked by a significant increase in the annual average market loss and changes in the return periods of accumulation losses. The loss amounts in conjunction with wind and water as catastrophe elements are also reaching new dimensions. For the purposes of this publication, we have collected and evaluated information derived from scientific sources and insurance practice.

So far, hardly any loss models have factored in these changes. The challenge of adjusting to changes in the risk situation, however, is something the insurance industry must accept. To this end, Munich Re and American Re draw on the latest scientific findings, because the more knowledgeable we are in anticipating risk developments, shifts in the exposure situation, and vulnerability to losses, the more exact we can be in adjusting insurance conditions, capacities, and price structures.

Munich Re has been analysing and documenting the effects of climate change for years. Our publication "Topics Geo – Annual review: Natural catastrophes 2005" also confirms that although the insurance industry worldwide has managed to cope with the record losses of the past year, the ability to provide cover for natural hazards in the future will depend on the development of adequate insurance solutions for catastrophe scenarios that have hitherto been considered inconceivable – we have to think the unthinkable.

Dr. Torsten Jeworrek
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Executive summary

Modelling the hurricane risk in the North Atlantic: Adjustments are needed

In 2004, the insurance industry had to pay a record sum of US$ 30bn for losses caused by North Atlantic hurricanes, especially in the United States and the Caribbean. This figure was far more than doubled in 2005 by the insured losses from tropical cyclones in this region, which topped US$ 83bn. Hurricane Katrina alone will probably cost the insurance industry around US$ 45bn. In meteorological terms too, the exceptional year of 2004 – with its four major hurricane loss events in Florida – was followed by the most active cyclone season since track data were first recorded in 1851. There were 27 named tropical storms in 2005, passing the previous record of 21 in 1933.

The intensities, i.e. wind speeds, have also reached peak levels in the last few years. Three of the ten strongest hurricanes ever recorded in the North Atlantic occurred in 2005. Hurricane Wilma had a record low central pressure of only 882 hPa – and hence, in all probability, the highest wind speeds in the Caribbean since 1851.

In addition, the recent past has seen a spate of exceptional windstorm events around the globe. This trend continued in 2005. Forming near the island of Madeira, Hurricane Vince was the most easterly and northerly tropical cyclone ever. It set course for the European mainland and reached the coast of Spain on 11 October. At the end of November, Tropical Storm Delta crossed the Canary Islands, the first tropical cyclone ever in this region.

It is no wonder that Munich Re speaks of “unsettling developments”. The many exceptional meteorological events and losses for the insurance industry speak for themselves. There is no doubt that the models used to simulate the hurricane risk in the North Atlantic need adjusting.

Science can make a central contribution to quantifying the required changes in these models. Scientific analysis is currently focusing on natural climate oscillations and the effects of climate change on the hurricane hazard. However, with the risk of change becoming increasingly manifest, risk carriers cannot wait until science has provided answers to all the relevant questions, particularly as it will not be able to do so in the short term. On the contrary, science and insurance must come to terms with a new situation – not only in the North Atlantic but probably in other regions too and with regard to other meteorological hazards.

The record losses from Hurricane Katrina in August 2005 made it very clear that adjustments are needed not only because the hurricane frequency and intensity distributions are changing, but also because of the secondary hazards associated with tropical cyclones like storm surge and inland flooding. This publication tackles the question of such secondary hazards, which have not yet been considered adequately in existing modelling approaches.

It is up to the insurance industry to incorporate in its risk management all the findings on the hurricane hazard, the loss potentials of storm surges and floods, and the factor of vulnerability. New loss distributions will consequently affect all its business processes – from the calculation of the risk price, to the calculation of the required risk capital, and to profit-oriented portfolio management. The results of re-evaluating the risk will vary from portfolio to portfolio. But one thing is certain: the adjustments required of all risk carriers will be substantial.

Tropical cyclone landfalls in the United States
Running ten-year average of annual frequencies.
Data source: NOAA

Climate cycles and global warming – Effects on risk evaluation

Unsettling development: The hazard situation in the North Atlantic has changed in the current warm phase, resulting in higher average annual losses. There is no doubt that the insurance industry must expect a new loss distribution and take appropriate measures with regard to its risk management.

Dr. Eberhard Faust, Munich

The 2004 hurricane season with four landfalls in and around Florida and the highest cyclone-related loss ever for the insurance industry already raised a very pressing question: has the hurricane risk in the North Atlantic changed systematically in comparison with the situation 10–15 years ago? The 2005 season, with even higher insured and economic losses, has given this question added urgency. Recent findings of climate research confirm the change in the hazard situation.

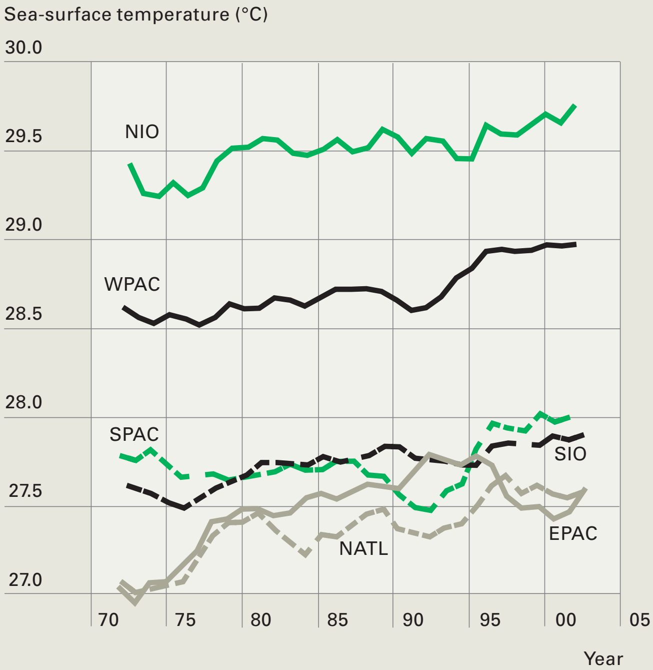
Sea surface temperatures and cyclone intensities worldwide

The wind speeds of a tropical cyclone are forced by the difference in temperature and pressure between the air surrounding the storm and its warm centre. The high temperature and the comparatively low pressure in the centre are due to sea surface evaporation – which in turn is due to the temperature of the sea's surface. Climate simulation models with cyclone modules show that a warmer earth with higher temperatures in tropical oceans results in more intense cyclones with higher wind speeds and heavier precipitation (Knutsen/Tuleya [2004], Journal of Climate). Although not the only influential factor – atmospheric stratification, vertical wind shear, and the depth reached by the warm surface water also play a part – sea surface temperature is one of the most important factors as far as the intensity of storms is concerned. So what developments have there been in the temperatures of the oceans' surface layers?

Scientific findings

According to a study performed by the Scripps Institute (Barnett et al. [2005], Science), it is very likely that anthropogenic climate change is already one of the prime reasons for the increase in the temperatures of upper sea layers (vgl. Tourre/White [2005], Geophys. Res. Lett.). This is borne out by a comparison of temperature trends since 1960 and simulation models. The trend in all tropical oceans during the summer season has averaged at approx. +0.5°C since 1970 (Fig. 1).

Fig. 1 Sea surface temperatures: Running five-year average



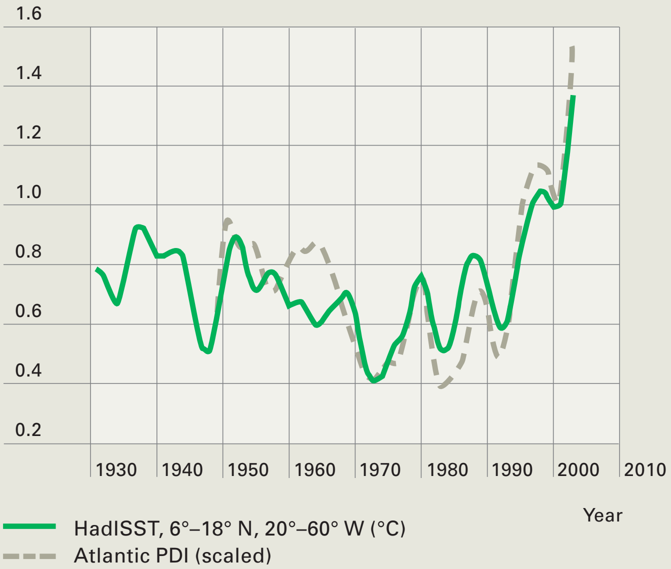
Source: Webster et al. (2005), Science 309.

Readings (°C) in tropical and subtropical ocean regions with cyclone activity since 1970.
NATL = North Atlantic, WPAC = West Pacific,
SPAC = South Pacific, EPAC = East Pacific,
NIO = Northern Indian Ocean,
SIO = Southern Indian Ocean

The findings of a study published in August 2005 (Emanuel [2005], Nature) show that in recent years there has been a sharp increase in the intensity of tropical cyclones – measured in terms of the maximum wind speed and the cumulative length of time with high wind speeds – correlating with the increase in sea surface temperatures (Fig. 2). This evidence initially applied to the North Atlantic and the Northwest Pacific only, but there are now good reasons for believing that this correlation is a global one.

The proportion of severe tropical cyclones (Saffir-Simpson Categories 4–5) has grown sharply throughout the world since 1970. This is expressed in absolute figures too, from around 8 per year at the beginning of the 1970s to 18 per year in the period 2000–2004 (Fig. 3).

Fig. 2 Correlation between sea surface temperature and annual intensity of cyclones

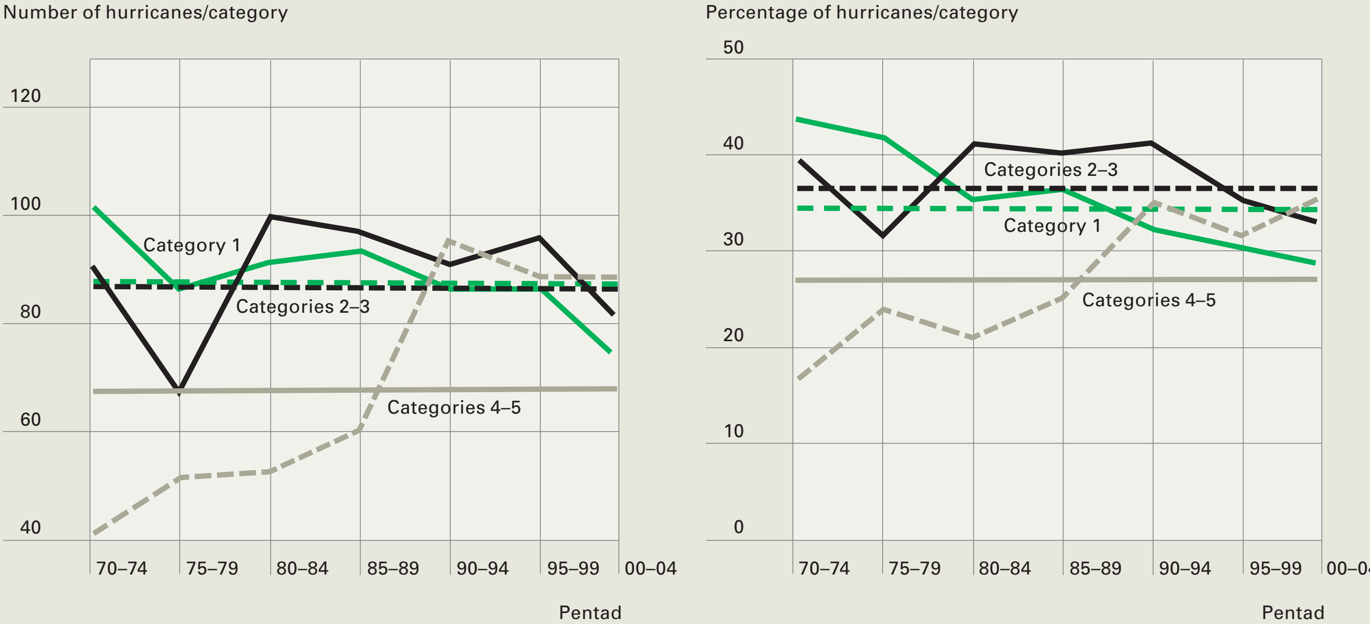


Source: Emanuel (2005), Nature

Sea surface temperature obtained from the Hadley Centre dataset (HadISST) in the main area of cyclone formation in the North Atlantic in correlation with the Power Dissipation Index (PDI), the accumulated annual wind energy of cyclones. For this comparison, the units were standardised and scaled.

Below left:
Throughout the world, severe cyclones (Saffir-Simpson Categories 4–5) have increased from 40 to 90 per five-year period since 1970. The number of weaker cyclones (Category 1) has decreased. There is no general trend to be seen as far as moderate cyclones (Categories 2–3) are concerned.
Below right:
Same as the chart on the left, but values shown as percentages of the total.

