TOPICS GEO

Natural catastrophes 2016
Analyses, assessments, positions
2017 issue

Year of the floods

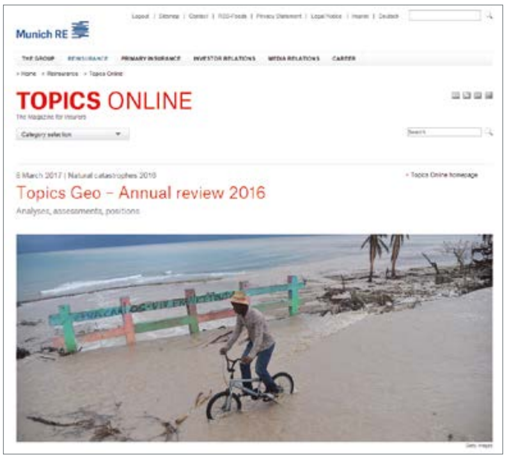
Rarely have flash floods, river flooding and storm surges been so prevalent as in 2016.
PAGES 27, 31 and 37

Resilience
More than just a buzzword

Hurricane Matthew
Haiti devastated once again

Analysis techniques
Compile your own statistics

Munich RE



>> You can find all articles in this magazine at: www.munichre.com/en/topicsgeo2016

Dear Reader,

2016 saw the highest natural disaster losses of the past four years. At US$ 175bn, they were back up in the mid-range, where they are expected to be. A bitter pill for many of those affected was that the share of uninsured losses – the gap in cover – remained high, with around 70% of losses not covered by insurance. By taking on some of the financial burden, insurance can do much to help people and countries get back on their feet quickly following a natural disaster.

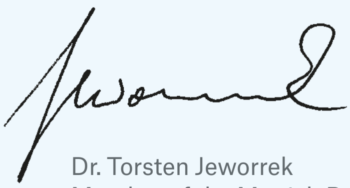
The latest issue of Topics Geo focuses on resilience: how losses can be reduced or – better still – prevented, and how to overcome a disaster as quickly as possible if one does strike. We discuss this topic with Robert Glasser, Head of the United Nations Office for Disaster Risk Reduction in Geneva.

Two events in particular stood out in 2016. The year's costliest disaster was a double earthquake that rocked the Japanese island of Kyushu. In the autumn, Hurricane Matthew devastated entire stretches of land in Haiti before striking the Bahamas and brushing the east coast of the USA. Matthew was the most powerful hurricane to hit the North Atlantic for almost ten years.

Another noteworthy feature was the large number of floods that accounted for almost a third of the year's overall losses. Looking at just one year, this could appear to be mere coincidence. But intensive research is being carried out to determine the extent to which climate change has influenced individual events. It goes without saying that there is still a long way to go in this field. But research enabling us to deduce that specific events will be more likely in future as a result of climate change would provide clear incentives to improve disaster prevention.

The current issue of Topics Geo looks into all of this and much more. I hope you find the articles both interesting and informative.

Munich, March 2017



Dr. Torsten Jeworrek
Member of the Munich Re Board of Management
and Chairman of the Reinsurance Committee

NOT IF, BUT HOW

Many extreme natural events only become disasters if the societies they hit are not adequately prepared for them. Preventing disasters is not just a question of finding the appropriate response after an event. It is about building up resilience in advance so that life can quickly return to normal.

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In focus

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Catastrophe portraits: China is no stranger to river flooding. However, in 2016 it was flash floods far from major rivers that were the main cause of the highest flood losses the country has seen for nearly 20 years.

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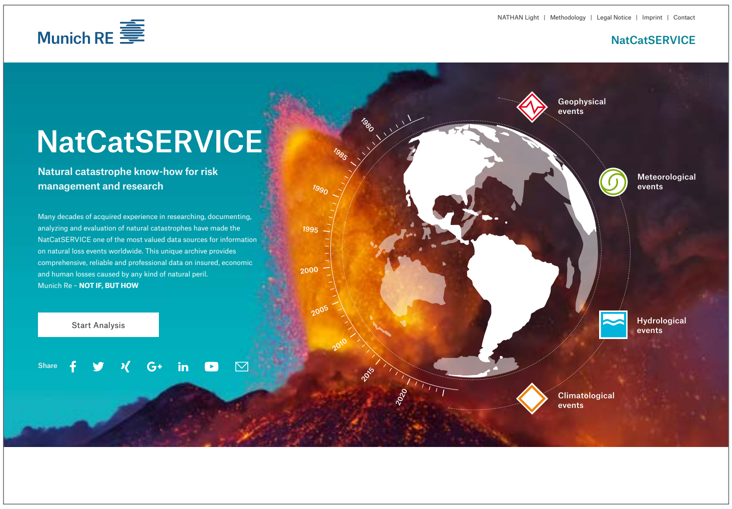
Catastrophe portraits

NatCatSERVICE and Research



NatCATSERVICE and Research: Individual analysis options are more important than ever. A new tool makes it possible to evaluate and analyse specific information tailored to the users' needs.

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Standards


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Resilience – Overcoming natural disasters

Losses from natural disasters are increasing in many parts of the world. Since even the best risk management cannot actually prevent major loss events, the focus must be on managing them. The keyword here is resilience, and insurance cover against natural hazards is a major component of this.

Hurricanes, floods and earthquakes – human beings are powerless to influence where Mother Nature will strike next, and with what intensity. However, the extent to which such events have a fortunate outcome or destroy people's livelihoods is by no means a matter of chance. Warning systems, safe buildings and well-coordinated aid and relief services can help ensure as many people as possible come through a loss event unscathed and recover quickly from its consequences.

Yet long-term impacts are inevitable if an extreme natural event hits people who are poorly prepared and vulnerable. Such was the case in Haiti, which still remains largely paralysed today after the destructive earthquake of early 2010. In October 2016, Haiti was hit by Hurricane Matthew, the consequences of which were many times worse because the country had not recovered from the earthquake damage. In contrast, life returned to normal long ago in Chile and New Zealand, two countries that were also hit by powerful earthquakes in late February 2010 and early 2011 respectively. Countries with low economic strength and poorly developed social systems are particularly vulnerable.

Restoring control

Resilience refers to the ability of individuals, societies or socio-economic systems to cope with the sudden impact of crises or disasters, and to restore as quickly as possible their ability to function and their capacity to act.

The concept of resilience is relatively new in the context of disaster reduction. It is characterised by resistance and flexibility and aims at quickly returning life to normal. It would be a mistake to see resilience merely in terms of resistance. This is because the ability to respond flexibly is a precondition for restoring normal conditions after a disaster. It would also be short-sighted to see resilience simply as an emergency response system, because the crucial criterion for resilient systems is that they are able to restore all key functions quickly.

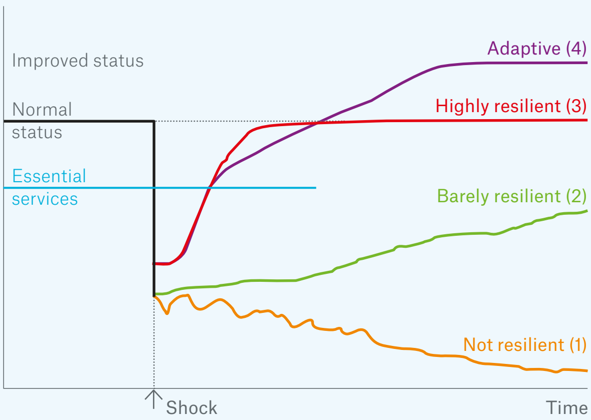
Features of resilient societies

Because accidents and crises can occur at any time and any place, the concept of resilience can serve as a guide for disaster protection, crisis management and damage limitation.

Resilient systems must meet a range of different requirements, based on the fact that resilience covers not only preparation and damage limitation but also the ability to respond appropriately following an event.

Firstly, they must be properly set up to combat extreme events through appropriate measures (Prepare) to ensure that a loss does not happen in the first place (Prevent). If it happens nevertheless, the protective measures established beforehand need to work properly to minimise the consequences (Protect). The next phase (Respond) relates to the system's agility, which is dependent on prompt, well-organised and effective emergency aid. Once the acute hazard is over, the rebuilding phase can begin (Recover). At this point, it is crucial that lessons are learned to ensure the system is even better prepared for future events. So resilience is not a static condition, but rather a characteristic of systems that are adaptive, flexible and constantly evolving.

How systems with different levels of resilience respond to shocks



(1) A society that is not resilient does not succeed in returning to its previous status after a shock. Recovery efforts fail.
(2) A society that is barely resilient is slow to return to its previous status, and generally does so only with external aid.
(3) In a highly resilient society, the shock is less severe (because of preventive measures), and all key functions are up and running again after a short time. The previous status is quickly restored. External aid is generally not required.
(4) An even higher level of resilience can be achieved by eliminating weaknesses in the earlier system during the recovery phase. Because of the planning this involves, the complete recovery period may take more time.

Source: Munich Re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Resilience efforts in practice

More and more countries are redoubling their efforts to achieve greater resilience. The motivation is the realisation that, because of the diversity, complexity and unpredictability of modern risks, a population's safety cannot always be guaranteed. As a result, the focus of considerations is increasingly on coping with loss events. The United Kingdom, for example, has launched numerous initiatives over the last ten years to strengthen resilience. Similarly, in the USA there is a special body within the National Security Council that deals with anchoring resilience as a core element in the national prevention and action plan for crisis scenarios. At the start of 2013, with his Presidential Policy Directive 21 "Critical Infrastructure Security and Resilience", Barack Obama initiated a raft of measures designed to make critical infrastructure more resistant in the event of a breakdown.

The topic is also gaining importance on a global level. The UNISDR, for example, has launched a campaign entitled "How to Make Cities More Resilient". The rationale behind this is that, with the global trend towards urbanisation, resilience of cities is key.

Highly vulnerable low-income countries with inefficient public bodies and poor infrastructure frequently struggle to achieve a sustainable strengthening of resilience. The statistics send a clear message: more people die from natural disasters in such countries than in rich countries, both in absolute terms and relative to the total population. Part of the reason is that in many of the poorest parts of the world, weather extremes like floods and droughts pose a greater threat to both the lives and the economic and environmental foundations of entire communities. Loss prevention measures and early warning systems offer substantial improvement.

Insurance as an instrument for strengthening resilience

After a disaster, focus shifts to coping with the consequences. This includes both humanitarian aid and financing systems. Insurance is a central component in managing the economic consequences by facilitating prompt repair and reconstruction efforts.

The results of scientific research show that well-functioning financial and insurance markets provide a markedly positive stimulus. One example is after the 2012 drought in the USA, when the US agricultural insurance scheme assisted many farmers with payments. Without these payments, it is highly likely that agricultural production would have been affected in 2013 as well. The scheme is a public-private partnership (PPP), where the private insurance industry provides its expertise to help ensure accurate risk assessments and rapid payouts. Since, alongside the government support, the farmers pay part of the premiums themselves, they also have an incentive to take action to minimise losses.

Generally speaking, adequate insurance protection can cushion the impact of natural disasters in two ways. Firstly, it motivates insureds to take preventive measures in order to save money on insurance premiums. Insurers allocate a price to the risk, thereby increasing the incentive to lower that price by implementing measures to minimise the risk. Secondly, payments following a disaster provide prompt financial relief, so that the reconstruction of factories, for example, can be tackled without delay. Recent studies show that if you take two countries with identical per-capita income, the country with the higher level of insurance cover will be more resilient to natural disasters.

G7 embraces climate insurance

The realisation that insurance can make a key contribution to strengthening resilience was reflected in the negotiations to reach a global climate protection agreement. The Paris Agreement at the 2015 climate summit recognises insurance solutions as a way to facilitate adaptation to climate change. At the G7 summit in Elmau in June 2015, the member states agreed to launch a climate insurance initiative (InsuResilience), highlighting the importance of financial risk transfer concepts, particularly for emerging and developing countries.

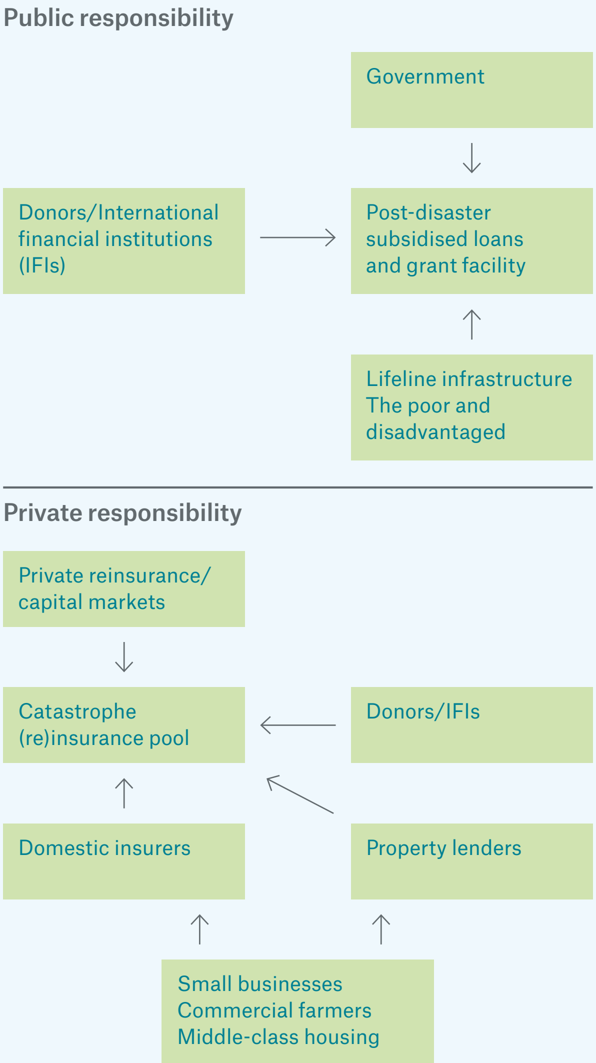
The objective, by the year 2020, is to expand insurance coverage against weather disasters in developing and emerging countries, an initiative from which around 400 million people will benefit. This will be organised either on a macro level with insurance cover for entire countries, or on a micro level with policies for individuals. In April 2016, representatives from UN organisations, the World Bank and the insurance industry announced the establishment of the Insurance Development Forum (IDF) to support projects like this. The plan is to incorporate the insurance industry's risk expertise into government regulations to reduce risks and improve access to insurance for those sections of the population most in need of protection. Today, we can already see pool solutions in operation in some African countries, in the Caribbean, and in Pacific island states.

In summary, it can be said that a better understanding of the concept of resilience and subsequent recommendations for political decision-makers can help achieve a significant reduction in the loss of life and the financial, social and environmental damage resulting from natural disasters. Insurance cover against natural hazards is a key component in allowing a population to get back on its feet as quickly as possible after a loss.

Insurance solutions in practice

In developing and emerging (D&E) countries, the vast majority of damage from natural disasters is not insured. The gap between insured and uninsured damage is much bigger than in industrialised countries. Between 1980 and 2016, D&E countries accounted for 10% of global uninsured losses but just 1% of insured losses. Following a disaster, lack of insurance cover can delay reconstruction, or even make it impossible, particularly in poorer countries. Many developing countries have inadequate financial resources, and generally rely on external help when a disaster strikes.

Public-private partnerships in catastrophe risk financing



Source: Munich Re, based on Global Facility for Disaster Reduction and Recovery (GFDRR)

Partnerships between governments, supranational organisations and the insurance industry have proved useful in providing better financial cushioning against the consequences of natural disasters. As a risk carrier, Munich Re participates in various risk pools, offering transnational insurance cover against risks from weather-related disasters, and in some cases also against earthquakes and tsunamis. These pools have emerged over the last few years in the Caribbean (Caribbean Catastrophe Risk Insurance Facility, CCRIF), in Pacific island states (Pacific Catastrophe Risk Assessment & Finance Initiative, PCRAFI), and in Africa (African Risk Capacity, ARC).

CCRIF was founded in 2007 as the world's first risk pool, and has many participating countries in the region. It insures 16 Caribbean states against earthquakes and hurricanes, and operates like a mutual insurance society. The fund retains a portion of the risks insured by the member countries, and transfers the rest to the reinsurance market. Payments are linked to the intensity of a natural disaster using what are called parametric triggers, rather than actual loss figures. This is to ensure payments can be made promptly, thereby providing much-needed liquidity. Thanks to the pool set-up, the risks are spread more effectively, which in turn reduces the total costs.

Between 2007 and 2016, CCRIF paid out almost US$ 68m in disaster aid to its member states. The largest payment was US$ 23m to Haiti in 2016, less than two weeks after Hurricane Matthew had devastated the southwest of the country. In 2016, the pool was extended to Central America, when Nicaragua became the first country from this region to join. The range of cover was also extended to include insurance against torrential rain.

PCRAFI is a programme financed by various donors and administered by the World Bank. Under the insurance programme, the member states (Vanuatu, Solomon Islands, Cook Islands, Marshall Islands, Tonga, Fiji and Samoa) cede risks from tropical cyclones and earthquakes/tsunamis via an insurance derivative to the World Bank, which then passes on these risks to the insurance market.

The parametric triggers used here also facilitate prompt payouts. The funds that are made available can then be used for emergency aid and clear-up operations following a natural disaster. PCRAFI was developed in close cooperation with the participating nations in order to ensure their exact needs were met. This involvement gave the countries a more accurate picture of their own risk exposure, allowing them to coordinate measures for risk prevention and reduction.

In 2010, the African Union decided to develop ARC, a drought insurance programme for African countries. During extreme droughts, small farmers typically use up their provisions within a few months, and are then forced to slaughter their cattle. The drought insurance is intended to prevent this happening. To become a member, a country must have drought emergency aid plans in place. These specify how insurance payments are used in the event of a disaster. In this way, the population receives prompt assistance. People can buy new seed, food for themselves and feed for their cattle. The payments are made automatically once satellite images show that a specified loss threshold has been exceeded.

Another example of an insurance solution to strengthen resilience is FONDEN (Fondo de Desastres Naturales) in Mexico. It was established by the Mexican government in 1999 after it had designated disaster prevention a national priority. Its objective is to ensure that the public infrastructure can be rapidly restored after a natural disaster. All the federal states pay into the fund and, if a loss event occurs, a local government can count on prompt payment. The fund is covered by a reinsurance policy.

One of the fund's main features is the detailed settlement or loss protocol, which forms part of the reinsurance treaty. The protocol defines the settlement process, and sets out deadlines and guidelines. As soon as independent sources have confirmed a disaster, the federal state affected draws up an initial loss estimate. After that, settlement follows the procedure defined in the loss protocol. FONDEN is therefore a programme that endeavours to make loss settlement transparent, as well as transferring the risk in question.

Disaster prevention works

Natural disasters usually result in large losses. The destruction of infrastructure and the breakdown in communication systems make it more difficult for the population to overcome the consequences of a disaster. A comparison between Hurricanes Katrina and Sandy illustrates the difference that preparedness and well-devised emergency plans can make. Whereas Katrina caused enormous damage due to poor flood protection and inadequate disaster preparedness, with the result that the crisis response was slow and sluggish, when Hurricane Sandy struck seven years later, the New York/New Jersey region was spared much more serious consequences thanks to relatively good emergency planning.

The Department of Homeland Security used Katrina as an opportunity to make fundamental changes to its procedures, and take a more comprehensive approach. In future, all areas of society should be prepared to face emergencies of any kind. A Critical Infrastructure Task Force concluded that increasing resilience, rather than strengthening and extending protection measures, should be the top priority. As a result, FEMA, the national response coordination centre, had already initiated key measures before Sandy made landfall. As well as public institutions, private and charitable organisations were also involved in the preparations to identify what people on the ground most urgently required. FEMA set up depots with aid supplies, established emergency centres, and sent more than 900 staff to the region. And its efforts paid off: losses were kept within reasonable limits, and life in New York and New Jersey quickly got back to normal after Sandy.

Bangladesh has also learned from experience. In the early 1970s, the government introduced the Cyclone Preparedness Programme (CPP) after a cyclone had claimed the lives of 300,000 people. The CPP has over 200 permanent staff, and has recruited almost 50,000 volunteer helpers. At its headquarters in the capital Dhaka, meteorological data on approaching cyclones are analysed and the information is passed on via radio, mobile phones and the internet. Volunteers receive first aid training, take part in exercises, and are equipped with everything they might need in an emergency. Thousands of concrete shelters, many of them on stilts, have also been built so that people can take refuge during cyclones. Over the rest of the year, the buildings are generally used as schools. When, in 2007, a cyclone of similar strength to that of 1970 swept across the same region, the number of fatalities was around 3,000 – significantly less than decades before.

Resilience

The objective of resilience is to help ensure people can overcome a potentially catastrophic event and return to normal life as quickly and effectively as possible. The range of possible precautionary measures includes setting up early warning systems, structural protection, adequate organisation and teaching people how to respond in an emergency situation. This infographic shows that creating a high level of resistance is a dynamic and flexible process.

Prepare

What natural hazards can affect me? Am I ready?

Even if an extreme event is not imminent, you should know how to prepare and protect yourself against it and how to respond if it does occur. A checklist is the preferred way to do this. It is important to be aware of your individual situation.

Emerging countries are hit particularly hard by natural disaster losses

- Industrialised countries: on average 0.8% of GDP
- Emerging countries: nearly 3% of GDP

Recover

How can I get back to my normal routine?

The most important requirement is that basic supplies and infrastructure are quickly restored to allow reconstruction to begin. A loss also presents an opportunity to improve on how things were before the disaster. This in turn will improve future resilience, bringing us back to the topic of preparedness.