Fig. 3 Development of cyclones of different intensities



Source: Webster et al. (2005), Science

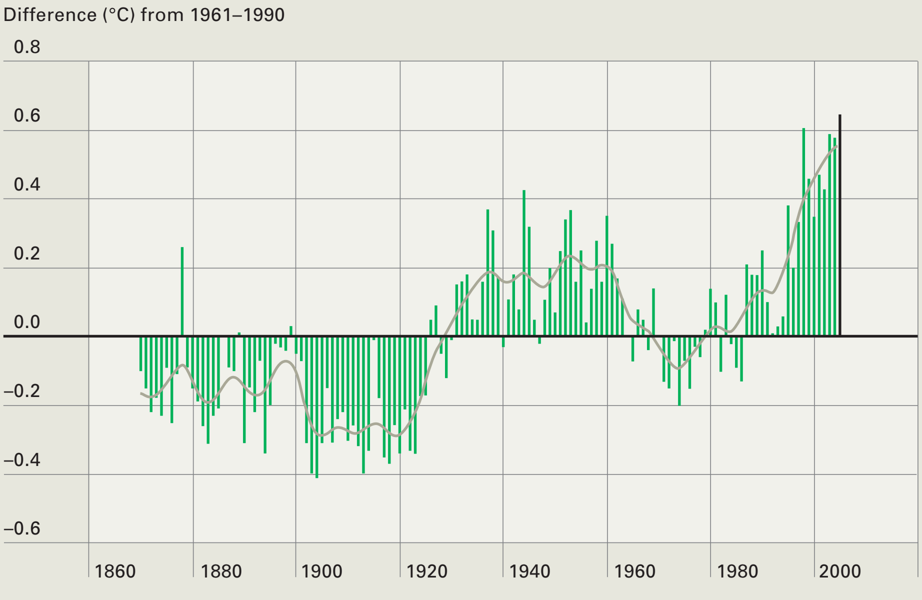
It is not only the intensity distribution that has shifted towards the more severe types of event; in some regions there has also been a change in terms of frequencies. The annual average number of cyclones occurring around the world is 80 (margin of deviation: 20) without any discernible trend. In the North Atlantic, on the other hand, the frequency has increased since 1970, i.e. since the beginning of a period with sea surface temperatures that were distinctly lower than today (Figs. 1 and 8). In line with the current very high temperatures, the 2005 season set an absolute record with 27 named tropical cyclones. The previous record of 21 was set in 1933. The number of hurricanes recorded in 2005 was also a new record at 15, surpassing the previous high of 12 in 1969. These records are particularly significant considering the fact that the average of the past 100 years is "only" ten named cyclones per season in the North Atlantic, six of which are of hurricane force.

Sea surface temperatures and cyclone activity in the North Atlantic

Fig. 4 tracks the annual average sea surface temperature in the North Atlantic since 1880. It reveals an oscillation between lower and higher temperature levels, the latter occurring before 1900, between the end of the 1920s and the end of the 1960s, and since the mid-1990s. The time series also underlines a further, quite decisive aspect: over the years, both the maximum and the minimum temperatures have reached higher and higher levels. The values recorded in recent years are therefore completely new. On the basis of current data, 2005 was an historical year, with the highest value since 1880.

Multidecadal oscillation and the superimposed long-term warming process both have a determining impact on cyclone activity in the North Atlantic.

Fig. 4 Annual average sea surface temperature in the North Atlantic



Source: The Met Office and the University of East Anglia statement on the climate of 2005, 15 December 2005

Deviation of the annual average relative to the average for the years 1961–1990. 2005 (black bar): average for January–November.

When comparing this with the development of sea surface temperatures in the main hurricane formation area in the tropical North Atlantic (10–20°N) it should be noted that here the oscillation phases are somewhat different and shifted in relation to the average of the North Atlantic as a whole (cf. the curves in Trenberth, K. [2005], Science 308). This is due to the fact that it takes years for the heat to be transported from the south to the north (see the following text).

The effect of natural climate oscillation: Atlantic Multidecadal Oscillation (AMO)

In the North Atlantic, alternating phases of exceptionally warm and exceptionally cool sea surface temperatures have been observed, each lasting several decades. The margin of deviation is roughly 0.5°C, with an oscillation period in the 20th century of about 65 years (Fig. 5). There is no uniform definition of the phase boundaries in the field of research[1]. The phases also shift from region to region, because it takes many years for the warm and cold water masses to spread across the ocean. The phases in northern regions, for example, differ by several years from those in the main area of hurricane birth in the tropical North Atlantic (10–20° N) (cf. the curves in Trenberth, K. [2005], Science 308).

If the AMO's effect on the temperature is measured as a temperature anomaly linked to a standard deviation in the AMO Index, the steepest increases in sea surface temperature during a warm phase take the form of a horseshoe. In the north, it covers Atlantic regions between North America and Europe in a belt around 40–65°N, then stretches southwards along the eastern edge of the North Atlantic basin into the tropical North Atlantic off the west coast of Africa, and from there moves westwards into the Caribbean and parts of the Gulf of Mexico.

[1] We use the phase boundaries proposed by Landsea et al. (1999) and Goldenberg et al. (2001).

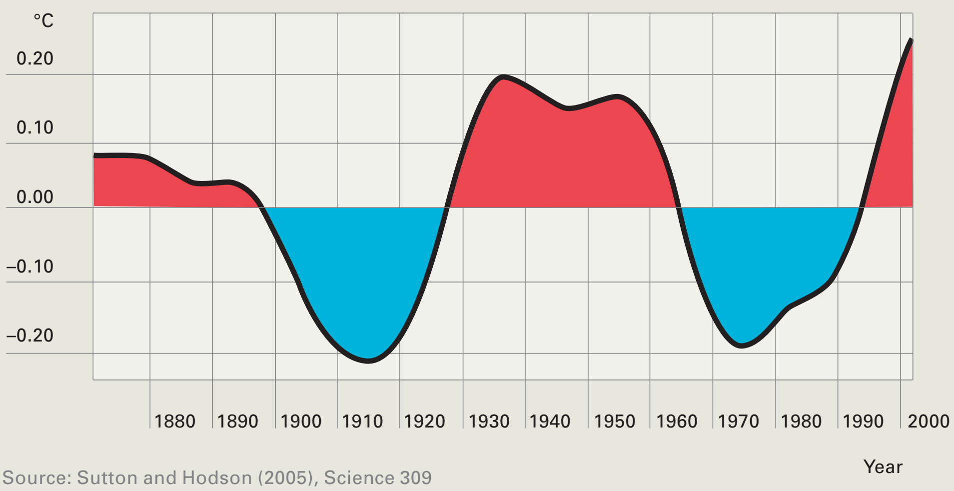
Ocean conveyor belt: Thermohaline circulation (THC)

Experiments using the climate model developed by the Hadley Centre in Britain, which links atmospheric and oceanographic data, have shed light on the mechanism of the multidecadal oscillation in the North Atlantic (Vellinga, M. and Wu, P. [2004], J. Clim 17; Knight, J. et al. [2005], GRL 32). This is a well-founded hypothesis that is attracting much attention in the current scientific debate. The key is to be found in thermohaline circulation (THC). The process may be described in simplified terms as a super-dimensional water conveyor belt in the ocean. Warm, saline water from the tropical North Atlantic, the Caribbean, and the Gulf of Mexico is transported by the Gulf Stream and the North Atlantic Current in the upper sea layers towards the north and the east.

Once it has discharged its heat into the atmosphere, the water, which is very dense due to its salt concentration, sinks to the depths in parts of the Labrador Sea and off the coast of Europe between Greenland and Scotland. This churning process, which is often termed "meridional overturning" (MO), is completed in these deeper layers by a current flowing south.

The sinking zones are to be seen as the engines of the circulation process, the churning rate being determined by the salt content of the water. The greater the churning effect of the THC, which crosses the equator in the south, the more heat is transported from tropical latitudes into northern latitudes, meaning that sea surface temperatures rise in the North Atlantic and the AMO is in a warm phase. The waters of the tropical North Atlantic are also heated up by the powerful THC process as they subsequently receive very warm water from regions south of the equator. The compensating cooling process takes place south of the equator.

Fig. 5 Atlantic Multidecadal Oscillation (AMO)



Source: Sutton and Hodson (2005), Science 309

AMO index 1873–2003 (°C). The index is based on sea surface temperatures in the tropical and extratropical North Atlantic. The detrended and filtered time series shows the deviation from the long-term average.

The temperature oscillation cycle: Alternating warm and cold phases

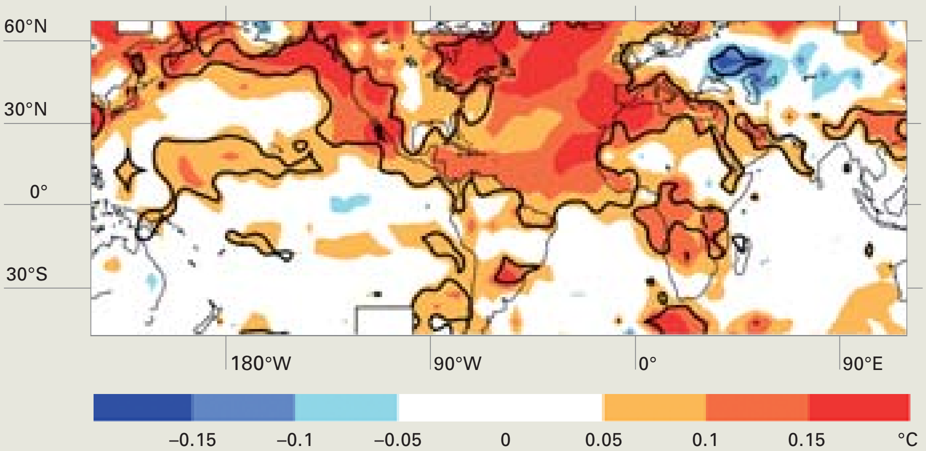
Climate model simulations help to explain how the multidecadal cycle of temperature oscillation functions. Starting at the maximum of the warm phase, very dense, saline water is to be found in the northern latitudes of the Atlantic. The sinking of this water acts as a powerful THC engine, while large parts of the ocean including the tropical North Atlantic are exceptionally warm.

A belt of convective clouds and torrential rain near the equator, the Intertropical Convergence Zone (ITCZ), tends to surge over what are currently the warmest regions of the tropical ocean. As the warm phase develops, exceptionally large amounts of heat from southern latitudes enter the tropical North Atlantic so that it becomes abnormally warm. The belt of cloud and rain therefore moves further north over the tropical North Atlantic and intensifies in the process. Heavy rainfall is consequently transported from the ITCZ into the tropical waters and reduces their salt content.

The less saline water is taken northwards by the ocean conveyor belt of the THC, and, after a phase delay of several decades, its slower sinking motion decelerates the THC engine. This results in a radical reduction in the transport of heat from tropical latitudes into northern and eastern regions of the North Atlantic and the ocean enters a cold phase. The ITCZ weakens and returns to a more southerly position closer to the equator. The temperature of the sea south of the equator rises. At that time, the salinity of the tropical North Atlantic can increase again, finally leading to a stronger THC after a few decades: a new warm phase has thus begun.

Besides increasing the intensity of storms in the North Atlantic, warm phases also generate more frequent hurricanes. Cold phases have the opposite effect. In the current warm phase, the average number of major hurricanes per year has already reached 4.1, compared with only 1.5 in the previous cold phase, corresponding to an increase of about 170%. The current warm phase in the North Atlantic began in the mid-1990s. How long it will continue is uncertain, but judging by past warm phases, it could go on for years, if not decades.

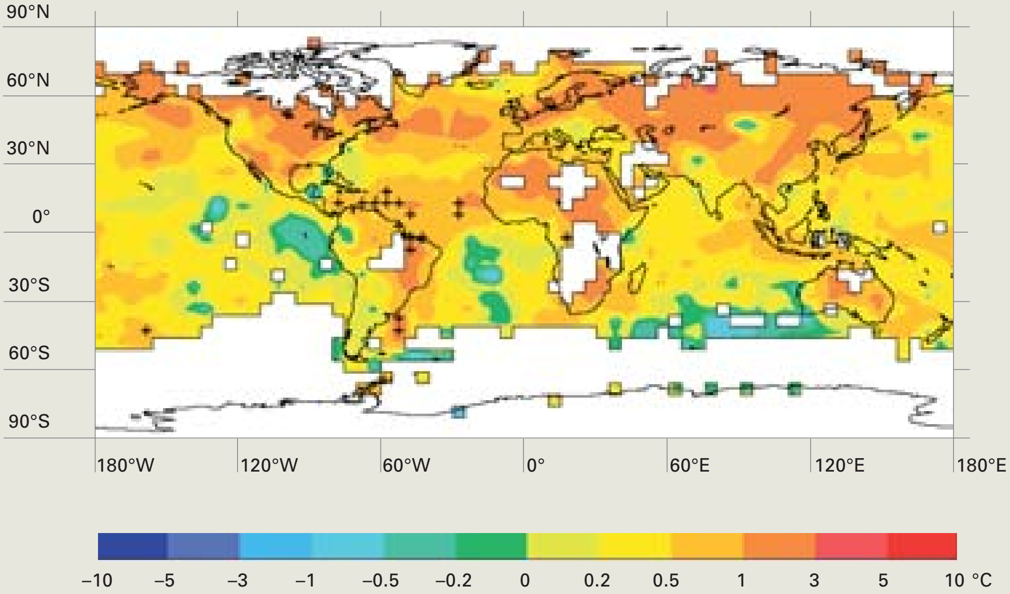
Fig. 6 Surface temperature anomaly



Source: Knight et al. (2005), GRL 32

Effect on the temperature in °C, associated with a positive standard deviation in the AMO index.