2010 economic growth after severe earthquakes at the beginning of the year:

- Chile (M_w 9.5, 27 February): +1.3%
- Haiti (M_w 7.0, 12 January): –5.5%

Respond

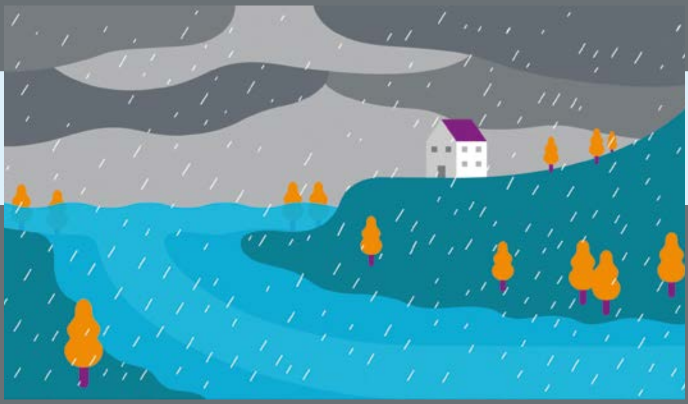
How can I limit the damage?

It is not possible to prevent damage entirely. But it can be minimised by responding appropriately and taking the right steps. The response begins with the early warning, reaches its peak during crisis management, and continues into the recovery phase.

Prevent

How can major losses be prevented?

Mississippi, USA
- Investment in flood management since 1927: US$ 14bn
- Damage prevented in 2011 flood alone: >US$ 100bn



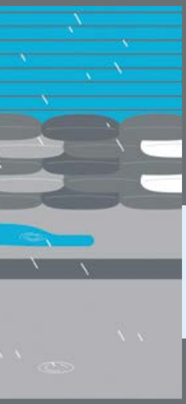
In many cases, major losses from moderate events can be prevented using fairly simple means. Avoiding the peril in the first place is always the best solution.

Protect

How can I better secure my possessions?

Hamburg, Germany
- Investment in flood protection since 1962: €2.4bn
- Damage prevented since then: >€20bn

Precautions taken by the authorities offer a general level of basic protection. This level can be permanently or temporarily increased for objects especially worthy of protection.



Bangladesh: Prevention and early warnings save lives
- Cyclone Bhola 1970: 300,000 fatalities
- Cyclone Sidr 2007: 3,300 fatalities

A global priority

Skype interview with Munich Re: Robert Glasser, Special Representative of the UN Secretary-General for Disaster Risk Reduction and Head of UNISDR.

The United Nations has made risk resilience a top priority, establishing a dedicated secretariat in 1999 to facilitate the International Strategy for Disaster Reduction (ISDR).

Munich Re:
It is now about one year since you assumed your role as Head of the UNISDR. What has been your most positive experience in this position so far?

Robert Glasser:
Most remarkable is the amount of progress I've seen in confronting disaster risk. I've now travelled extensively to take part in regional platform meetings with ministers, officials and heads of government. It's really striking to see how much progress has been made in some places, although not everywhere. And of course there's still a huge amount of work to do.

But I am now seeing disaster risk reduction plans. I see in some cases even national constitutions being amended to incorporate disaster risk. I see improving regulatory environments and a stronger role of parliament in enacting laws and regulations. There is also huge success in elements of the disaster risk reduction agenda, particularly in such areas as early warning systems, evacuation plans and storm shelters in countries like Bangladesh, India and Pakistan. The engagement of private-sector stakeholders is also improving.

What do you see as the major contributing factors to strengthening resilience in the face of natural disasters?

One of the most critical factors adding to the threat and its unpredictability is climate change, so it follows that efforts to reduce greenhouse gases are a major contribution to resilience. I say that because everything we do to reduce disaster risk will be overwhelmed on a planet faced with ever-increasing greenhouse gas emissions. Arguably, the most urgently-needed contribution is to cut down greenhouse gas emissions. Then if I look at the next level of detail, I'd say we need to ensure that disaster risk is incorporated into core economic planning.

Countries have to understand disaster risk and what it's costing as well as the trends, because with climate change and other factors the past is no longer a reliable indicator of the risks you face in the future. The insurance industry has this data and is therefore absolutely fundamental in the overall risk management programme.

How can the insurance sector and insurance-related risk transfer mechanisms support your effort to improve resilience?

Transferring risk is of course one of the most important tools countries have in managing risk. While countries need to do everything they can to reduce risk in other ways – by making sure they're not constructing hospitals in flood zones, for example – at the end of the day, once they've done all they can, they should have options to transfer a portion of the risk through insurance.

In some countries, however, the regulatory framework makes it difficult for insurers to assume this role. Especially in communities that are marginalised, the insurance industry is in a unique position to develop suitable products like mutuals that can reach stakeholders who tend to be particularly vulnerable and exposed to hazards.

A further aspect is the fact that governments need first to fully understand risks before they can decide on measures to mitigate them and consider risk transfer. There are huge gaps in both rich and developing nations when it comes to understanding their exposure. Here, the insurance community can offer key support to countries and other stakeholders in raising awareness and laying the groundwork for risk transfer.

You've mentioned the vulnerability of poorer communities. What should be done to further increase resilience in developing and emerging countries specifically?

While all countries face the challenge of building resilience with limited resources, the gaps in developing nations are far greater. These countries are hugely disproportionately affected when disaster strikes. In our analysis, the average annual loss from natural catastrophes in low-income nations equates to over 20% of their annual social expenditure. Secondly, there are gaps in knowledge about disaster losses and generally weak tools for risk profiling and for incorporating risk into economic planning. All of these areas need attention for us to reduce disaster risk, and the insurance industry has a key role to play in every one.

Are there any flagship public-private partnership projects you think could serve as a blueprint – that could be upscaled or copied?

There are actually quite a few in this sphere. Some of them are linked to microinsurance, enabling communities to access insurance products, and working with governments and NGOs. The UNISDR has a major private-sector partnership operating both at a global level with multinationals and at the regional level with very dynamic chapters of private-sector firms, particularly in Japan and the Philippines. This alliance, called the Arise Network, is developing a series of public-private partnerships to reduce disaster risk. Activities range from incorporating risk in the curriculum of business schools, fostering a new generation of executives with an understanding of disaster risk, to working with small to medium-sized enterprises to test their resilience and preparedness regarding disasters – and everything in between.

There's also a very interesting initiative we're just beginning linked to the financial sector regulators, the Bank for International Settlements and the Financial Stability Board. We've found important opportunities to incorporate disaster risk into the global regulatory environment that sets the rules for the insurance sector around the world. The challenge is to work out what the appropriate role of the public sector is, because there has to be a compelling private-sector interest as well. It has to be win-win.

The first of four priorities for action stated by your organisation for the next 15 years is "understanding disaster risk". How can insurers support you in this regard?

One of the key ways is what I've mentioned, ensuring that disaster risk is embedded in core economic planning. Working backward from there, there are a whole variety of steps, like understanding disaster loss and risk profiling. On a global level, it would be extremely useful if insurers would open up their data on risk and make it more available. I know in many cases it's proprietary information, but I think there is a compelling shared interest – on the part of insurers as well – in pooling what we know where there's a lack of open knowledge. This will enable better pricing of risks and open up markets, so more risk can be transferred.

Resilience – More than just a buzzword

Professor Peter Höppe,
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Resilience is one of the most talked-about topics today in the field of disaster prevention and management. It is a key component of sustainable development (as formulated by the UN in 2015 in its Sustainable Development Goals), and looks set to become as ubiquitous as the word sustainability – the most popular term of the last few years. Essentially, the objective of resilience is to put societies in a position where they can cope with loss events as efficiently as possible.

In this context, it is important not to disregard the other components of natural disaster management, which also help to strengthen resilience.

The first of these is the mitigation of natural hazards, in other words influencing their frequency and/or intensity. Unfortunately, there are in fact very few options that can be called upon at short notice to do this. Attempts are being made in some regions to combat extreme hail events by seeding thunderstorm clouds from an airplane with condensation nuclei (silver iodide). However, there is no scientific evidence to suggest this actually reduces hail intensity. Other forms of geo-engineering, for example efforts to influence tropical storms, have so far proved to be nothing more than visionary ideas and are not really considered feasible. In terms of weather-related natural hazards therefore, climate protection will remain the most effective instrument to avoid accumulations of unmanageable events for the next few decades.

Risk reduction can also be achieved through managing exposure. This includes cutting back on development in high-hazard regions such as coastlines or areas that are prone to flooding. This harbours enormous potential, but it is a potential that is often neglected in the pursuit of short-term gains, or because poorer people simply have nowhere else to live.

A further component is reducing vulnerability. For example, the loss susceptibility of buildings can be reduced by enforcing stricter standards on more loss-resistant construction methods or by using more suitable building materials, while protection measures like dykes can help to reduce the risk for entire areas.

After that come measures for acute disaster management, such as early warning systems, evacuations and emergency aid.

All these measures help to reduce material losses and human suffering. If a society is affected less by an extreme event, it can get back on its feet faster and is therefore more resilient per se.

Another feature of resilient societies is that they are in a position to quickly repair damaged infrastructure and begin reconstruction. Insurance plays a key role in this context, since it contributes to prompt and reliable financing of recovery measures. This applies in particular for emerging and developing countries.

Several economic studies in the last few years have shown that high insurance penetration assists a country's economy after a major natural disaster. The greater the proportion of insured losses, the less of a decline there will be in economic output following a natural disaster, and therefore the faster the country can recover. In countries with very high insurance penetration, there can even be a positive effect on economic output.

At any rate, there are a number of reliable indications that insurance generates positive effects irrespective of a society's level of prosperity. This means that, given two countries with identical per-capita income, the country with higher insurance cover will be better able to withstand natural disasters. In other words, the higher the insurance penetration, the more resilient the societies in question will be.

Kumamoto suffers double quake

In April 2016, two powerful earthquakes within 28 hours caused major damage in southwestern Japan. In terms of the overall loss, this was the third most expensive earthquake event in Japan's history after the Tohoku earthquake in 2011 and the Kobe earthquake of 1995.

Christoph Bach and Martin Käser

Japan

Earthquake losses 2016
US$ 31.3bn

Uninsured earthquake losses in 2016: **81%**

Earthquake losses as a percentage of overall losses in the last 30 years: **78%**

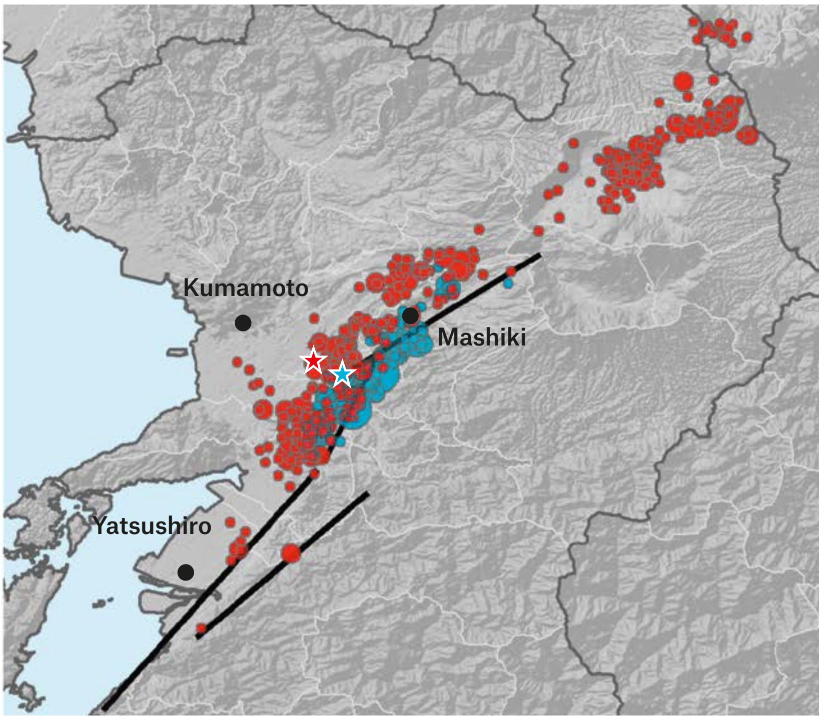
Because of its position on the boundary of several tectonic plates, Japan has suffered more than most from powerful earthquakes. In the south of the country, the Philippine plate pushes itself five centimetres further under the Eurasian plate every year. The resultant rock stress triggered a series of quakes starting on 14 April 2016. On that day, a foreshock with a moment magnitude of 6.2 hit the island of Kyushu, and was followed by smaller aftershocks and, finally, the main shock on 16 April with a magnitude of 7.0 (see map on page 20). The series of earthquakes caused numerous landslides, and many old buildings in particular suffered severe damage. Large industrial facilities were at a standstill for days. In a number of places there was ground liquefaction, which caused very serious damage to buildings.

Earthquakes away from the actual plate boundaries

The quakes occurred on known "crustal faults" at a shallow depth of around ten kilometres, mainly in the Futagawa-Hinagu fault zone. This type of fault, far away from the actual plate boundaries, is frequently caused by internal deformation of the tectonic plates as a result of external pressure. Despite their lower magnitude and longer return periods compared to subduction quakes – where one plate pushes under another – crustal quakes are often more destructive because they occur nearer populated areas. Unlike the foreshock, the fracture caused by the main shock in Kumamoto reached the surface. The ground opened up in several places, and there were local horizontal slips of more than two metres.

According to the Japan Meteorological Agency (JMA), both quakes generated exceptionally high ground acceleration of over 10 m/s². For the same region to suffer severe earthquakes in close succession is also considered quite a rare occurrence.

Distribution of aftershocks from first quake (blue) and second quake (red)



★ First quake (14 April)
★ Main shock (16 April)
● Aftershocks on 14 and 15 April
● Aftershock on 16 April

Magnitude
○ 3.0–3.9
○ 4.0–4.9
○ 5.0–5.9
○ ≥6.0

— Fault

Source: Munich Re, based on Japan Meteorological Agency data

Costliest earthquakes in Japan measured by overall losses

Location	Year	Losses (original values in US$ bn) Total	Insured	Uninsured	Fatalities
Tohoku	2011	210	40	81 %	15,880
Kobe	1995	100	3	97 %	6,430
Kumamoto	2016	31	6	81 %	69
Niigata	2004	28	0.8	97 %	46
Niigata	2007	3	0.3	90 %	11

Source: Munich Re NatCatSERVICE

Buildings already damaged in the foreshock were considerably more vulnerable to the ground motion in the second large quake. This resulted in large losses despite the high building standards.

Earthquake-resistant construction in Japan

Official building standards have been in force in exposed regions of Japan since 1924. They have been updated many times. There were major changes, for example, in 1981 (after the 1978 Miyagi quake), following which, though a building may suffer damage from strong ground motion, it should not be capable of collapsing. There were many smaller changes in the years thereafter, relating, for example, to the stability of wooden buildings in 2000 and the requirement that all buildings under construction be inspected by an independent body and checked for compliance with the building standards, in 2006.

The series of earthquakes in April caused large losses in the Kumamoto prefecture and surrounding towns (e.g. Mashiki). There were 69 deaths, and many people were injured. Almost 300,000 had to be evacuated after the main shock. Some 8,000 buildings collapsed and more than 140,000 were damaged, 24,000 severely. A large proportion of the buildings that collapsed were wooden buildings with heavy roof structures built according to the pre-1981 building standards. Several cultural heritage sites (including Kumamoto Castle and the Aso Shrine) were damaged, as was infrastructure (roads, bridges and railway lines), either directly by the quake or by subsequent landslides.

Most old houses in Japan are made of wood and have heavy roofs. The collapse of such houses accounted for the lion's share of the losses from the 2016 Kumamoto quakes.

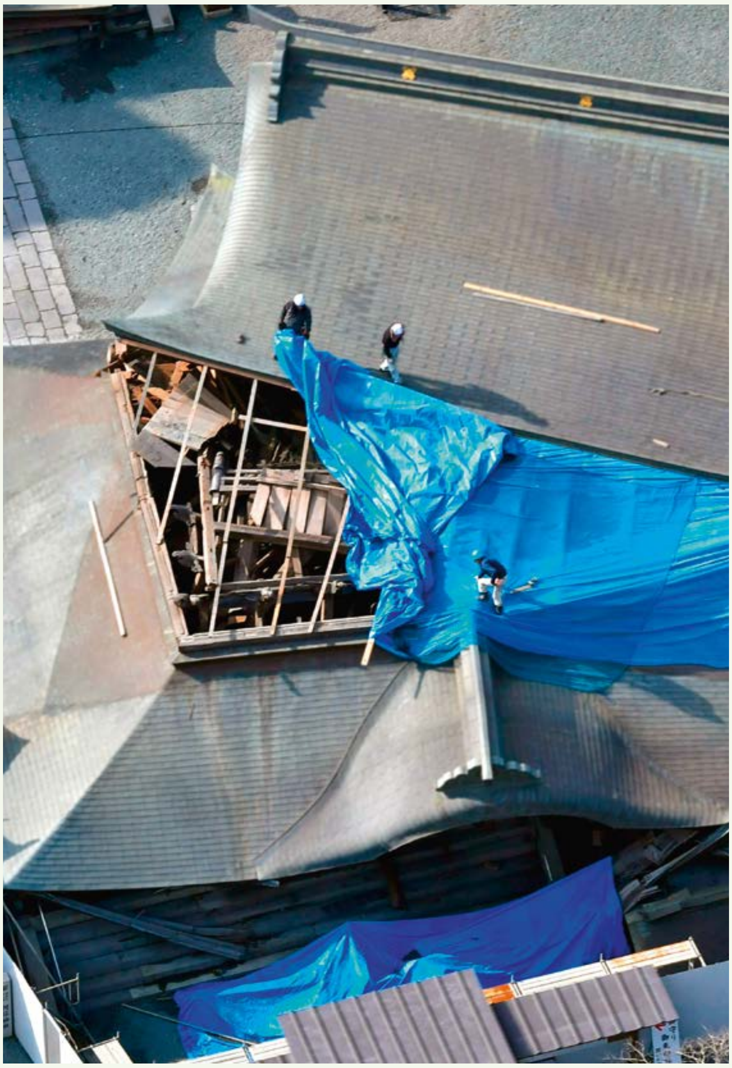
Supply chains disrupted

Firms producing cars, electronic components and pharmaceuticals are based in the industrial area to the northeast of Kumamoto. Though the structural damage to buildings tended to be minor, production at several sites was brought to a standstill, at least in the week following the quake, causing worldwide interruptions in the supply chain for downstream production facilities. The industrial losses in Kumamoto once again highlight the extent to which just-in-time production is utterly dependent on a steady supply of individual components.

The overall loss for the two earthquakes in Japan amounts to around US$ 31bn, of which US$ 6bn was insured, making Kumamoto Japan's third-costliest earthquake after Tohoku in 2011 and Kobe in 1995 (see table on page 20). Residential buildings and their contents accounted for over half of the overall losses – and almost three quarters of the insured losses.

As there has been a considerable rise in the number of buildings insured, the insured losses in 2016 were significantly higher than for the Kobe quake in 1995. The proportion of households insured against earthquakes with private insurance companies has more than tripled since Kobe, from 9% to 29%. Nevertheless, due to the persistently low insurance density in Japan, the uninsured portion of the losses was higher than for comparable disasters in other industrialised countries like New Zealand (see page 47).

The earthquakes did not spare centuries-old religious sites such as the Aso Shrine.



The Beast: Wildfire in Canada

In 2016, the insurance industry was taken by surprise when a forest fire produced the costliest insured loss ever in the Canadian market. Until then, wildfire losses of this magnitude had only ever happened in California, where the hazard is much greater.

Markus Steuer

Canada

Highest insured losses

1. Fort McMurray
US$ 2.9bn (overall losses of US$ 4bn)

2. Alberta floods 2013
US$ 1.5bn (overall losses of US$ 5.7bn)

The forest fire, which locals dubbed “the Beast”, was likely started by one or more persons on 1 May southwest of Fort McMurray, a city of around 80,000 inhabitants situated in the heart of Canada’s boreal coniferous forests. The conditions were ideal for the fire to spread rapidly. Following a dry, mild winter, the snow cover had been thinner than usual and therefore melted earlier in spring. As there had been no significant rainfall since the middle of April, the vegetation was highly flammable.

Fire raged for two months

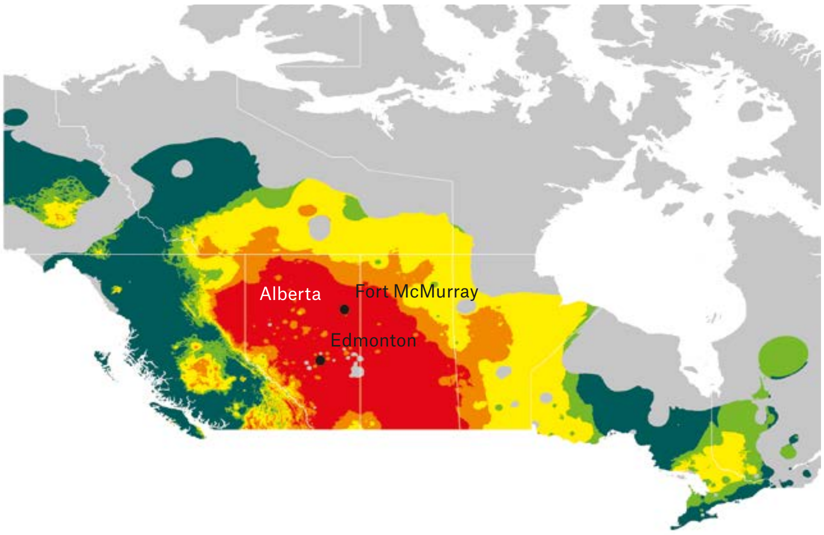
The forest fire quickly spread out of control and Fort McMurray was evacuated. On 3 and 4 May, daytime temperatures climbed to over 30°C, much higher than what was usual for that time of year. The wildfire danger was extremely high (see map on page 24) and the flames, fanned by the wind, reached the city despite desperate efforts on the part of the fire services. Approximately 2,000 buildings, equivalent to roughly 10% of the town, were destroyed.

It was more than two months before the fire was fully brought under control in early July. In total, some 590,000 hectares were affected, an area twice the size of Luxembourg. Fortunately, there were no fatalities from the fire.