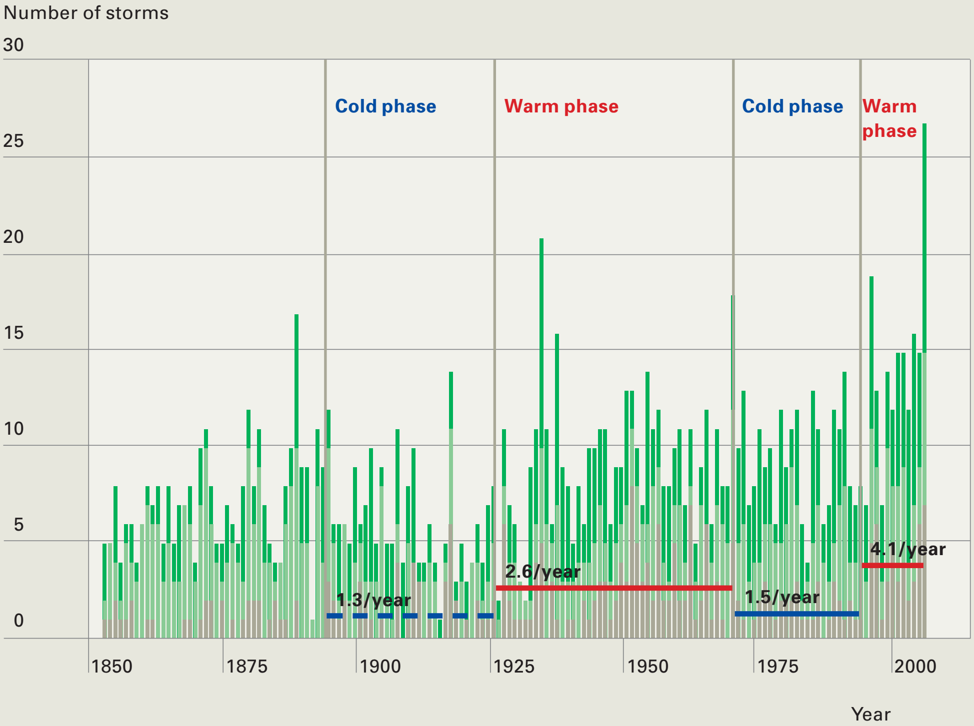
Fig. 7 Anomalies in the 2005 surface temperature



Source: The Met Office and the University of East Anglia statement on the climate of 2005, 15 December 2005

Temperature anomalies for January to November 2005, relative to the average for 1961–1990. Crosses indicate the warmest anomaly ever measured at that location.

Fig. 8 Annual frequencies of tropical cyclones of various categories



Data source: NOAA, Unisys; graph: Munich Re

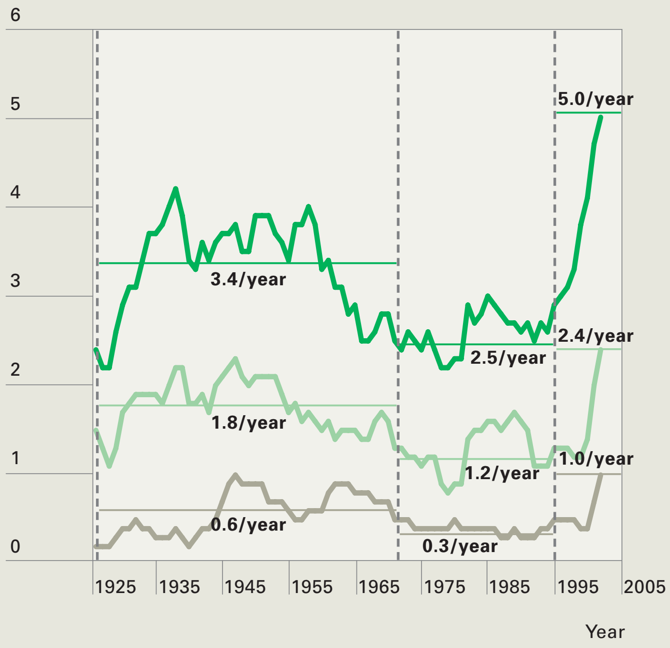
Horizontal lines relate to the average annual number of Category 3–5 hurricanes during the warm and cold phases in the North Atlantic. Phase boundaries after Landsea et al. (1999) and Goldenberg et al. (2001).

- Tropical storms and hurricanes
- Hurricanes (Categories 1–5)
- Major hurricanes (Categories 3–5)
- Annual frequencies of major hurricanes in warm or cold phases

Superimposed long-term warming of the North Atlantic

Cyclone activity in the North Atlantic is determined not only by the natural multidecadal oscillation but also by a superimposed long-term warming process. We have already seen that sea surface temperature and hurricane activity increase from one warm phase to the next (Fig. 4). Between July and September 2005, positive sea surface temperature anomalies of up to 2°C were registered in some parts of the tropical North Atlantic and the Caribbean, with average readings for January to November 2005 reaching record levels at several points on the map (Fig. 7). The number of major hurricanes per year has risen from 2.6 in the previous warm phase to 4.1 in the current warm phase – an increase of 60% (Fig. 8). There are strong indications that this long-term warming is due to climate change (Barnett et al. [2005], Science 309; Tourre/White [2005], GRL). From this we may conclude that the current unusually high level of activity is largely due to the prevailing warm phase in the natural climate oscillation but that it is also intensified by the long-term process of anthropogenic global warming.

Fig. 9 Tropical cyclone landfalls in the United States



Data source: NOAA, Unisys; graph: Munich Re

Running ten-year average of annual frequencies. Vertical lines signify the beginning and end of warm and cold phases. Horizontal lines signify the annual average of each phase. Phase boundaries after Landsea et al. (1999) and Goldenberg et al. (2001).

Tropical storms and hurricanes
Hurricanes (Categories 1–5)
Major hurricanes (Categories 3–5)

Higher frequency of cyclone landfalls

Both the natural climate cycle and global warming appear to produce not only more hurricanes but also more cyclone landfalls. Between the last warm phase (1926 to 1970) and the current warm phase beginning in the mid-1990s, the average number of landfalls of various Saffir-Simpson categories increased as follows (Fig. 9):

Category 3–5 hurricanes:	+67% (from 0.6 to 1.0)
Category 1–5 hurricanes:	+33% (from 1.8 to 2.4)
Tropical cyclones and Category 1–5 hurricanes:	+47% (from 3.4 to 5.0)

This comparison reflects above all the influence of global warming.

The change in level between the last cold phase (1971 to 1994) and the current warm phase has the following impact on the number of landfalls (Fig. 9):

Category 3–5 hurricanes:	+233% (from 0.3 to 1.0)
Category 1–5 hurricanes:	+100% (from 1.2 to 2.4)
Tropical cyclones and Category 1–5 hurricanes:	+100% (from 2.5 to 5.0)

This comparison shows above all the influence of natural climate oscillation.

Change in the loss distribution – Effects on the insurance industry

The extreme changes in the number of tropical cyclones and their landfalls can mean only one thing: a different loss distribution must be assumed for the current warm phase than in the years before.

As described above, the annual number of major hurricanes in the current warm phase is about 170% higher than in the previous cold phase. In terms of landfalls, the increase is in the order of 230%. Even if we compare the loss distribution of the current warm phase with a loss distribution which is indifferent to the natural climate cycle and is based on all years since 1900, we should still expect a large difference. This is borne out by a comparison of the hurricane intensity distributions for the whole period of 1900–2005 and the current warm phase 1995–2005. It clearly shows that the proportion of severe storms has risen and that of moderate storms has fallen (Fig. 10).

As the loss distribution in present models has usually been based on all loss events since 1900 and does not distinguish between the various phases, it is inevitable that the present estimate of loss levels is too low. In fact, recent Munich Re analyses confirm that the annual loss expectancy value increases if the current warm phase loss distribution is taken as a basis rather than a distribution that does not factor in the different phases. This is where the insurance industry is confronted with a great challenge. It must respond to the present-day hazard and loss distribution and take them into consideration adequately in its risk management.

In addition to highlighting this need to respond to changes in the climate, the record losses generated by Hurricane Katrina have also shown that there are some aspects which amplify tropical cyclone losses but which are disregarded in current loss models or are not given sufficient weight in the estimate of the overall insured loss. These aspects include:

- the effects of storm surge and flood;
- complex relationships in the insurance of business interruption that have a loss-aggravating effect;
- the limited number of loss adjusters, which hampers the settlement process when there are large numbers of individual claims;
- substantial increases in the prices for materials and wages for the work of restoration and in the costs of alternative accommodation when buildings are damaged and uninhabitable;
- more severe damage and delayed, more expensive repairs when the same region is hit by several storms within a short time.

Fig. 10 Intensity distributions of hurricanes

Graph: Munich Re

Comparison of intensity distributions for the period 1900–2005 and the current warm period 1995–2005. The intensity classification was based on the maximum wind speeds reached according to NOAA HURDAT and Unisys (for 2005).

Some of these aspects are often subsumed under the term "demand surge". The experience gained with Katrina, however, has shown that this is a term that can be used to describe only one partial and limited aspect of the losses resulting from such a major event. The challenge to the insurance industry is more extensive, since it must not only respond to the present-day hazard situation but also adequately integrate new and hitherto little heeded hazards in its risk management.

Glossary

Anthropogenic climate change and global warming

Atmospheric CO_2 concentration before industrialisation was 280 to 300 ppm. This level of concentration had not been exceeded in the previous 650,000 years at least – and probably not even in several million years. During the industrial age, greenhouse gas emissions increased continuously. In 2004, atmospheric CO_2 concentration reached a level of 380 ppm. There are other greenhouse gases such as methane or dinitrogen oxide that increased equally fast over the same period.

Greenhouse gases alter the radiation characteristics of the atmosphere. This results in the lower atmosphere absorbing much more solar energy in the form of long-wave heat radiation. This anthropogenic global warming is augmented by the natural greenhouse effect. Long before the industrial age and even before the emergence of mankind, the earth's atmosphere contained greenhouse gases (in particular CO_2), and these warmed the earth's surface by roughly 33°C. If there had been no natural greenhouse effect, life on earth would have been impossible.

Tropical cyclones

General expression for storms forming over tropical oceans. Depending on their intensity and the region involved, they are called hurricanes (Atlantic and Northeast Pacific), typhoons (Northwest Pacific), or cyclones (Indian Ocean and Australia).

Atlantic warm and cold phases

The warm and cold phases in the North Atlantic are part of the Atlantic Multidecadal Oscillation (AMO). The AMO is based on a mechanism that may be compared to a huge conveyor belt in the ocean, which transports water from tropical regions into northern and eastern regions of the North Atlantic in alternating strong and not so strong phases. As a result, the sea surface temperatures in certain ocean regions are unusually high or unusually low for several decades. The churning motion, which is driven by the temperature and salinity of the water, is called thermohaline circulation (THC).

Natural climate oscillations

Natural climate oscillations can be differentiated by the respective time scales. They are not driven by external influences on the earth's climate system, such as changes in solar irradiance or anthropogenic greenhouse gas emissions. Examples of natural climate oscillations are the El-Niño/Southern-Oscillation events (time scale: several years), the North Atlantic Oscillation (time scale: quasi-decadal), and the Atlantic Multidecadal Oscillation (time scale: several decades).

The Saffir-Simpson Hurricane Scale

		Mean wind speed			
	Description	m/s	km/h	mph	knots
1	Weak	32.7–42.6	118–153	73–95	64–82
2	Moderate	42.7–49.5	154–177	96–110	83–96
3	Strong	49.6–58.5	178–209	111–130	97–113
4	Very strong	58.6–69.4	210–249	131–155	114–134
5	Devastating	69.5–	250–	156–	135–

Tropical cyclones and hurricanes in the North Atlantic
The names given in 2004 and 2005.

2004

ALEX BONNIE CHARLEY
DANIELLE EARL FRANCES
GASTON HERMINE IVAN
JEANNE KARL LISA
MATTHEW NICOLE OTTO

2005

ARLENE BRET CINDY
DENNIS EMILY FRANKLIN
GERT HARVEY IRENE
JOSE KATRINA LEE MARIA
NATE OPHELIA PHILIPPE
RITA STAN TAMMY VINCE
WILMA ALPHA BETA
GAMMA DELTA EPSILON
ZETA

Peak meteorological values and never-ending loss records

The last two years have been dominated by extreme tropical cyclones. The belief that the exceptional year of 2004 would be followed by a period of calm in 2005 turned out to be mistaken. The time has come for a radical rethinking of how hurricane risks are evaluated.

Ernst Rauch, Munich

The record-breaking year of 2004

2004 was marked by the highest regional frequencies and intensities of tropical cyclones in the North Atlantic since the recording of meteorological tracks began in 1851.