Fort McMurray lies in the middle of the largest oil-sand deposits in Alberta. Oil production in the region had to be stopped for several weeks because of the risk posed by the fire. Thousands of workers were brought to safety and a lodge providing accommodation for workers burned down. There was no significant direct damage to facilities or the pipelines. However, the oil companies sustained substantial indirect losses as a result of business interruption.

Wildfire danger on 4 May 2016, as indicated by the Fire Weather Index (FWI)

The FWI provides an estimation of the danger posed by a potential fire. If the FWI is above 30, a forest fire will achieve high intensity and spread fast. Although the extreme fire danger in many parts of Alberta in May 2016 was exceptional for such an early stage of the wildfire fire season, Fort McMurray has experienced days with a similarly high danger level over the last 35 years.



Fire Weather Index	Fire danger
0–5	Low
>5–10	Moderate
>10–20	High
>20–30	Very high
>30	Extreme

Source: Munich Re, based on Canadian Forest Service, Natural Resources Canada

The most expensive forest fires worldwide for the insurance industry. The events are listed according to insured losses in original values.

Month(s)	Country	Overall losses in US$ bn	Insured losses in US$ bn	
		Original values	Original values	In 2016 values (inflation-adjusted)
May–July 2016	Canada	4.0	2.9	2.9
Oct.–Nov. 2007	USA	2.9	2.3	2.7
Oct.–Nov. 2003	USA	3.5	2.0	2.6
October 1991	USA	2.5	1.7	3.0
Sept.–Oct. 2015	USA	1.4	0.9	0.9

Source: Munich Re NatCatSERVICE

Comparison with other forest fires in Canada

The Fort McMurray fire resulted in insured losses of US$ 2.9bn, making it both the world's costliest-ever forest fire (see table below) and the costliest natural disaster in the history of the Canadian insurance market.

The scale of the damage from this event easily surpassed all previous forest fires in Canada. For example, in 2011 one third of the small town of Slave Lake in the province of Alberta burned down. More than 500 buildings in the region were destroyed or badly damaged. Overall losses came to US$ 1.1bn (in original values), of which US$ 720m was insured. The area affected (22,000 hectares) was much smaller and, in contrast to the Fort McMurray event, the fire service was quickly able to bring the flames under control. There were also major forest fires in British Columbia and southwestern Alberta in 2003. Particularly hard hit was the town of Kelowna, where 239 residential buildings were destroyed, and insured losses came to US$ 160m.

Much greater risk

The enormous damage caused by the 2016 wildfire illustrates how the risk has increased in the region. Thanks to the growth in the production of oil sand, the isolated town of Fort McMurray has expanded dramatically since the 1970s. In turn, this has resulted in a concentration of assets in the fire-exposed areas close to the forest.

Although it is likely that the natural climate phenomenon El Niño contributed to the mild temperatures and dry conditions during the winter of 2015/16, the recent wildfire in Canada could well be a foretaste of what the future will bring as a result of climate change. The increase in average temperatures is likely to prolong the forest fire season there. And if the number of heatwaves increases, as climate models predict, there will also be a higher probability

Panic-stricken residents were forced to flee from the approaching wall of flames.

The destroyed residential areas in Fort McMurray were close to the forest, where flames could easily spread to people's homes. Yet even in areas that were more or less razed to the ground there were pockets of houses which survived largely unscathed, apart from some heat damage to the outer walls.

of more intense forest fires. This is because severe events typically occur on the few critical days when the wildfire danger is very high. Warmer temperatures may also encourage infestation by bark beetles, as their larvae have a better chance of surviving under the bark in mild winters. Warm, dry summers promote the development and spread of the beetles because drought stress weakens the resistance of the trees. The dead trees provide additional fuel for future fires.

The growing risk and the recent loss events show that wildfire is one of the most important types of natural catastrophe in terms of risk management for Canadian insurers. For this reason, it is essential that the wildfire risk becomes an integral component in the pricing of natural catastrophes in Canada. This applies even more to the assessment of accumulation scenarios. In the light of recent events in Canada – Kelowna, Slave Lake and now Fort McMurray – underwriters will in future need to take a much closer look at where exposure accumulations are located in high-hazard regions.

Rainstorms over Europe

From late May until mid-June, a persistent large-scale weather pattern with thunderstorms produced intense precipitation which caused both local flash floods and widespread flooding in central Europe. The floods struck many places with no warning.

Sophie Bachmair and
Eberhard Faust

Europe
Series of flash floods 2016
US$ 2.4bn – Germany's third-largest flood loss ever
Over 30 flash flood events in just two weeks in Germany
Highest flood losses in Greater Paris since 1910

Southern and central Germany were the first to be affected by the severe weather when violent thunderstorms and hail hit on 26 May 2016. Parts of Baden-Württemberg received over a month's worth of rain in just one day on 29 May. Four people lost their lives in flash floods. Many houses in the town of Braunsbach were damaged or destroyed, and a well-known car manufacturer was forced to halt production temporarily.

Almost simultaneously, storms in France and the Benelux countries caused floods: at first only smaller rivers were affected, but the Loire and Seine later burst their banks, too. In the town of Nemours to the south of Paris, the River Loing rose to a record level. In Paris, the Louvre and the Musée d'Orsay had to be closed and works of art moved to higher storeys.

From 31 May to 1 June, further flash floods followed in Saxony, Bavaria, and in Austria. In Simbach in Lower Bavaria, the stream of the same name rose from 0.5 metres to around 5 metres within just a few hours, flooding around 5,000 households. Seven people lost their lives. Continuing this chain of events, central Europe and Germany in particular witnessed repeated cases of localised damage from severe thunderstorms throughout the first half of June.

Blocking weather pattern

The floods in central Europe stemmed from an unusual general weather pattern that persisted for an exceptionally long time, from 27 May to 9 June. A characteristic feature of the pattern was that the fast-flowing, high-altitude air current known as the jet stream formed a wave over Europe that resembled the Greek letter omega (see map on page 28). In a region within this omega pattern, numerous thunderstorms formed in unstable stratified air, fostered by a deep low-pressure system over Germany and neighbouring countries. At the same time, large parts of northeastern and central France were hit by thundery rain under the influence of the accompanying surface low, Elvira. Protracted duration is a typical feature of omega blocks, which prevent weather systems from moving eastwards.

The block had devastating consequences in some regions. In Germany, storms formed on a daily basis from 28 May to 5 June, each bringing over 50 mm of rainfall. As the storms hardly moved, all of the rain fell on an area of just a few square kilometres. In some locations, daily precipitation rates were measured that statistically occur just once every 200 years. In areas with more sloping terrain and valley incisions, such as the towns of Simbach and Braunsbach, the huge amount of local rainfall led to abrupt and destructive flash floods. In contrast, early warning systems in place for the Loire and Seine made it possible to give advance notice and evacuate several thousand people.

Building damage in the billions

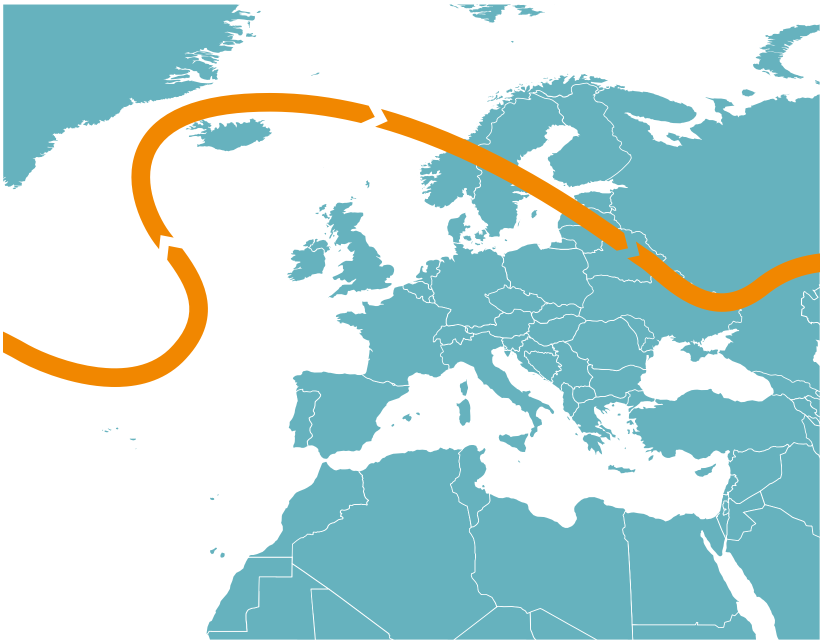
The overall loss from the storms in Germany is estimated at €2.6bn. Insured losses amount to €1bn in the property line, and €200m in motor insurance. Besides the inundation depth, the key factor for damage caused by the flash floods was the flow velocity and the trees, boulders, debris and sludge the waters swept along with them. However, it is extremely difficult to account for such variables in catastrophe models. In France, the insured loss from the floods came to €1.2bn. Of this amount, slightly more than half was attributed to residential buildings, almost a quarter to commercial buildings, one sixth to agriculture, and approximately one twentieth to the motor insurance class. 1,220 municipalities were affected and 175,000 claims filed.

Risk of change

Return periods considerably longer than 150 years (Seine), and of approximately 100 years (Loire), were calculated for the three-day precipitation totals that led to the

Omega block prevents change in weather

Track of the fast flowing, high-altitude air current (jet stream) over Europe averaged over the period 27 May to 9 June, with an arched loop pointing northwards that resembles the Greek letter omega ( ). Omega blocks are extremely persistent and prevent weather systems from changing.



Source: Munich Re, based on NCEP/NCAR reanalysis data

Flash flood triggers

The starting point for flash floods are small-scale thunderstorm cells. Masses of warm, moist air rise to high altitudes and condense into towering clouds. Such thunderstorm cells can theoretically occur anywhere, and it is virtually impossible to predict where they will discharge their rain. How quickly, where, and to what extent heavy precipitation leads to flash floods and inundation depends on the catchment characteristics. Factors favouring a dangerously rapid run-off of surface water include steep terrain, low water retention capacity of the land due to a high proportion of paved and developed areas, soil that is saturated with water or clogged through mud, and little or no vegetation. If the soil is saturated after repeated cloudbursts, slopes can become unstable, resulting in landslides. Due to their high kinetic energy, the discharged masses of water sweep along debris and eroded soil. When rivers and streams become blocked, water builds up behind the obstacle. If it gives way, a surge-type flood wave forms. The dominant factor in flash floods, however, is extreme rainfall over a very short period.

On 1 June 2016, following several hours of thunderstorms, brown waves roared through the Bavarian town of Simbach. The water masses swept along soil, rubble, wood, and many other materials.

floods in the Seine and Loire catchment areas. A climate model-based study showed that the probabilities of such precipitation events in the region are roughly double that of a virtual world without climate change. The intense storms in Germany broke a number of records. It was the largest area to have ever been hit by a continuous period of thunderstorms prone to torrential rain in the observation period since 1960.

This record is due to the exceptional persistence of the weather pattern. It corresponds to a phenomenon that was discussed in Topics Geo 2014 (page 35 ff.). That is, we are now observing persistent weather patterns more and more frequently during the summer half-year in the northern hemisphere. Their long duration can result in extreme outcomes.

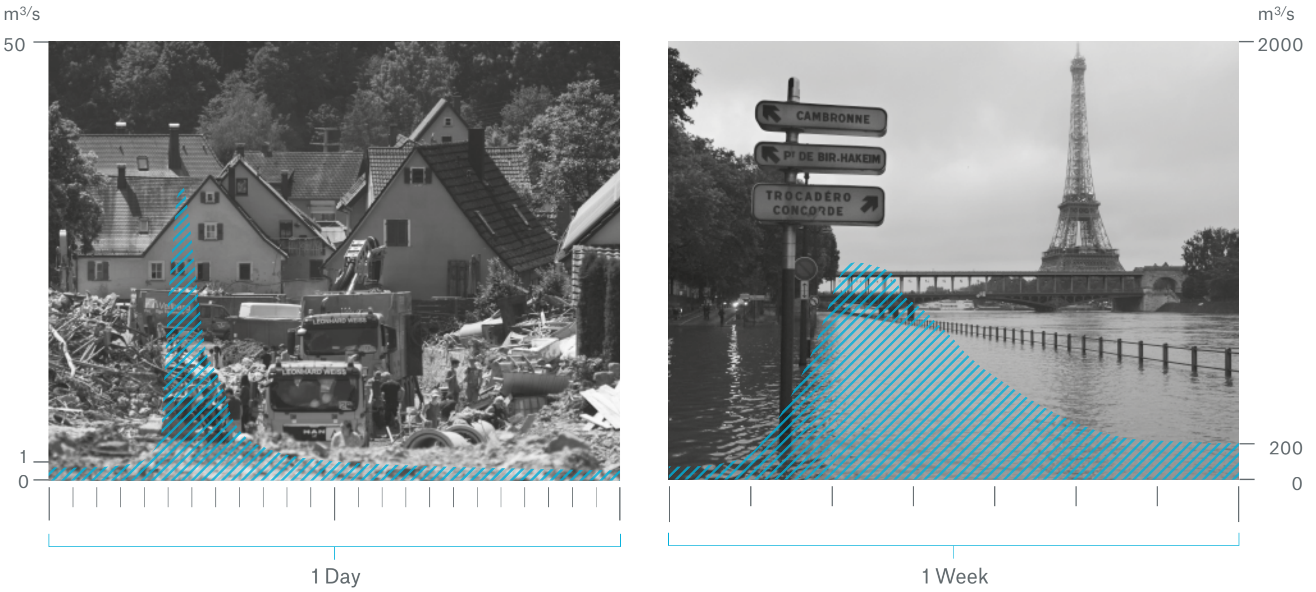
Identify storm risks early on

The summer of 2016 demonstrated that a single weather pattern can trigger both localised intense precipitation with flash floods and large-scale precipitation with river floods. In the case of extreme rainfall and flash floods, measures such as watercourse restoration, a reduction in surface sealing, flood protection structures, and higher capacities for culverts and drainage systems are of little use in reducing potential loss consequences when bound by realistic cost-benefit analysis. For such extreme events, it would seem more expedient to develop hazard maps due to specific extreme precipitation scenarios for communities, pointing out likely run-off paths, locations where debris accumulation is expected, and inundation areas within the built-up sectors.

Evacuation plans can be drawn up based on this information, and corresponding emergency drills held with the participation of residents and emergency forces. Following the events of 2016 in Europe, it should be clear that extreme amounts of precipitation within a very short time are possible almost anywhere. Flood insurance should therefore form a central element of risk prevention, even for locations far from rivers.

Differences between flash floods and river floods

The discharge diagrams show two notional examples, with the typical hydrographs of a flash flood and a river flood wave. For flash floods, the maximum discharge is reached very quickly. It can exceed the normal discharge by a factor in the tens or hundreds. In large rivers, on the other hand, the flood discharge increases gradually, and seldom reaches more than ten times the normal value. In absolute terms, the discharge peak and volume (blue hatched area) of a river flood are many times higher than for a flash flood. Large areas are submerged in a river flood. Flash floods, in contrast, sweep along rubble and debris in sloping terrain.



“Like a hole in the sky”

Hardly a year goes by without floods in China. Rivers are being forced into narrow courses and urban areas are becoming increasingly impermeable. After several years without any historic flood disasters, 2016 saw exceptional flood damage once again.

Wolfgang Kron

China

Floods 2016

Overall losses: **US$ 28bn**

Uninsured portion: **98%**

Costliest flood year since 1998 (US$ 33bn in 2016 values)

China’s last devastating flood disaster took place in 1998, when flooding on the Yangtze and Songhua rivers kept entire regions in suspense for weeks on end. Losses came to some US$ 20bn and almost 4,000 people lost their lives. Just like in 1998, an exceptionally strong El Niño event preceded the 2016 floods. The Chinese authorities had issued warnings back in the spring about the possibility of a particularly intense flood season in the central and lower Yangtze regions. Starting in June – earlier than usual – new flood flashpoints developed on an almost weekly basis.

Flash floods: a nasty surprise

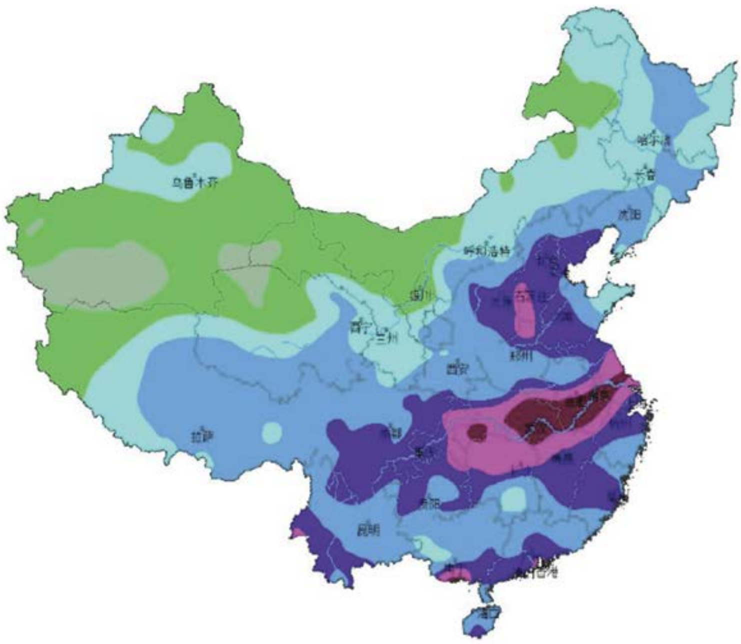
Although there were similarities between the events of 1998 and 2016, there were also striking differences. The 1998 floods were primarily a result of river flooding that plagued the Yangtze and Songhua rivers and their major tributaries. In contrast, the 2016 catastrophes were a combination of many different, intense and often localised individual events. Critical flood stages were reached on 363 small and medium-sized rivers.

At over 600, the number of fatalities was remarkably high. One reason is that you generally have very little time to save yourself in a flash flood, as these develop much more quickly than river floods. A second is that people increase the risk further by attempting to rescue their prized possessions when time is of the essence. What’s more, flash floods develop much more power than river floods and are therefore more dangerous.

Floods in the Yangtze region

The most costly period of flooding started in mid-June in the Yangtze catchment area in central China. For almost a month – during the season known locally as the plum rains (“mei-yu” in Chinese, see pages 34–35) – it was one rainstorm after another. Nanjing, situated on the lower Yangtze, received 1,055 mm of precipitation between January and July, the second-highest amount on record and twice the normal figure. The whopping 550 millimetres that fell during the mei-yu season (June and July) even smashed the old record. The floods wreaked great damage in the city.

Precipitation in China from 22 June to 22 July 2016



- 1–10 mm
- 11–50 mm
- 51–100 mm
- 101–200 mm
- 201–300 mm
- 301–500 mm
- >500 mm

Source: National Meteorological Center, CMA

The mei-yu period is typically characterised by rather steady rain, but the 2016 season was interspersed with a large number of thunderstorms, with localised torrential rain and even hail in some areas. There were landslides in many places and a total of 179 dyke breaches. Although major rivers like the Yangtze ran dangerously high, this did not lead to catastrophic losses. Overall, the floods in the Yangtze region cost around US$ 20bn, of which just 2.5% was insured. At least 237 people died.

Flood causes in China

One of the most spectacular local events befell the city of Wuhan, at the junction of the Yangtze and Han rivers. More than any other city, Wuhan exemplifies the river flood risk in China. From 1 to 6 July, precipitation in the city's four districts was between 930 and 1,087 mm, a new record. Roads, railways and underground lines were flooded. Wuhan is also a symbol of the unbridled expansion of Chinese cities, where drainage infrastructure is unable to keep pace. Since 1949, the city's built-up area has grown by some 200 square kilometres to approximately 550 square kilometres (2015 figure). As a result of this expansion, one third of the retention volume of the surrounding lakes, where many million cubic metres of water had been held temporarily during floods, was lost.

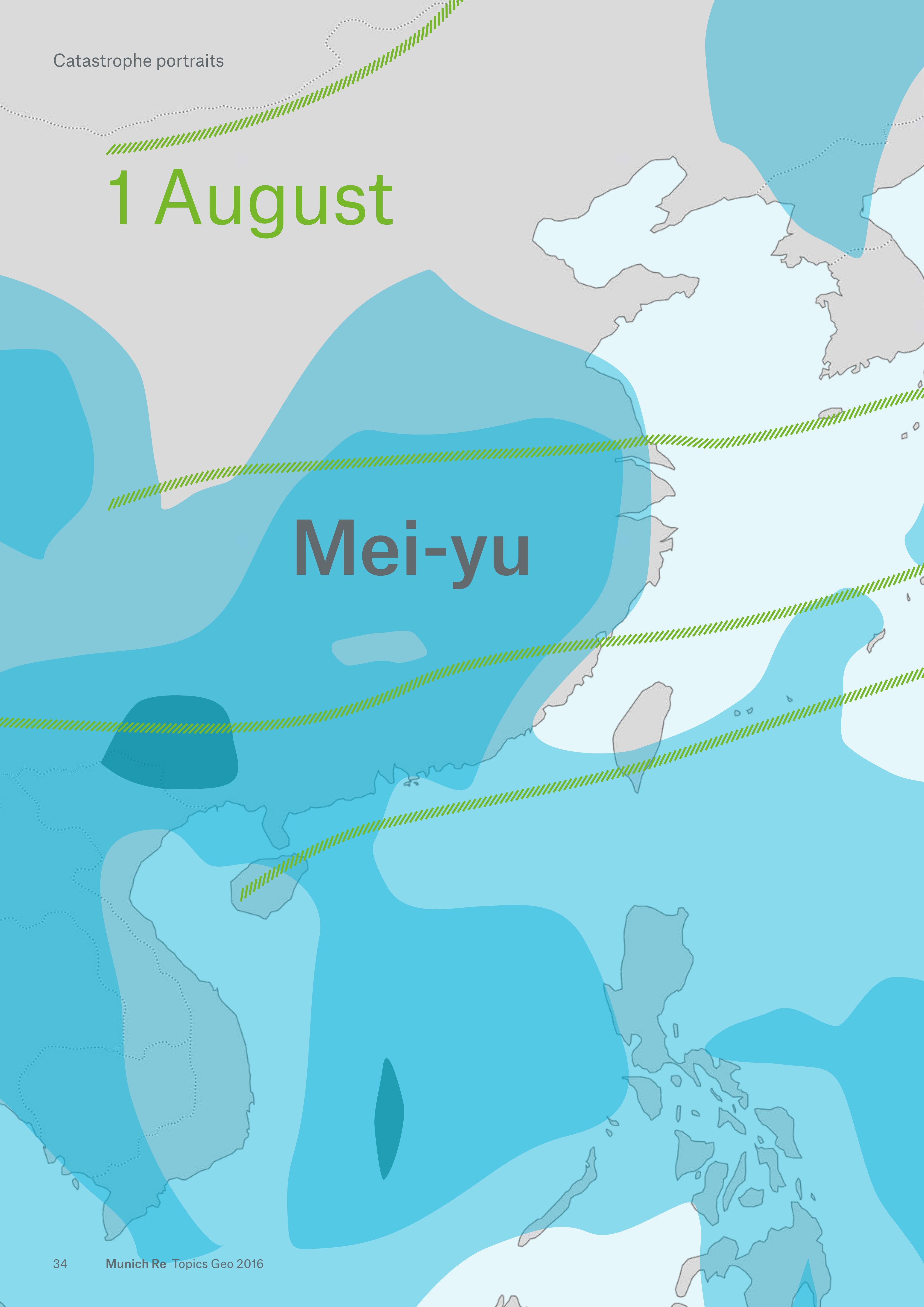
Did the Three Gorges Dam help?