Hurricane Ivan was particularly significant for the insurance industry: its HDP (Hurricane Destruction Potential), which is the sum of the squares of the maximum wind speed in 6-hour periods for the duration of the storm, was 71,250. For the sake of comparison, the average HDP value of all tropical cyclones recorded in the Atlantic in each entire season between 1950 and 1990 was 70,600.

Hurricane Destruction Potential (HDP)

$$HDP = \sum_{i=1}^{k} v_i^2$$

v = maximum gusts in knots within a six-hour period
k = number of six-hour periods during the lifetime of the hurricane

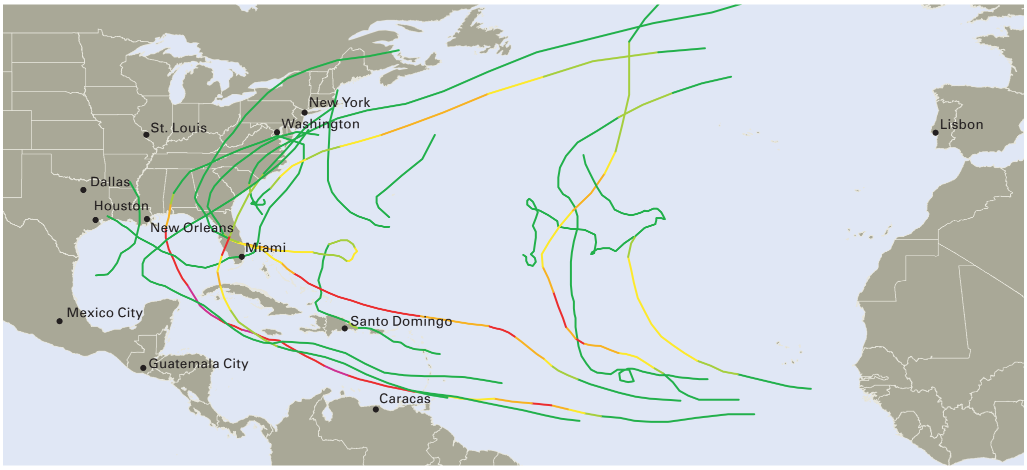
The sum of the squares of the maximum wind speed in each six-hour period provides an approximate measure of a hurricane's kinetic energy. Wind speed v is usually given in knots in the United States.

Hurricane Ivan set new records in terms of duration and intensity, but the latest scientific findings suggest it will not be an exception for very long. The study (Emanuel [2005], Nature) quoted in the section "Climate cycles and global warming – Effects on risk evaluation" shows that the Power Dissipation Index (PDI), which represents the accumulated wind energy of tropical cyclones in the North Atlantic for a whole year, increased sharply in correlation with the higher sea surface temperature. The PDI is calculated in a similar way to the HDP. A closer analysis of this change makes it clear that there has been an increasing trend in the strength and duration of hurricanes and thus in their destruction potential too.

2005 – An increase is possible

In this season, both hurricane activity, i.e. the number of tropical cyclones, and the observed intensities reached new peak levels. The new maximum values were far above the old records of 21 tropical storms (1933) and 12 hurricanes (1969). A total of 27 named tropical cyclones developed in the North Atlantic, 15 of which reached hurricane force with wind speeds exceeding 118 km/h.

Abb.11 Tracks of tropical cyclones and hurricanes in the Atlantic in 2004



In 2004, 15 tropical cyclones developed in the Atlantic, nine of which reached hurricane force with wind speeds exceeding 118 km/h.

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

(Saffir-Simpson Scale)

The intensities were no less striking. The list of the ten strongest hurricanes ever recorded includes Wilma, Rita, and Katrina, all from the year 2005. On 19 October, Wilma had a central pressure of 882 hPa, the lowest ever recorded. This suggests that it also had higher wind speeds than any other hurricane in the Caribbean since recordings began in 1851.

The beginning and end of the hurricane season in 2005 were also marked by exceptional meteorological features. The hurricane year began very actively with seven tropical cyclones in June and July – two more than the previous record of five by the end of July. Hurricane Epsilon marked the end of the season in December, along with Tropical Storm Zeta, which was still active in the Atlantic even at the beginning of January 2006: two storms that did not observe the "official" end of the hurricane season on 30 November.

Losses caused by the hurricane series in 2004 and 2005

The four most devastating hurricanes with landfalls in the Caribbean and the United States – Charley, Frances, Ivan, and Jeanne – presented the insurance industry with a new peak loss from tropical cyclones in the Atlantic of around US$ 30bn.

The most expensive year for insurers in this region before then was 1992, when Hurricane Andrew generated insured losses of US$ 17bn. According to Munich Re's analyses, Andrew would cost the insurance industry almost US$ 30bn today, given the increase in insured values in the affected regions of Florida and Louisiana since then.

The sum total of individual losses from hurricanes in 2004 was therefore not an extraordinary figure in itself. The surprising part was that a loss of these dimensions occurred only 13 years after Hurricane Andrew, since there are commercial models that put the "return period" for an annual market hurricane loss of US$ 30bn at well over 30 years.

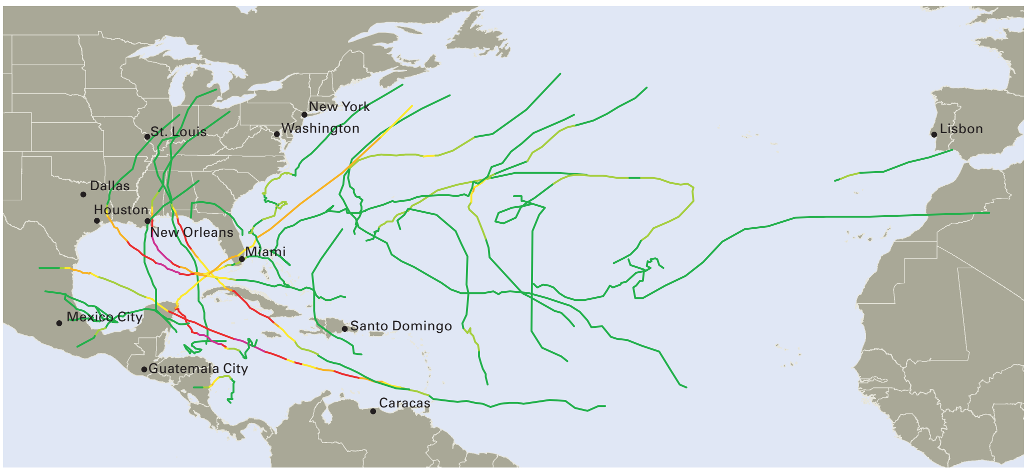
The high loss accumulation from a series of moderate hurricanes was also unexpected for some risk carriers. Many insurers had responded to Hurricane Andrew by concentrating their efforts on estimating the accumulation loss potential of one major event – but these estimates were to be put to the test in 2005.

The natural catastrophe year of 2005 was marked by record losses from hurricanes in the North Atlantic, with insured losses exceeding US$ 83bn. Munich Re estimates that Hurricane Katrina alone generated privately insured market losses of US$ 45bn. This figure was boosted by Rita and Wilma, each costing around US$ 10bn, and significant insured losses from other storms like Dennis, Stan, and Emily.

A phase of rethinking is necessary

Two aspects in particular marked the year 2005: a megaloss caused by Hurricane Katrina and a succession of moderate hurricane losses. Only a year after the most expensive natural catastrophe year in original values, the optimism displayed by many a market player proved to be unfounded. 2004 was not a solitary exception.

Fig. 12 Tracks of tropical cyclones and hurricanes in the Atlantic in 2005



In 2005, 27 tropical cyclones developed in the Atlantic, 15 of which reached hurricane force.

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- Category 4 (210–249 km/h)
- Category 5 (≥ 250 km/h)

(Saffir-Simpson Scale)

Losses in 2004 and 2005: Insured market losses from hurricanes

United States (mainland only)	approx. US$ 95bn
Gulf of Mexico (offshore)	approx. US$ 14–15bn
Caribbean	approx. US$ 2bn
Mexico	approx. US$ 2bn
North Atlantic (United States, Caribbean, Mexico)	approx. US$ 115bn

In all these regions, a process of fundamental rethinking is called for in the evaluation of hurricane risks. The United States mainland is particularly important in this regard, since high insured values will inevitably lead to high insured accumulation losses when the time comes.

Hurricane Katrina: Meteorological aspects

Hurricane Katrina developed out of a low-pressure vortex over the Bahamas on 23 August. As the eleventh tropical cyclone of the 2005 hurricane season, it crossed South Florida in the Miami area as a Category 1 hurricane (measured on the Saffir-Simpson Hurricane Scale).

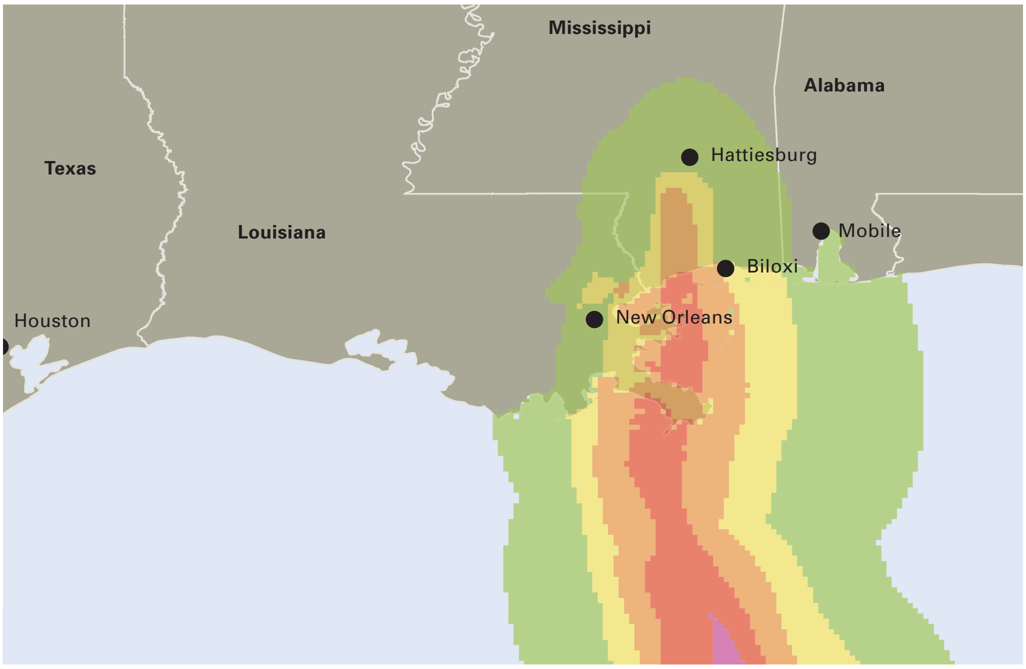
In the days that followed, Katrina moved over the eastern part of the Gulf of Mexico with a rapid increase in intensity. Over those areas where the water temperature was 1–2°C above the long-term average, the hurricane already reached force 5 on 28 August. This corresponds to wind speeds of approx. 340 km/h in peak gusts.

Shortly before making landfall on 29 August in the state of Louisiana – some 30–50 km east of New Orleans – it weakened to a Category 4 hurricane. An analysis of wind speed data published by the National Hurricane Center in Miami in December 2005 adjusted its strength at landfall again, lowering it even further to Category 3. Upon landfall in Louisiana and when it moved on to the states of Mississippi and Alabama, Katrina caused massive windstorm damage and, initially on a local scale, flood damage due to torrential rain.

Just a few hours after the hurricane vortex had passed over South Louisiana, the levees were breached on Lake Pontchartrain and on an artificial drainage canal. Large parts of New Orleans were flooded. The affected areas lie below sea level in a kind of soup bowl, and there is no natural drainage.

As draining is only possible using pumps or by natural evaporation, it took several weeks to dry out the city. It was not until early December 2005 that important infrastructure installations were back in place and access to the city of New Orleans was completely restored.

Fig. 13 Distribution of maximum wind speeds



Hurricane Katrina in the Louisiana and Mississippi region. The wind field is based on the last published version before our editorial deadline.

Wind field source: NOAA/AOML/HRD; graph: Munich Re

- Category 1 (118–153 km/h)
- Category 2 (154–177 km/h)
- Category 3 (178–209 km/h)
- Category 4 (210–249 km/h)
- Category 5 (≥ 250 km/h)

(Saffir-Simpson Scale)

Causes of catastrophes – Scenarios in the United States

The figures tell a depressing story. In 2005, over 83 billion dollars of insured values were destroyed by hurricanes in the United States, the Caribbean, and Mexico. Identifying and simulating possible loss scenarios may not be able to prevent natural catastrophes, but it can certainly mitigate their effects, save lives, and reduce property losses.

Dr.-Ing. Wolfgang Kron, Munich

Katrina, the sixth most powerful hurricane since recordings began in 1851, caused widespread devastation along large sections of the US Gulf Coast. And yet this hurricane – like the flooding of New Orleans – did not come as a complete surprise. Experts and the media had been discussing this very scenario for years (e.g. Brouwer [2003], Civil Engineering), and it was definitely not a question of if but when disaster would strike.