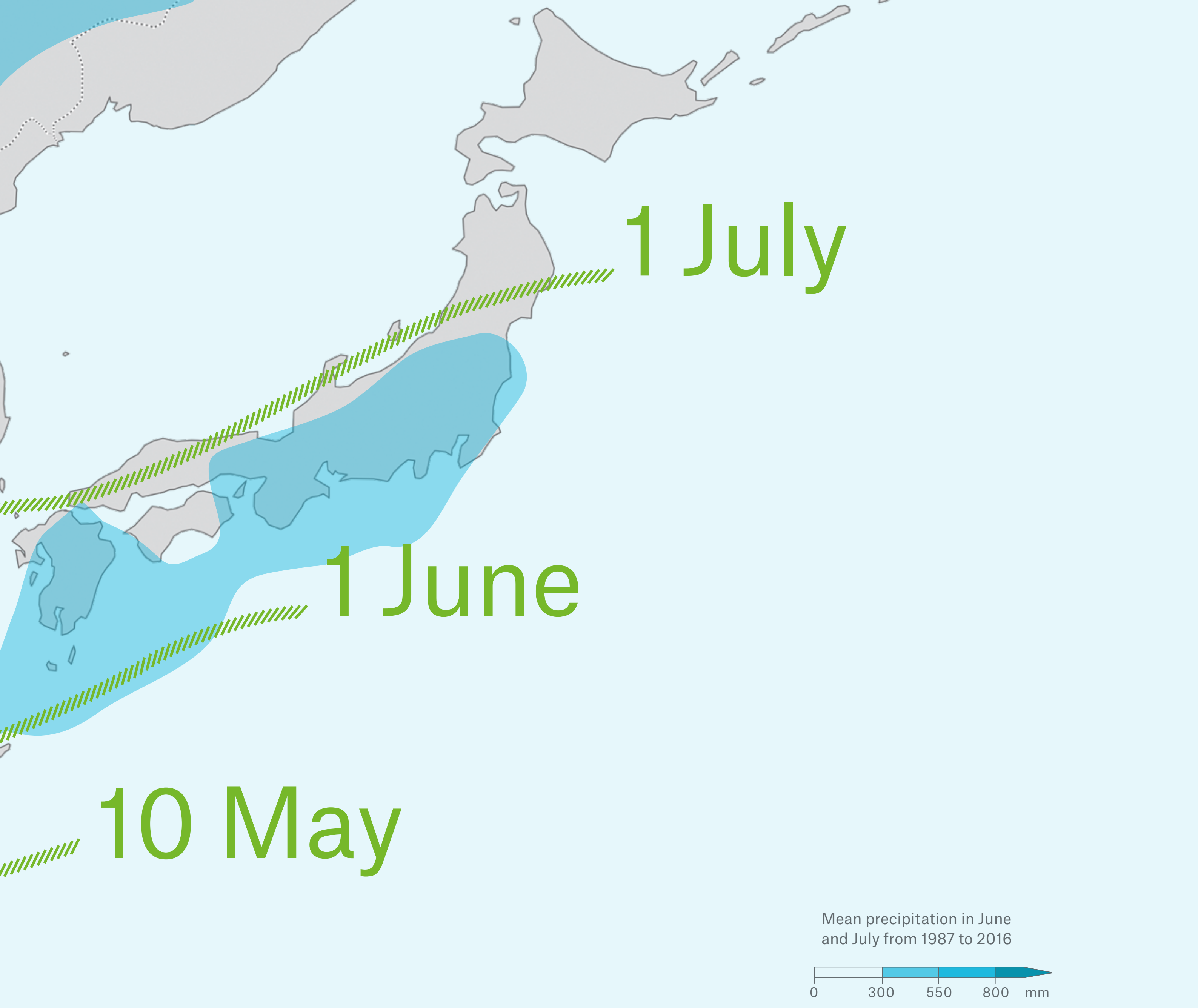
Whereas the floods on the Yangtze in 1998 came mainly from Sichuan through the Three Gorges, on this occasion they occurred downstream of the mighty dam. Nevertheless, the Three Gorges project still played a pivotal role in 2016. During the flood period on the middle and lower course of the Yangtze, a significant amount of the water coming from the upper reaches of the river was held back by the dam, thereby lowering the flood peak by almost 40%. Without the retention in the Three Gorges reservoir, the critical water level in the Yangtze upstream of Wuhan would have been exceeded for seven days. This illustrates that a reservoir can play a key role in flood management, even if it is not used to reduce a flood wave flowing into it. That said, the Three Gorges project cannot prevent all floods.

Rainstorms over large cities

The second billion-dollar event in 2016 hit the northeast of China, affecting provinces that are together home to over half a billion people. From 18 to 21 July, an easterly-moving corridor of precipitation hit Taiyuan, Zhengzhou, Shijiazhuang, Tianjin and Beijing. In just three days, well over 50 millimetres of rain fell on an area covering 900,000 square kilometres, with as much as 250 millimetres descending on an area covering 36,000 square kilometres. Historic records were exceeded in 22 districts. The town of Dongshan

It was China's cities that suffered most from the extreme rainfall during the 2016 mei-yu season. One eye-witness said it was as if "someone had poked a hole in the sky". Flash floods brought life in many places to a complete standstill.


1 August
Mei-yu



What is mei-yu? During the summer monsoon season, warm and humid air from the Pacific flows towards the Asian continent, meeting cold, dry air from the north. The air mass boundary moves slowly towards the northwest, but can remain stationary for days. It is along this front that rain falls in vast quantities: either in the form of steady rain for weeks on end if the front moves slowly, or as torrential storms if the front moves quickly. The rainy season, known as "mei-yu" in China, begins in mid-May in Taiwan and early June in Japan and southern China, arriving in the Yangtze region in mid-June, and later reaching northern China and Korea. Mei-yu means "plum rain": the rainy season coincides with the plum harvest on the middle and lower Yangtze. The heavy rains lead to considerable flooding in central China in particular, where huge swathes of the land are flat.

Source: Munich Re, based on NCEP/NCAR reanalysis data near Beijing experienced 454 millimetres of rain, and up to 140 millimetres fell in some places in the space of an hour. 149 towns and districts in the province of Hebei suffered damage, and almost 15 million people were affected by the floods, which left 164 dead. Overall losses amounted to US$ 4.5bn, 85% in Hebei alone.

The district of Xintai in the southwest of the province was particularly badly hit. Here, a sudden flood wave topped the dyke, flooding a neighbourhood in the middle of the night without warning. One example in the same district highlighted serious shortcomings, with the illegal development of a riverbed that had dried up only a few years before. The area suffered extensive damage.

Increase in flood protection and prevention measures

Following the traumatic events of 1998, China launched an extensive flood protection programme. Over the following ten years alone, the government invested more than 620 billion yuan (US$ 87bn). Centres were set up for data collection, flood forecasting and early warning, and a flood management strategy was drawn up. By the end of 2006, 85,800 dams, retention basins and polders had been built or retrofitted, together with 280,000 kilometres of dykes, providing protection for 550 million people and 45 million hectares of farmland. As a result, the impact of the annual floods has diminished, even though values have risen.

The new strategy is focused on flood management, and thus on reducing the risk, instead of achieving the best possible level of flood protection. However, the primary focus of these efforts was on river floods. Little attention was given to coping with intense local precipitation. In fact, in some cases it was almost entirely neglected. A heavy price was paid for this omission in the summer of 2016.

Lessons learned from the floods

In rural areas, greater emphasis must be placed on more sustainable development, taking account of the local environment. Improvements also need to be made to flood and water management in general. Advanced planning and improved early warning possibilities are essential. Likewise, planning of emergency management measures can – and must be – improved.

In megacities like Wuhan and Beijing, the objective must be to optimise the entire spectrum of disaster prevention and risk reduction measures. This includes not only suitably designed rainwater drainage systems, more efficient early warning capabilities and flood defence measures, but also efforts to ensure a rapid return to normality following a catastrophe. Particular emphasis must be placed on increasing resilience: supply lines and traffic routes must not be left unusable for days, but instead be able to perform their key tasks again within a very short time.

Great potential for insurers

The low proportion of insured losses to overall losses (2%) in the summer of 2016 highlights the enormous gap in cover, despite efforts by the government over the years to promote insurance protection. Often, cover is only found in the industrial sector, primarily at international companies. Very few private households are insured. The reason for this, especially in rural areas, is a lack of financial resources in conjunction with a lack of risk awareness. What's more, most people trust that the government will assist them if they suffer serious personal damage.

There have, however, been some tentative efforts to enhance resilience, with local authorities trying to obtain insurance protection for their communities. In this way, at least some of the losses can be compensated after a disaster, and those affected put in a position from which they can return to a normal life. There is enormous potential and a corresponding need in this regard in China. Thus far, however, there has been very little recognition that this type of insurance is good for everyone concerned. Efforts are still needed to convince people of this, as is greater awareness of what is needed for an insurance solution to be effective. Specifically, this includes hazard maps, claims statistics, and data on value distributions in regions at risk of flooding.

Matthew: A storm of three tales

Hurricane Matthew was the first Atlantic hurricane for almost ten years to reach the highest category 5 status. It caused enormous damage during its passage through the Caribbean and onwards to the United States.