Is New Orleans no longer insurable against flooding?

The flooding of New Orleans was an all-or-nothing type of loss event, i.e. either nothing or next to nothing would happen or those affected would face total disaster. As the probability of all-or-nothing events tends to be very low, they entail an element of surprise which can exacerbate losses significantly.

Before Katrina it was assumed that any flooding of New Orleans would claim thousands of lives (Fischetti [2001], Scientific American). The only reason this did not happen in 2005 is because the hurricane did not hit the city full on, with the result that the levees did not fail across the board. Drowning as such was therefore not the number one cause of death. Most of the approx. 1,300 victims died of exhaustion, dehydration, starvation, or asphyxiation, or were the victims of homicides.

The experts were also surprised by something else: flood control failed in New Orleans not only because the levees were overtopped and collapsed due to erosion but also because the water simply pushed them away (Seed et al. [2005]). On 17th Street Canal, a 40-m section of the levee slid back 14 m, even though the water level was still a good 60 cm below the crest. Analyses will now have to establish whether the levee breaches in New Orleans were the result of faulty design or poor construction.

Levee breach on the west side of London Avenue Canal, New Orleans
Faulty design is likely since the water pushed the levee aside, along with its integrated concrete wall.

The levees were built in the 1960s and were designed to withstand Saffir-Simpson Category 3 hurricanes. They were also supposed to stand up to storm surges with wind speeds of up to 209 km/h. Why then did this catastrophe occur when Katrina only hit New Orleans with wind speeds of a Category 1 and 2 hurricane? Most of the levees are made of swamp peat with a high concentration of organic substances. They stand on a relatively thin layer of clay which lies on a natural layer of peat. In the centre of the levee is an impervious concrete wall which extends into the peat layer. Initial studies suggested that the impervious wall was not deep enough. Water probably flowed under the wall and saturated the subsoil, thus reducing its stability (Seed et al. [2005]).

Should studies reveal that other levees in New Orleans display similar shortcomings, then the residents of this city really are living dangerously. A medium-strength storm surge caused by a Category 1 or Category 2 hurricane making landfall near the "Big Easy" could be enough to inundate the city all over again. Reinforcing, let alone rebuilding, the levees will take years. And that will be too long, as Munich Re estimates the current probability of fresh floods to be many times higher than in the past.

New Orleans is by no means an isolated case – Other flood scenarios in the USA

There are plenty of other places in the United States where billion-dollar floods could also occur. Flood scenarios must also include river flooding and flash floods, not just catastrophes from storm surges. Here are some examples:

Storm surge in Texas (Galveston/Houston)

While Galveston never properly recovered economically from the storm surge of 1900, Houston some 80 km inland prospered. However, the long distance between Houston and the Gulf Coast gives a false sense of security, since the city is linked to the ocean by the Houston Ship Channel, which can carry storm surges far inland. Large industrial complexes line up along the channel like pearls on a string. An overtopped or even breached levee would result in insurance losses totalling billions of dollars. The city has already received several warning shots. In June 2001, Tropical Storm Allison left the city centre under water and caused overall damage estimated at US$ 6bn. And the track of Hurricane Rita in September 2005 only just missed Houston and Galveston.

Storm surge in Florida (Miami)

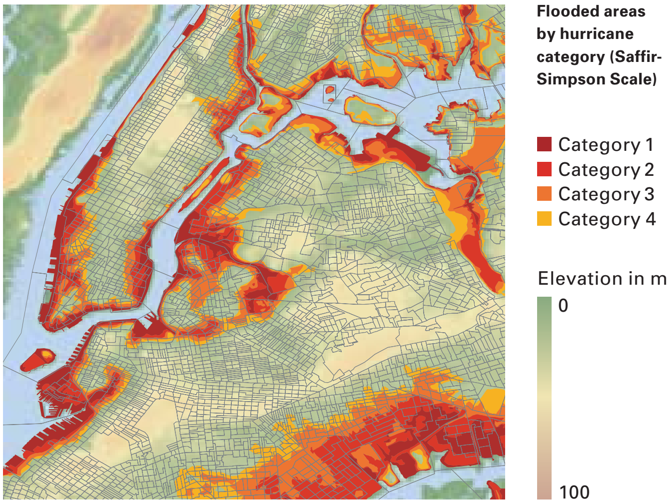
The residents of Miami have long feared a major storm surge along the beach front. Hotel complexes worth many billions of dollars – all of which are insured – are built just a few metres from the shore. There would not only be enormous property losses. Business interruption losses could also reach astronomical figures as Florida attracts 50 to 60 million holidaymakers every year. Hurricane Andrew in 1992, up till last year the costliest hurricane of all time, gave Miami a stern warning of what to expect.

But it is not just the coast of Florida that is exposed, since areas inland are also at high risk. The levees at Lake Okeechobee failed on two occasions last century, with thousands being swept to their death in the ensuing torrents of water.

Storm surge in the northeast (New York)

A storm moving northwards along the east coast and hitting Boston or New York could cause staggering losses, if it flooded, say, South Manhattan and large parts of Long Island. Even if such an event is a lot less likely than a direct hit in Miami, New Orleans, or Houston, it is still far from impossible. In 1938, the New England Hurricane caused widespread devastation in Massachusetts and New York State. Given the immense concentration of values in Greater New York, a major hurricane could cause losses amounting to hundreds of billions of dollars, and a substantial proportion would be storm surge losses. Munich Re assumes the insured losses in such an event would be in the US$-100bn range.

Fig. 14 Flood zones in New York



The areas that would probably be flooded in the context of various hurricane categories illustrate the enormous loss potential of a storm surge following a hurricane that hits New York.

Source: SLOSH model storm surge zones – New York State
Elevation data: USGS

Mississippi-Missouri flood (St. Louis)

St. Louis lies at the confluence of the Mississippi and Missouri rivers. In the summer of 1993, rainfall lasting several weeks caused nearly all rivers and lakes in the Midwest to burst their banks. Almost 50,000 km² of land was flooded and 200,000 people had to be evacuated. Although it was primarily rural areas that were flooded, the losses still came to US$ 21bn. The insurance industry paid out US$ 1.3bn, US$ 270m of which came out of the National Flood Insurance Program. The Great Flood of '93 was by no means the worst possible loss event, because the next flood that occurs could hit large urban areas and industrial complexes.

Flood on the lower Mississippi (New Orleans)

Before Katrina, the Great Mississippi Flood of 1927 was the worst in American history – and the reason for building the levees standing today on the lower reaches of the river. Heavy rainfall in the centre of the Mississippi catchment in autumn 1926 had filled the river's tributaries in Kansas and Iowa. In early 1927, the floods moved on to Kentucky and Tennessee. By May, the Mississippi downstream from Memphis was 100 km wide. The levee was breached using 30 tonnes of dynamite in order to divert the flow of water – New Orleans was saved.

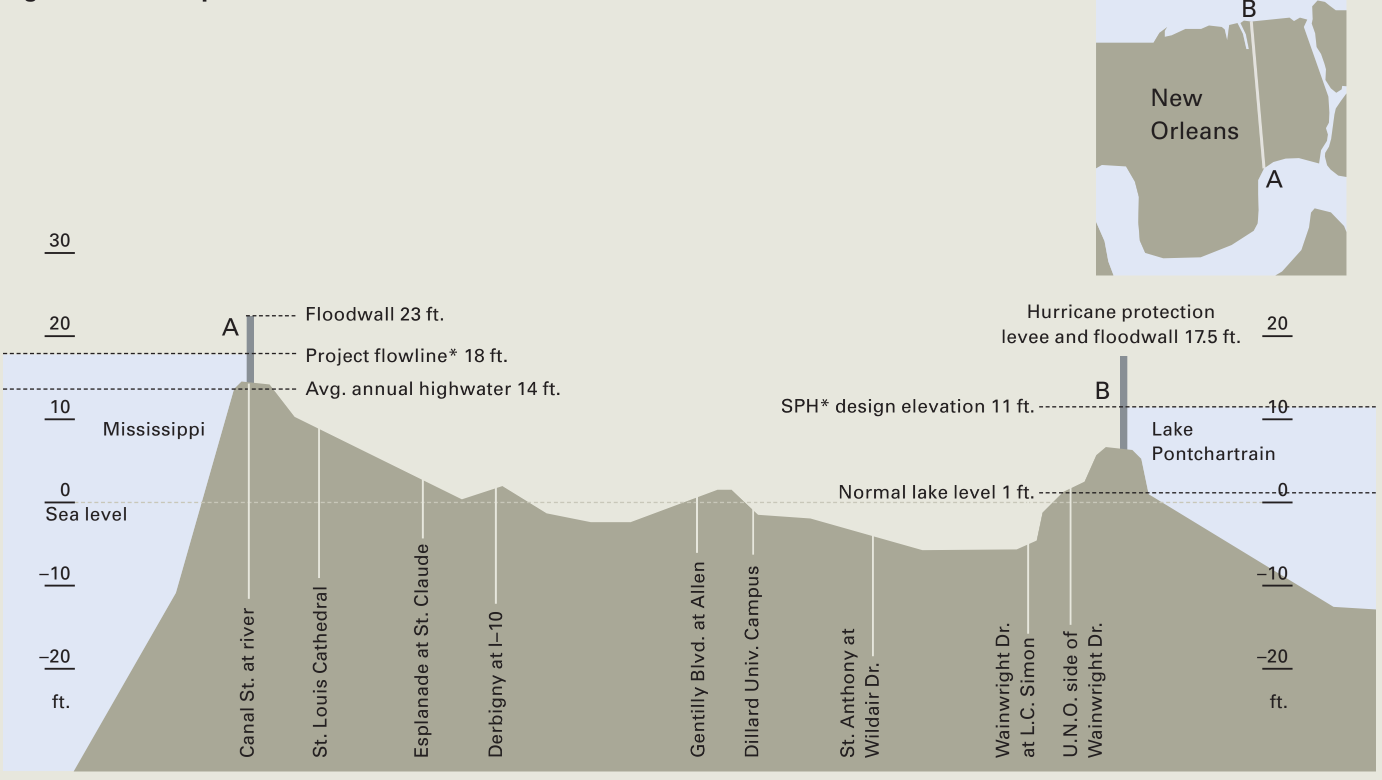
Although many dams were subsequently built on the Tennessee river, another flood on this scale cannot be ruled out entirely. For the insurance industry, the critical stretch of river would be the section between Baton Rouge and New Orleans, which is known as the "longest port in the United States".

Levee breach in the Central Valley, California (Sacramento)

The most fertile part of California is the Central Valley, formed by the Sacramento River to the north and the San Joaquin River to the south. At least 40% of the United States' fruit and vegetable crops are grown here. Both rivers flow between levees which are over 150 years old in places and are now in a very poor state. In 2004, a levee broke in the Stockton area and 50 km² of agricultural land was flooded. The loss came to US$ 100m. It will take years to restore all the levees to a safe condition.

Sacramento, the state capital of California, is just 10 m above sea level on the river of the same name, which is flooded every year during the snowmelt in the Sierra Nevada. No town in the United States has a higher flood risk. The levees only offer protection against a one-hundred-year flood, less than those in New Orleans. A levee breach in the city would put the homes of 300,000 people under as much as nine metres of water. Although there is

Fig. 15 Elevation profile of New Orleans



The diagram shows a cross-section from Canal Street on the banks of the Mississippi to the banks of Lake Pontchartrain near the University of New Orleans.
Diagram: Munich Re

* The Standard Project Hurricane (SPH) design elevation and the Mississippi project flowline are defined by the US Army Corps of Engineers and applicable to coastal flood protection.

no danger of thousands being killed in the floods, the losses would still be enormous.

Flash floods in the west (Las Vegas, Denver)

Las Vegas is the fastest-growing city in the USA with some 1.7 million inhabitants. The concentration of values is high, with nine of the ten largest hotels in the world located there. Las Vegas is surrounded by mountains up to 600 m high, and these have sent flash floods gushing into the city on more than one occasion in the past. On 8 July 1999, up to 80 mm of rain, over half the annual average, was recorded in Las Vegas Valley in just over an hour.

Denver, called the "Mile-High City" due to its elevation of 1,600 m above sea level, is also directly at the foot of high mountains. Thunderstorms with large amounts of rain, hail, and lightning strokes are not uncommon there. A rainstorm directly over the city could cause catastrophic losses and claim many lives. Flash floods could also cause enormous damage in many other cities of the American west and southwest, for example in San Antonio, Dallas, and Austin.

Conclusion

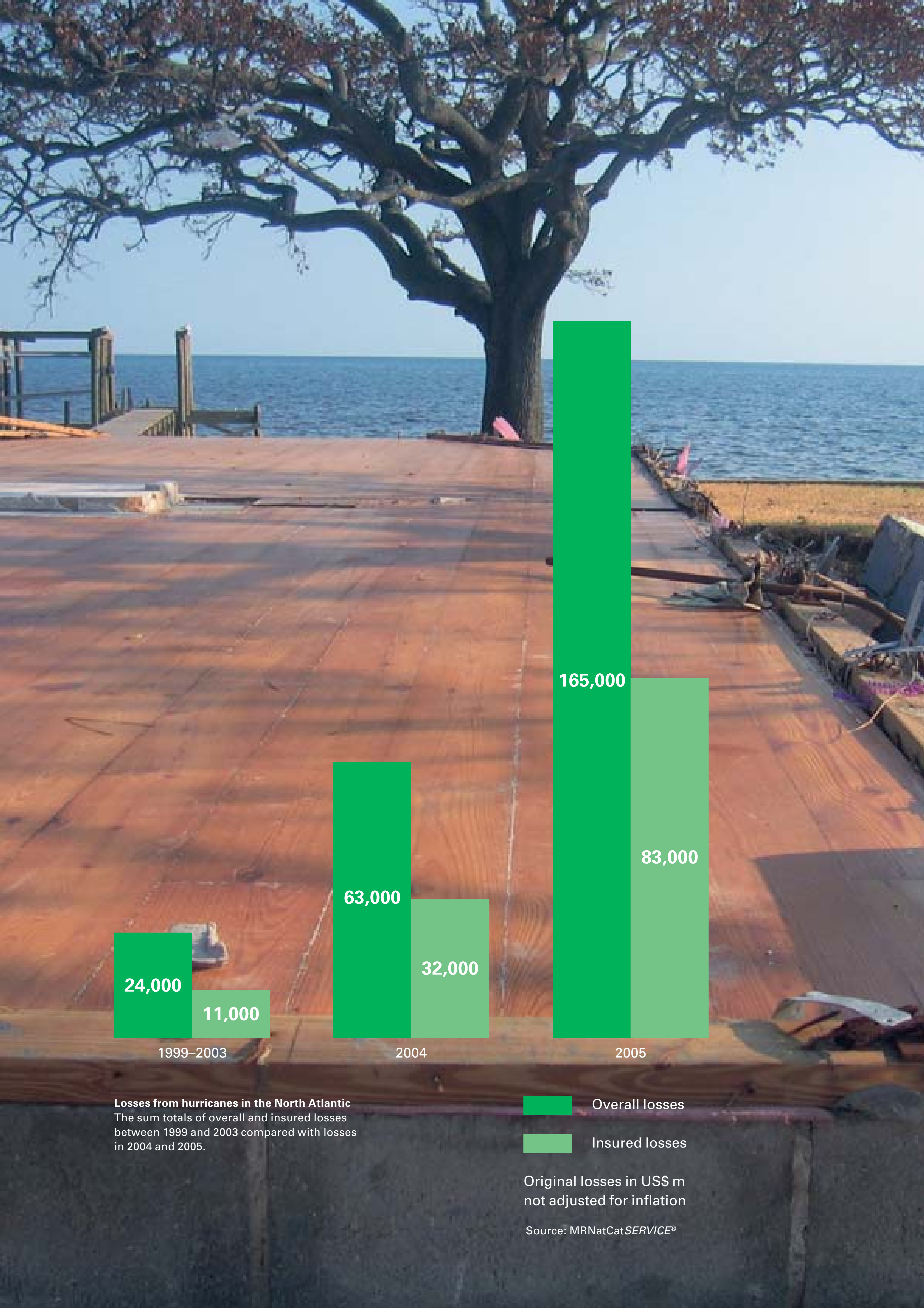
The New Orleans disaster horrified everyone: the people, governments, catastrophe experts, and the insurance industry. It generated a flurry of feverish activity which is unlikely to go on for long.

The case of New Orleans is different from other natural hazard events in two respects. Firstly, flood control is a matter of large-scale aerial protection rather than of structural protection for individual buildings, which is typical of windstorm and earthquake protection. This places a very different emphasis on responsibilities. Moreover, minor factors can have a major impact. A few centimetres' difference in the water level or a single levee breach can result in the flooding of huge areas. However, by preventing the frequent occurrence of minor floods, this kind of protection tends to make people less alert to the dangers that really exist. A major event then usually produces a state of "hyperawareness" in which all attention is focused on this one single type of event for a short while. Other examples of this phenomenon besides Katrina include the 2002 floods in central Europe and above all the tsunami of 26 December 2004.

In order to protect ourselves against the consequences of extreme natural events in the future, we have to consider possible catastrophe scenarios which have been deemed inconceivable in the past. However, it will remain difficult to insure all-or-nothing events like the flooding of New Orleans, as the degree of risk is the product of almost zero (probability) and almost infinity (extent of losses), i.e. an undefined value. For example, dyke protection in the Netherlands is so well-developed that the probability of it being defeated is only 10^{-4} (i.e. a return period of 10,000 years). However, if this scenario did occur one day, large parts of the country would soon be under water with losses costing hundreds of billions of dollars.

To be equipped for such scenarios, a functioning risk partnership between the population, the insurance industry, and the state must be in place. This includes the following:

- Adequate risk awareness in all sections of the population and instruction for the people on how to protect themselves in the event of a catastrophe
- Preventive measures designed to reduce and minimise the catastrophic effects of natural hazards (laws, land-use restrictions, technical protection measures, etc.) and an efficiently prepared crisis management (emergency measures, suitable equipment and supplies, financial support, etc.)
- A risk management that enables primary insurers and reinsurers to process a huge number of loss reports within a short space of time and to carry high accumulation losses



Losses from hurricanes in the North Atlantic
The sum totals of overall and insured losses between 1999 and 2003 compared with losses in 2004 and 2005.

Loss aspects – Calm after the storm?

The four major hurricanes in 2004, Charley, Frances, Ivan, and Jeanne, presented an entirely new set of challenges for insurers' and reinsurers' claims departments. But all that had gone before was eclipsed by Katrina in 2005, when water damage became a leading loss factor.

Klaus Wenselowski, Munich,
and Stefan Hackl, Munich

Around two million individual losses occurred in the Caribbean and the United States in the space of just six weeks in 2004. Most of these losses were in a single US state: Florida. Loss adjusters scarcely had time to inspect the damage and settle losses because, after just a few days, they had to be evacuated along with the rest of the people as the next hurricane was on its way. This pattern was repeated until Jeanne, the last hurricane of the season, had swept over Florida.

Difficult conditions for loss adjusters

Who could say with any certainty which hurricane was responsible for which losses? What deductibles would insureds have to pay? How tempting was it for insureds to take advantage of the situation? It was all very chaotic – at least at the beginning of the loss adjustment process. Most insurers were equipped to deal with one hurricane. But two? Or even four?

And there were other problems as well. The storms caused widespread damage to the highly exposed overhead telephone and electricity lines, cell phone communications were only possible with a few companies. Those people who had mobile phones from different companies could count themselves lucky. The internet technology designed for claims handling underwent an intense field test. It formed a vital link between insureds, insurance companies, and loss adjusters – who made use of every available computer to communicate with each other. GPS (Global Positioning System) devices also proved very useful, enabling loss adjusters to locate damaged objects even without any road signs left to guide them.

From the very start, politicians were eager to show that they had learnt from the mistakes made in connection with Hurricane Andrew. Insurers were given time limits for loss inspections and settlement proposals. Insurance companies also had to deal with public adjusters, who were keen to obtain as much compensation for insureds as possible. The cost of repairs was driven up in terms of both labour and materials (demand surge). On the Caymans and other Caribbean islands hit by the hurricanes, repair materials became scarce. There were also shortages of labour. Some repairs were carried out by workers with little or no training, thus leaving the buildings even more vulnerable to subsequent storms.

The damage

Many repairs are still waiting to be completed even more than one year after the hurricane, particularly on private homes with only minor damage to their roofs, windows, and facades. This is because the repair trade initially concentrated on the more lucrative large contracts such as condominiums. Besides wrecked private homes and condominiums, it was mostly mobile homes that sustained serious losses. Many of them were reduced to total losses because their exterior walls were damaged by carports and other extensions which had been caught by the wind like a sail, with the result that the homes' interiors were also exposed to the full impact of the storm. Such light structures were damaged inland as well because the wind and rain from the hurricanes were still a destructive force even away from the coast. Third-party recoveries were considered in cases where, for example, objects were damaged by flying debris from destroyed buildings, but little advantage could be taken of this option.

Background: Foundations of a house on the Mississippi coast that was completely torn away by the storm surge generated by Katrina.

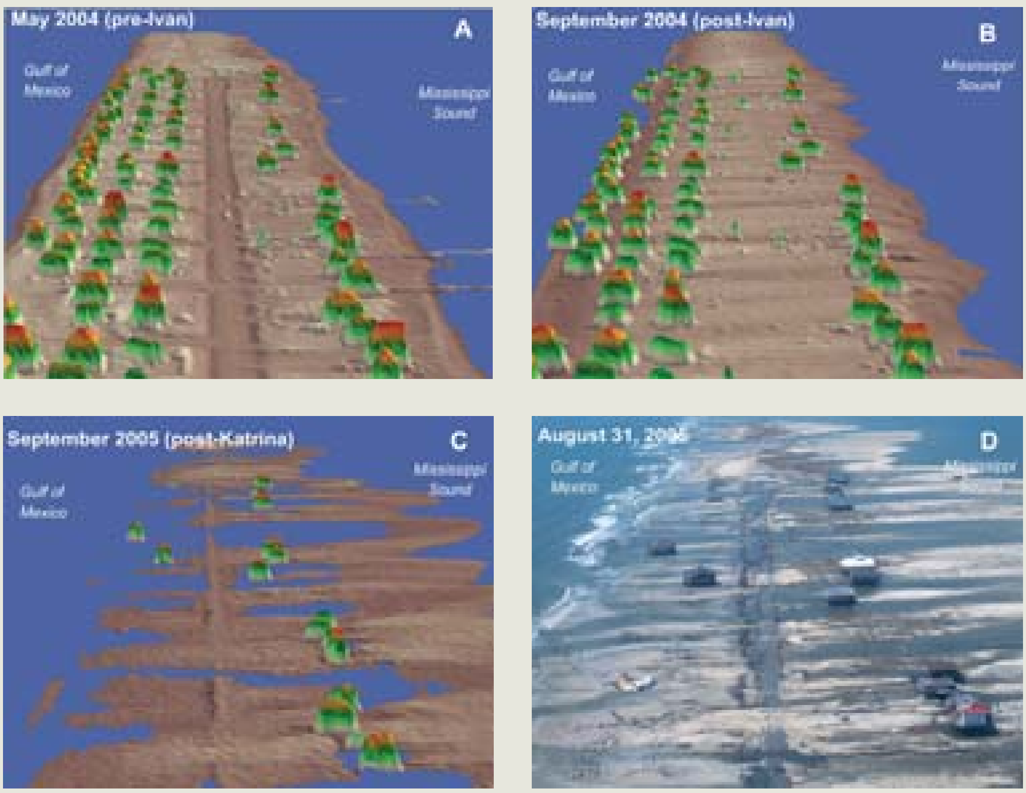
It was often difficult for reinsurers to aggregate losses or allocate them to the correct treaties. Databases were used to check the location of objects affected, the cause of loss, the allocation of losses to a particular occurrence (usually limited to a period of 72 hours), and the possibility of multiple payments or double entries. Each individual loss had to be assigned to a specific occurrence and the relevant deductible applied in each case. An examination was also made to ensure that the correct deductions were made for payments out of the Hurricane Catastrophe Fund. This fund had been set up by the state authorities in 1993 following the losses caused by Hurricane Andrew.

Lessons had indeed been learned from Hurricane Andrew. This was borne out, for example, by the fact that only one US insurance company ran into financial difficulties as a result of the 2004 hurricanes. Many insurance companies, however, assumed that the 2004 hurricane season was a one-off event which would be followed by a series of quieter years. By the spring of 2005, however, it was already clear that this assumption had been too optimistic. The forecasts based on the prevailing water temperatures were clearly pointing to another year of major hurricane activity.

Record losses caused by water

Everything changed when Katrina struck at the end of August. With its multiple landfalls, Hurricane Katrina produced some two million individual losses in the United States alone, almost as many as in the whole of the previous year. The estimated insured losses are 50% higher than the grand total from the "Fab Four" hurricanes the previous year. Overall losses are estimated at over US$ 120bn. Besides wind-related damage, it was the damage caused by water in particular which generated these enormous losses. A huge storm surge hit the coast of Louisiana and Mississippi. A series of levee breaches resulted in torrents of water streaming from Lake Pontchartrain into lower-lying areas of New Orleans, leaving 80% of the city under water. Initial reports on the causes of the breaches indicated that the levees were not built on sufficiently firm ground. Due to the pressure of the water, the levees slid up to 14 m in some places – or simply collapsed. One breach at least is thought to have been caused by a barge that was torn from its moorings by the storm. Furthermore, insureds are also seeking to bypass the flood exclusion by filing lawsuits against the US Army Corps of Engineers and building companies alleging negligent design and construction of the levees.

Fig. 16 Before and after: Ivan and Katrina sweep over Dauphin Island



Three-dimensional lidar images of the topography of the island off the Mississippi Sound before and after Ivan (A and B) and after Katrina (C). Image D is an oblique aerial photograph taken after Katrina on 31 August 2005.

Source: NASA

When the city of New Orleans was grazed by the outer bands of Hurricane Rita just one month after the first levee breach, a stretch of levee that had undergone makeshift repairs was breached again. Parts of New Orleans that had been successfully drained were flooded a second time. For reinsurers this constituted a new loss occurrence, which further complicated the claims settlement process.

The subsequent lootings and fires also have to be analysed in detail. There does not appear to be a direct link between the fires and Katrina or the flooding. Many fires only broke out when the power supply was turned back on or were started by looters in an attempt to cover their tracks.

A few years ago, a large-scale "dry run" on the US Gulf Coast involving a hypothetical hurricane named PAM brought results that were similar to the effects of Katrina. The exercise was based on a Saffir-Simpson Category 3 hurricane hitting the levees of New Orleans. The outcome: fatalities, residents who refused to be evacuated, and pollution.

The levees are unlikely to have been completely reinstated, let alone improved, by the beginning of the next Atlantic hurricane season in June 2006. Both the local population and the insurance industry have to assume that the 350-mile system of levees no longer offers adequate protection against a Category 3 hurricane or higher. The insurance industry must factor this into its reassessment of the risk.

Difficult settlement process

Some individual losses involved staggering amounts. If mobile homes were the surprise package in 2004, then 2005 belonged to shipyards and floating casinos. These casinos are linked by short walkways to large hotels on land. The reason for this method of construction is recent legislation in Mississippi prohibiting casinos on the mainland. The law has already been amended to avoid a similar situation in the future. The storm surge triggered by Katrina damaged almost all the casinos along the Mississippi coast. Most of the casino ships were torn from their moorings and were swept inland. Some were washed up onto highways, others did not get quite that far and just rammed into their hotels. Property and business interruption losses are enormous, somewhere in the region of half a billion dollars.

Since 1968, owners have been able to insure their homes and small commercial risks against flood damage under the National Flood Insurance Program, a separate optional cover in addition to the traditional homeowner policy, which does not cover flood. The devastating flood damage in the wake of Katrina has already led to a number of suits being filed, all seeking coverage of the flood damage under private homeowner policies.

The private insurers' defence is based on a variety of arguments – that they have not received a premium for flood protection, for example, whilst other homeowners had indeed purchased the state cover. In the case of industrial risks, flood damage is generally covered although frequently subject to a limit.

The evacuation of the city raises further grounds for discussion with regard to claims settlement. Business interruption losses resulting from the evacuation may also be covered. But what happens when there is no property damage – does the cover also apply in this case? The egress/ingress clause involves similar problems. This clause states that business interruption losses are indemnified if access to the business premises is made impossible by, for example, destroyed roads or fallen trees.

The damage to refineries, chemical plants, private oil tanks, and cars primarily caused by the flood often produced a layer of mud several inches thick with various concentrations of toxic substances. In most cases, the perilous mixture cannot be attributed to one single perpetrator. Only in some specific cases, such as those involving tank farms, is it possible to assign the pollution of the area to one or more perpetrators.

Various covers for environmental impairment

The very widespread comprehensive commercial liability policies, which are based on the standard ISO terms and conditions, exclude environmental impairment (absolute pollution exclusion). However, environmental liability policies available for large companies in the United States cover environmental damage as long as it is due to named perils listed in the policy (pollution named-perils cover). This includes, for example, lightning stroke. The damage must also be caused by sudden and accidental events.

A few specialised insurers in the United States also offer special environmental policies. However, these are a lot less widespread than the comprehensive commercial liability policies. Environmental impairment is covered – both on and off the policyholder's own business premises. Furthermore, the cover includes environmental impairment on the policyholder's own business premises as a result of natural hazard events. Damage from toxic mould is also usually covered.

In property insurance, ground pollution is included in the cover for clean-up costs, albeit with a sublimit. All in all, however, the insured costs for environmental impairment are less significant than property losses.

Reinsurers have to check the aggregated individual losses from Katrina. Between the first landfall in Florida and the second in Louisiana, there was a time gap which exceeded the standard agreement of 72 hours. For the reinsurance industry, this therefore constitutes two clearly separate loss occurrences.

Outlook

What are the lessons to be learned from Katrina? How can people protect themselves behind levees that are known to be hardly capable of withstanding a Category 3 hurricane? Can insurance and reinsurance be granted in hurricane-exposed areas for floating casinos with their huge potential for business interruption losses – particularly as they are exposed to enormous wind speeds, storm surges, and tremendous wave forces on the coast.

Or is this problem solved by the new legal changes which now permit the construction of casinos on the mainland? And should the insurance industry even give active support for the calls to rebuild New Orleans at another, safer place?

Given the experiences from every single hurricane in 2004 and 2005, it is now crucial that concrete adjustments are made to underwriting guidelines. Changes need not and will not be completely uniform. The decisive factor, however, will not simply be creating adjustment processes but also implementing them rigorously. Because the next storm is sure to come.

Damage caused by wind and storm surge
A damaged commercial building in Mississippi on the Gulf of Mexico.

The offshore industry – Conditions, prices, and capacities under scrutiny

Hurricanes Katrina and Rita each caused losses in the offshore energy industry estimated at up to US$ 6bn. There is a broad consensus among experts that this new loss dimension will have a significant impact on the insurance terms and conditions and on the capacity available.

Wolfgang Ulbrich, Munich

Background

Following the major damage caused by Hurricane Ivan in 2004, the offshore energy industry was hit even harder in 2005 by Katrina and Rita. Once again, all production facilities in the path of the hurricanes had to be shut down and evacuated, leaving much of America's oil and gas production paralysed. Many refineries located in the landfall areas were also affected. In the wake of Katrina, the US government was forced to tap its national oil reserves and import more refinery products from abroad in order to maintain energy supplies. Numerous oil platforms and production facilities were destroyed and pipelines damaged. In order to restore production, all available repair capacities were mobilised, not just those in the Gulf of Mexico. At the beginning of December 2005, however, 16% of the oil platforms were still out of operation and over 30% of oil production was still not fully restored.

Losses

The key factor for the higher losses in 2005 were the tracks of the hurricanes: Katrina and Rita crossed over a lot more production facilities, especially near the coast. Moreover, these installations are among the oldest and the applied design codes no longer meet modern standards. All three hurricanes, however, showed that even state-of-the-art structures, such as those used in deep water for several years now, can also sustain serious damage. This is particularly relevant, since the exploration and installation of production facilities will be conducted increasingly in deep-water conditions in the future. Nevertheless, the fact remains that while many older facilities suffered total losses, the newer installations frequently sustained only partial damage to the superstructure.

Offshore losses caused by Ivan, Katrina, and Rita

Loss/damage type	Ivan 2004	Katrina 2005	Rita 2005
Platforms destroyed	5 fixed platforms 2 caissons	36 fixed platforms 10 caissons	48 fixed platforms 14 caissons 1 deepwater tension leg platform
Platforms with major damage	1 fixed platform 2 SPAR platforms 2 deepwater platforms 1 deepwater tension leg platform	14 fixed platforms 2 caissons 4 deepwater platforms	30 fixed platforms
Rigs destroyed	1 platform rig	1 jack-up 3 platform rigs	1 jack-up 3 rigs disappeared
Rigs adrift	5 mobile offshore drilling units	1 jack-up 5 semi-submersibles	3 jack-ups 10 semi-submersibles
Rigs damaged	1 platform rig 1 mobile offshore drilling unit	2 platform rigs 2 jack-ups 5 semi-submersibles	7 jack-ups 2 semi-submersibles 1 submersible

The damage to production facilities was significantly greater in 2005 than in 2004.

Source: Gard, Norway, using original source MMS

In addition to direct property losses, there were also considerable consequential losses such as direct and contingent business interruption. While business interruption accounted for some 70% of the insured loss from Hurricane Ivan, the proportion of such losses from Katrina and Rita is likely to be much lower. However, the exact distribution was not known at the editorial deadline. Mudslides on the ocean floor following Hurricane Ivan had a particularly disruptive effect on operations in the coastal network of pipelines. Some important pipelines were shifted a long way from their proper positions (by several hundred metres in some cases), meaning that safe operations were no longer possible. This resulted in the shutdown of several facilities which had not been directly affected by Ivan but which use these pipelines. Other facilities were unable to resume operations because the refineries they supply were damaged. This caused not only direct business interruption losses but in places even larger contingent BI losses. For the 2005 hurricane season, however, no major cases of pipeline displacement and concomitant losses have been reported thus far. They are also highly unlikely given the oceanic topography below the hurricane tracks in question.

Loss estimates and typical losses

According to current estimates, the insured offshore energy losses from Ivan amount to between US$ 2bn and US$ 2.4bn. Katrina and Rita are each expected to produce losses of up to US$ 6bn. When several events on this scale occur in quick succession, they represent a loss with an entirely new dimension in terms of financial strain. The estimated global offshore energy premium volume ranges between US$ 1.8bn and 2bn per year. The Gulf of Mexico's share of this figure is US$ 400m–500m.

Loss examples

Fixed platforms

– Complete (steel) structure collapses or topples over.
– Partial losses to the structure and superstructure occur due to wave impact and wind.

Floating platforms

– Anchoring breaks, platforms drift away (over a distance of several hundred kilometres in some cases); facilities not affected by a hurricane can be damaged in a collision.
– Installation sinks completely.
– Anchoring is damaged without the installation being lost.
– Damage to/loss of deck superstructures through storm and wave impact. Water inflow in the deck superstructures destroys the control units and renders living quarters and other installations useless.

Pipeline systems

– Connecting points to the platforms are damaged because structures collapse or break off.
– Damage is caused by installations and anchor chains drifting.

To the property and business interruption losses can be added costs for clean-up operations and wreck removal (usually insured) as well as liability losses.

Repair capacities available in the Gulf of Mexico were already fully utilised after Ivan and repair work had not been completed. Katrina and Rita made the situation even worse. Depending on the extent of the damage in each case, there may be significant waiting times for repairs.

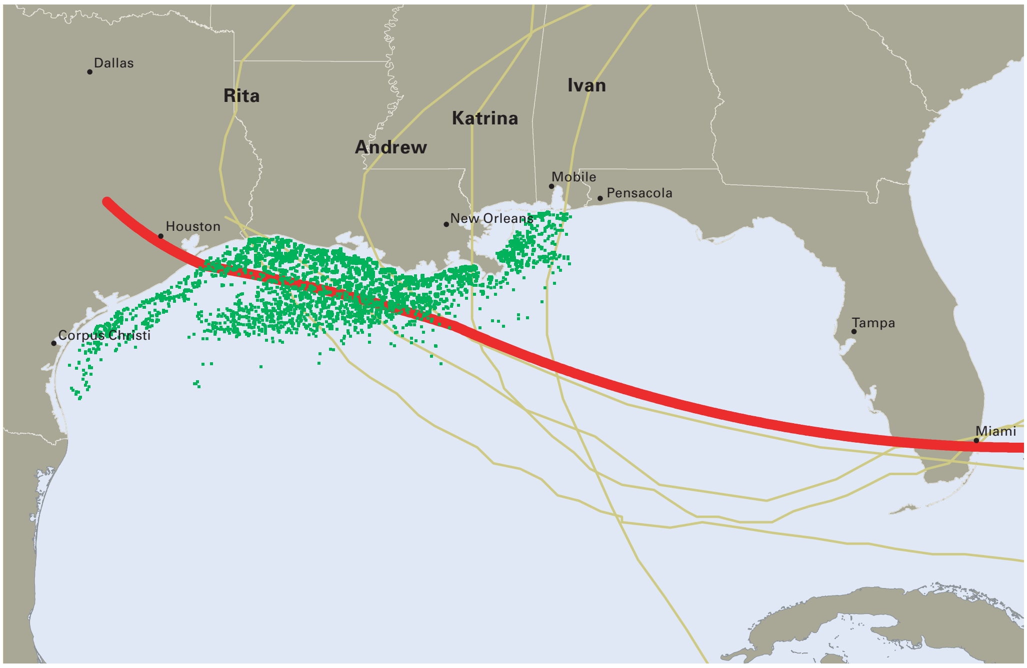
Effects on the insurance industry

In the wake of the massive losses, a thorough revision of the terms and conditions and a reduction in capacity must be expected. The central themes are premium structure and the easy availability of large capacities witnessed in the past especially for complex (in terms of underwriting) direct and contingent business interruption covers. An important basis for changes in covers is provided by the new Loss of Production Income wording produced by the London market, which was embarked upon shortly after Ivan and has been available since June 2005. Also, some players in the primary insurance market plan to introduce event limits for natural hazards in general and windstorms in particular on a policy or risk basis and within the context of accumulation control across the entire portfolio.

Furthermore, some underwriters are restructuring their portfolios on a geographical basis (e.g. in order to reduce exposure in the Gulf of Mexico) and this will improve the risk distribution. Examining whether premiums are still commensurate with the risk is a further vital step towards maintaining the insurability of this business in the future.

Reinsurers will also have to carry out further measures depending on the respective type of participation and the market segment concerned. This will primarily involve a fundamental review of the structure of conditions and prices and the further development of risk models on the basis of re-evaluated return periods. Offshore energy insurers would also do well to remember that, besides being hit by Ivan, Katrina, and Rita, offshore energy facilities were only just missed by Dennis and Wilma – two further hurricanes in 2005.

Fig. 17 Oil rigs in the Gulf of Mexico



The oil rigs were hit very hard by Ivan, but even more so by Katrina and Rita. Nevertheless, accumulation scenarios with even greater losses are conceivable. These include hurricanes that move parallel to the coast.

Diagram: Munich Re

- Platform
- Tracks of Andrew, 1992, Ivan, 2004, Katrina, 2005, and Rita, 2005
- Possible onshore/offshore accumulation loss scenario in the Gulf of Mexico

Consequences for the insurance industry: New loss distributions

Ernst Rauch, Munich

Tropical cyclones in 2004 and 2005: Consequences for the insurance industry

Katrina, Rita, and Wilma made a noticeable dent in many insurers' balance sheets in 2005. In conjunction with the losses from Charley, Ivan, Frances, and Jeanne, the "Fab Four" tropical cyclones of the previous year, they made it clear that the hurricane hazard must be completely re-evaluated.

What is to be done? The insurance industry must adjust the probability of landfalling tropical cyclones of various intensities in the North Atlantic, i.e. the very basis of its definition of windstorm hazard. Science has made considerable progress in this area, particularly in 2005. Today we know that the description of the hurricane hazard as the average of a time series of over 100 years cannot serve as the basis for an adequate risk measurement. On the one hand, windstorm activity is subject to natural cyclical fluctuations, and on the other, there is a superimposed trend towards more frequent and more intense cyclones. Besides rigorous climate protection as the necessary response to this trend, a new quality is required in the context of risk management.

Adjustments needed in risk evaluation

A clear indication of this is provided by the losses suffered by the insurance industry in 2004 and 2005. In the United States alone, hurricane losses carried by private insurers came to around US$ 80bn – not including the losses covered under the National Flood Insurance Program. Losses involving offshore risks in the Gulf of Mexico also accounted for around US$ 12bn.

Commercial modelling software of the 2005 generation puts the annual loss expectancy for the Hurricane USA risk at US$ 6–8bn. Even a simple comparison with the loss sum quoted above shows that there is a considerable need to adjust the models for the hurricane risk in the North Atlantic. And, as stated in the section on peak meteorological values and record losses, it was only 13 years since Hurricane Andrew, the last very large loss.

Holistic risk management

However, the lessons taught by Katrina & Co. go far beyond adjustments to the risk assessment made necessary by the changing hazard. In the future, loss accumulations must be managed more holistically (i.e. taking into account all lines of business with their allied perils) – as the articles in this brochure clearly show.

The required holistic approach must include catastrophe scenarios that have been unthinkable up to now. Examples like 11 September 2001 and the long-repressed danger of New Orleans being flooded must be regarded as signals indicating that the known quasilinear conceptual models must be replaced. It is time for new methods of analysis to replace the estimation of possible accumulation losses simply by extrapolating from past experience.

Outlook

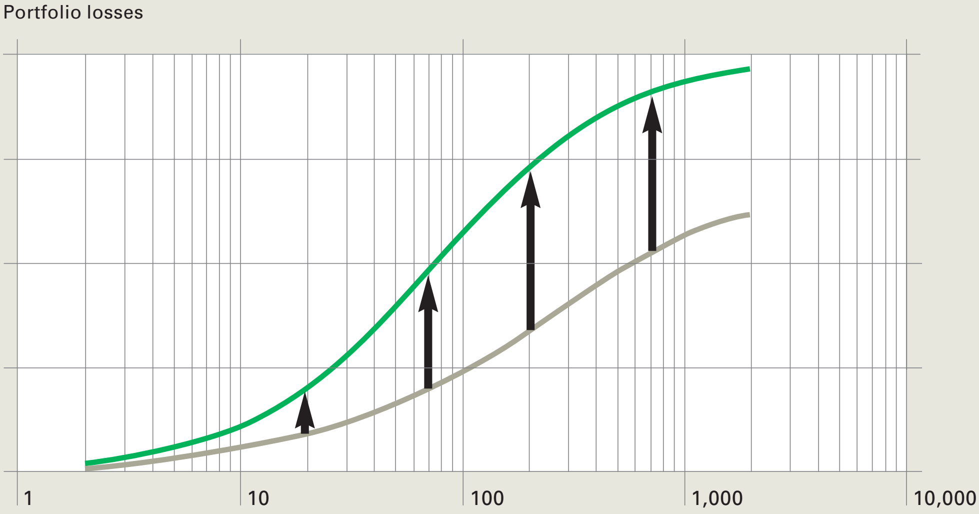
Munich Re is already using an extended modelling approach in the measurement and management of its Hurricane USA risks in the 1 January 2006 renewals. The graph (Fig. 18) shows in simplified terms how the loss distribution for a US-wide hurricane portfolio is affected by the joint factors of adjusting to the changed hazard, adding new perils and non-modelled supplemental perils (e.g. theft/looting, arson, contamination), and considering loss amplification effects (e.g. claims inflation, repair cost delay inflation, coverage erosion) in megacatastrophe scenarios.

In this publication, our discussion of the need for changes in risk modelling has concentrated on the hurricane risk in the North Atlantic. Nevertheless, we are continuing our analyses of natural climate cycles and the effects of climate change with regard to hazards in other regions too, such as tropical cyclones in the Pacific and Indian Oceans and winter storms in Europe. This will enable us to register future changes in risks before they happen and incorporate them in our risk models.

This is an absolutely vital success factor. Our underwriting competence must keep pace with evolving knowledge if we are to be in a position to judge the profitability of the business we are offered and to make the right decisions. Ongoing review of the risk models we use is therefore at the top of our agenda.

There is no doubt that the insurance industry must come to terms with many more challenges in providing cover for accumulation losses from natural catastrophes. We are gearing our risk management more than ever to the enormous loss potentials and the changing risk situation. Our products and services are urgently sought after and we will take advantage of this opportunity but will only accept business at risk-adequate prices and conditions.

Fig. 18 Change in the loss distribution for a US-wide hurricane portfolio



Source: Munich Re, Geo Risks Research

The upper curve shows the adjustment of the loss distribution including the following factors:
- **Higher hurricane frequency**
- **Higher intensities**
- **Re-evaluation of the storm surge and flood risk (not including NFIP)**
- **Loss-aggravating factors in connection with megacatastrophes**

A chronicle of losses in 2004 and 2005

2004 Atlantic hurricane season summary

Name	Date	Maximum Saffir-Simpson category	Maximum sustained winds	Region	Fatalities	Overall losses US$ m	Insured losses US$ m
Hurricane Alex	31 July–6 Aug	3	195 km/h	USA: NC			
Tropical Storm Bonnie	3–12 Aug		105 km/h	USA: NC. Canada	4	5	
Hurricane Charley	9–14 Aug	4	240 km/h	Cuba. Jamaica. Cayman Islands. USA: FL, SC, NC	36	18,000	8,000
Hurricane Danielle	13–21 Aug	2	175 km/h				
Tropical Storm Earl	13–15 Aug		80 km/h				
Hurricane Frances	25 Aug–8 Sept	4	230 km/h	Bahamas. Turks and Caicos Islands. Cayman Islands. USA: FL, GA, SC, NC, MD, VA, NJ, NY	39	12,000	6,000
Hurricane Gaston	27 Aug–1 Sept	1	120 km/h	USA: VA, SC, NC	8	100	65
Tropical Storm Hermine	29–31 Aug		65 km/h				
Hurricane Ivan	2–24 Sept	5	270 km/h	Barbados. Cayman Islands. Cuba. Dominican Republic. Grenada. Haiti. Jamaica. St. Lucia. St. Vincent and the Grenadines. Trinidad and Tobago. Venezuela. Colombia. USA: FL, AL, DE, GA, LA, MD, MS, NC, NJ, NY, PA, TN, VA	125	23,000	12,500
Hurricane Jeanne	13–29 Sept	3	195 km/h	Haiti. Dominican Republic. Puerto Rico. Bahamas. USA: FL, DE, GA, MD, NC, NJ, NY, PA, SC, VA	2,000	9,200	5,000
Hurricane Karl	16–24 Sept	4	230 km/h				
Hurricane Lisa	19 Sept–3 Oct	1	120 km/h				
Tropical Storm Matthew	8–10 Oct		75 km/h	USA: LA			
Tropical Storm Nicole	10–11 Oct		80 km/h	Bermuda			
Tropical Storm Otto	26 Nov–5 Dec		80 km/h				

Source: NHC and MRNatCat*SERVICE*®. Loss and fatality counts are for all impacted countries.

2005 Atlantic hurricane season summary

Name	Date	Maximum Saffir-Simpson category	Maximum sustained winds	Region	Fatalities	Overall losses US$ m	Insured losses US$ m
Tropical Storm Arlene	8–13 June		110 km/h	USA: FL	1		
Tropical Storm Bret	28–29 June		65 km/h	Mexico	2	10	
Hurricane Cindy	3–7 July	1	120 km/h	Mexico. USA: AL, LA, MS, GA	3	250	160
Hurricane Dennis	5–13 July	4	240 km/h	Jamaica. Cuba. USA: FL, AL	76	3,100	1,200
Hurricane Emily	11–21 July	4	245 km/h	Caribbean. Mexico	13	400	250
Tropical Storm Franklin	21–29 July		110 km/h	Bahamas			
Tropical Storm Gert	23–25 July		75 km/h	Mexico			
Tropical Storm Harvey	2–8 Aug		105 km/h	Bermuda			
Hurricane Irene	4–18 Aug	2	175 km/h				
Tropical Storm Jose	22–23 Aug		80 km/h	Mexico	6		
Hurricane Katrina	23–31 Aug	5	280 km/h	USA: AL, FL, LA, MS	1,322	125,000	60,000
Tropical Storm Lee	28 Aug–2 Sept		65 km/h				
Hurricane Maria	1–10 Sept	3	185 km/h				
Hurricane Nate	5–10 Sept	1	145 km/h	Bermuda			
Hurricane Ophelia	6–18 Sept	1	140 km/h	USA: NC, SC	1	50	35
Hurricane Philippe	17–24 Sept	1	130 km/h				
Hurricane Rita	18–26 Sept	5	280 km/h	USA: FL, LA, TX, MS	10	16,000	11,000
Hurricane Stan	1–5 Oct	1	130 km/h	Mexico. Guatemala	> 840	3,000	100
Tropical Storm Tammy	5–6 Oct		80 km/h	USA: FL, GA			
Hurricane Vince	9–11 Oct	1	120 km/h	Portugal. Spain			
Hurricane Wilma	15–25 Oct	5	280 km/h	Mexico. USA: FL	38	18,000	10,500
Tropical Storm Alpha	22–24 Oct		80 km/h	Dominican Republic. Haiti	28		
Hurricane Beta	27–31 Oct	3	185 km/h	Nicaragua. Colombia. Honduras		16	
Tropical Storm Gamma	18–21 Nov		80 km/h	Honduras. Belize	37		
Tropical Storm Delta	23–28 Nov		110 km/h	Spain, Canary Islands. Morocco	20	375	
Hurricane Epsilon	29 Nov–8 Dec	1	140 km/h				
Tropical Storm Zeta	30 Dec–6 Jan 2006		100 km/h				

Source: NHC and MRNatCat*SERVICE*®

Hurricane season 2004

Hurricane Charley: The roofs of dwellings were often torn off, sometimes completely, as in this case in Punta Gorda on the west coast of Florida. This also leads to the contents being severely damaged.

Hurricane Charley: This mobile home in Pine Island put up little resistance to the high wind speeds. Mobile homes contributed significantly to hurricane losses in 2004.

Hurricane Frances: This carport in Florida was not strong enough to withstand the wind pressure of the hurricane.

Hurricane Ivan: This office building in Pensacola, Florida, still looks good, but it lost part of its roof during the storm. Older office buildings in the city centres were often badly damaged.

Hurricane Ivan: Many boats and yachts moored in harbours were washed ashore. Or they were tossed around on their moorings by the storm, as here on the Cayman Islands.

Hurricane Ivan: Mould growth in a hotel on Grand Cayman is promoted by infiltrating moisture and the prolonged stoppage of air-conditioning systems. The power supply had collapsed after Ivan.

Hurricane season 2005

Hurricane Dennis: Dennis caused flood damage to this house in Navarra, Florida, only five weeks after repairs from the previous year's Hurricane Ivan were finished.

Hurricane Emily: The wreck of a sports plane leans against a tree and a shed after the Yucatan peninsula was hit by Hurricane Emily.

Hurricane Katrina: The City Hall at Biloxi is a sturdily built structure. It withstood the high wind speeds almost unscathed.

Hurricane Katrina: The Ocean Warwick oil rig was severely damaged by Katrina and drifted a good 100 km from its original position; it went aground on Dauphin Island in Alabama.

Hurricane Rita: A flooded refinery in Port Arthur, Texas, in the wake of Rita. Environmental impairment is covered by international industry policies and special policies in the United States.

Hurricane Stan: Stan and Wilma caused enormous damage mainly on the Gulf of Mexico, but also in other areas in Mexico. Catastrophic floods reached as far as the Pacific coast. The photo shows a school in Tapachula, Chiapas, destroyed in Hurricane Stan.

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