John Hanley and Mark Bove

America

Hurricane Matthew 2016

Haiti: **546 fatalities**

Bahamas: Insured losses of **US$ 600m**

USA: Overall loss of **US$ 5.5bn**, mainly as a result of flooding

After developing from a tropical wave off the west coast of Africa and moving westwards across the Atlantic ocean, Matthew became a tropical storm off the coast of Barbados on 28 September. Despite developing in a region with high vertical wind shear, which ordinarily acts to suppress hurricane intensification, Matthew rapidly intensified over a 36-hour period on 29 and 30 September, ultimately reaching category 5 strength. This rapid intensification can, in part, be explained by high ocean heat content values in the Caribbean during its development, which acted to limit the hurricane's self-induced negative feedback from ocean cooling to favour intensification. Matthew thus became the most southerly (13.3°N) hurricane to reach category 5 strength in the Atlantic.

Losses

After reaching its peak intensity, Matthew deflected to the northwest and reduced in intensity to a category 4 storm. It then tracked northwards close to Jamaica before making landfall over Haiti's southern Tiburon Peninsula and over Cuba's eastern Guantanamo province as a category 4 storm on 4 October. With wind gusts exceeding 250 km/h, prolific rainfall and surge heights exceeding 3 metres, Matthew was the strongest storm to hit Haiti since Hurricane Cleo in 1964. The consequences for Haiti were devastating, especially as the country was still struggling with the effects of the 2010 earthquake.

Matthew weakened to a category 3 storm after passing over Haiti and Cuba. However, on 5 and 6 October, while approaching the Bahamas, Matthew underwent a re-intensification process as it once again encountered areas of high ocean heat content, resuming category 4 strength. The sea surface temperatures and ocean heat content in this section of the Caribbean were close to record highs for this time of the year.

USA spared the worst

The next landfall was on 6 October, when Matthew made landfall on the most populated islands of the Bahamas, becoming the most damaging hurricane to hit the country since Hurricane Frances in 2004. After passing Grand Bahama, Matthew then took a northwesterly path towards the United States. A small deviation westwards would have brought Matthew ashore in Florida and exposed the landfall region to its worst winds, while a more northerly motion would have resulted in Matthew brushing or travelling parallel to the coast for hundreds of miles, potentially damaging a much larger section of US coastline.

Ultimately, Matthew stayed just offshore of the states of Florida and Georgia as it moved around the western periphery of an area of high pressure. This resulted in Matthew's strongest winds remaining offshore, limiting the severity of wind damage. However, the near-parallel motion along the coast aggravated surge flooding to the north of the storm, where easterly winds and storm motion combined to enhance surge heights and destructive wave action along the coast.

During this period, Matthew continued to slowly weaken in intensity as it started to turn northwards, then northeastwards, off the coast of Georgia, ultimately making its final landfall as a minimal category 1 storm near Charleston, South Carolina. Although the winds had decreased significantly, the rainfall associated with Matthew had not. Heavy precipitation, with totals of 300 mm across a large section of North and South Carolina, triggered the worst flooding in the region since Hurricane Floyd in 1999. Once ashore, Matthew started moving faster to the northeast, exited the United States over Cape Hatteras and sped out to sea as an extratropical storm.

Although the Bahamas escaped the full force of the storm, Hurricane Matthew still caused considerable damage.

By the time Matthew had passed, much of southwest Haiti had been reduced to little more than rubble and debris. Tens of thousands were left homeless by the storm in one of the world's poorest countries.

Haiti: Humanitarian crisis

Haiti is one of the poorest countries in the world, with 59% of the population living on less than US$ 2 a day. Weak infrastructure, poor building quality and a lack of strong state institutions, coupled with devastation of the local ecosystem through practices such as large-scale deforestation, leave the population particularly vulnerable to any type of natural disaster.

Destruction by wind and rain

The areas of Haiti that were hit by hurricane Matthew constitute some of its poorest regions. Three departments in the southwest of the country were badly affected by damaging winds gusting up to 250 km/h, with many settlements in these departments experiencing near total destruction of all non-concrete buildings. Other departments were more affected by torrential rainfall, with three-day totals reaching up to 700 mm in places. This torrential rainfall not only caused widespread flooding in these departments, but also triggered deadly landslides which Haiti is particularly vulnerable to as a result of widespread deforestation in recent decades. Official statistics from the Haitian government list 546 deaths, although the true figure is likely to be considerably higher. Figures from the UN estimate that over 2.1 million people (approximately 20% of Haiti's total population) were directly affected by the storm, two thirds of whom were in need of immediate assistance in the aftermath of the event. An estimated 175,000 people were displaced as a result of the storm and were in need of emergency shelter, while over 800,000 people were identified as suffering extreme food insecurity. Crops in the worst-affected areas were more or less completely destroyed. Hurricane Matthew accelerated an existing cholera epidemic in Haiti as drinking water was contaminated as a result of flooding.

Low insurance penetration

Overall losses on the island came to approximately US$ 1.4bn. Only an extremely small portion of this was insured. Haiti is a participant in the Caribbean Catastrophe Risk Insurance Facility (CCRIF) with the Caribbean Development Bank (CDB) paying Haiti's insurance premiums over the past few years in support of Haiti's overall disaster risk management strategy. Haiti will receive US$ 23m as a result of Matthew. This represents the largest payment ever made by the CCRIF. The UN's Office for the Coordination of Humanitarian Affairs (OCHA) set a target of raising US$ 139m in aid for Haiti.

Bahamas: A close shave

A direct hit by a hurricane on the two main islands of New Providence and Grand Bahama is rare. Forecasts in the days leading up to landfall in the Bahamas were predicting a worst-case scenario: a likely direct hit by Matthew as a category 4–5 hurricane on the capital Nassau in New Providence, followed by a subsequent direct hit on the largest settlement in Grand Bahama, Freeport. These two cities combined account for over 75% of the Bahamas' total population of 400,000. Luckily, Nassau was spared such a scenario as the storm track deflected 25 km to the west compared with the original forecast.

Fortunate track deviation from forecast

The images on page 41 show a comparison of Matthew's observed track and modelled wind field with the track and storm surge forecast by the NOAA two days prior to landfall. They illustrate just how lucky Nassau was, as it is situated in the northeast of the island New Providence. Without the observed 25 km deviation in Matthew's path, gusts of up to 230 km/h could have been experienced in Nassau, resulting in much greater storm damage. Nassau actually experienced peak wind speeds of 150 km/h, which is in line with the modelled wind gusts.

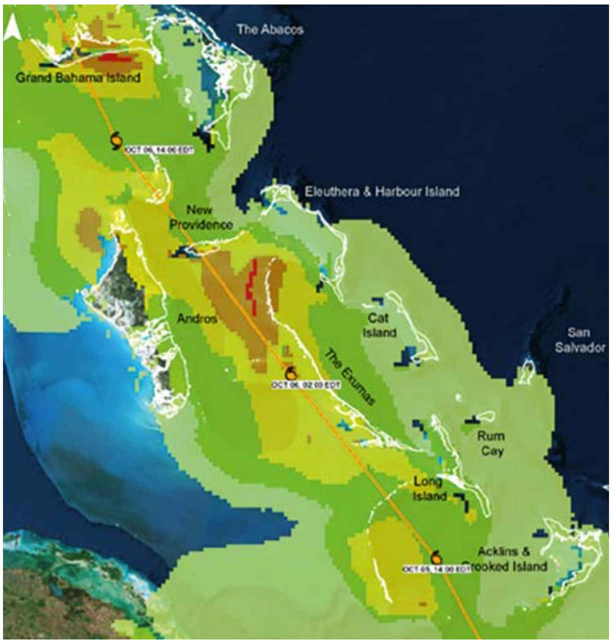
The residents of New Providence and Grand Bahama were fortunate in two other crucial respects. Firstly, instead of the predicted three to four metres, the storm surge was only half a metre to a metre high, penetrating only as far as one kilometre inland. Secondly, unlike in Haiti and Cuba, the Bahamas saw only 100 to 200 mm of rain. There was consequently much less flooding than would have occurred with a category 4 hurricane.

Insured losses overestimated

Initial loss estimates from the risk modelling community two weeks after the event estimated insured losses in the Caribbean in the range of US$ 1–3bn (with the Bahamas accounting for approximately 90% of this figure). Post-event reconnaissance trips by Munich Re to the Bahamas reported insured loss figures of US$ 500–700m for the Caribbean (the Bahamas accounted for US$ 450–600m of this). While such deviations in observed insured losses compared with modelled losses may seem large, they are not surprising when considering that the location of the track and associated wind speeds cannot be precisely known shortly after an event and small deviations in either can lead to highly diverging loss estimates.

Forecast and reality

The path and storm surge levels that the NOAA predicted 48 hours before landfall in the Bahamas would have indeed caused enormous losses.

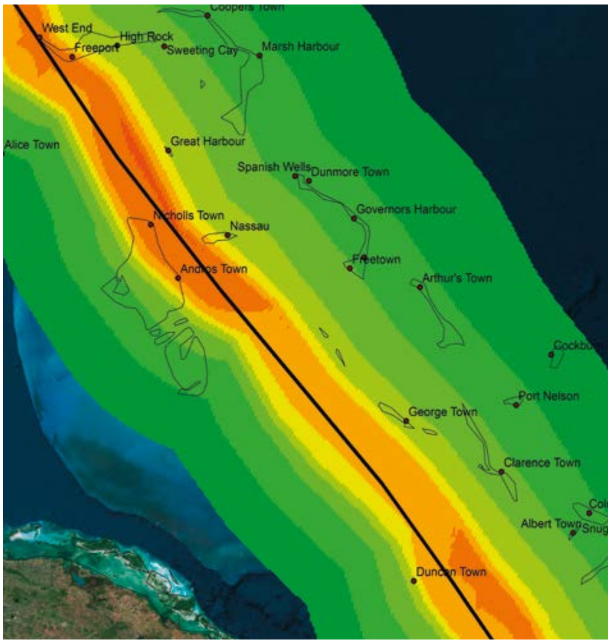


- 1–3 ft
- 3–6 ft
- 6–9 ft
- 9–12 ft
- 12–15 ft
- 15–20 ft
- >20 ft

1 ft = 0.3048 m

After Matthew had passed, Munich Re calculated the peak wind speeds (three-second gusts) on the basis of the observed wind field.

Source: Pacific Disaster Center



- ≤100 km/h
- 101–125 km/h
- 126–150 km/h
- 151–175 km/h
- 176–200 km/h
- 201–225 km/h
- 226–250 km/h
- ≥251 km/h

Source: Munich Re, based on H-Wind data (RMS)

USA: Storm surge and rain drive up losses

Since the strongest winds associated with a tropical cyclone in the northern hemisphere are on the right-hand side of the eye (with respect to forward motion), Matthew's track – just offshore and parallel to the Florida coast – kept the storm's strongest winds out to sea. However, Matthew's near-miss exposed over 250 miles of Florida's east coast to damaging winds, with localised gusts exceeding hurricane force.

Protective measures effective

Most of the wind damage was light, consisting of lost shingles and siding. Only older buildings, not subject to Florida's strict wind codes, occasionally showed signs of more severe wind damage to their roofs. In Georgia and the Carolinas, wind damage was primarily limited to tree-fall damage that was exacerbated by torrential rains loosening root systems.

Matthew's strong winds pushed Atlantic waters ashore ahead of its path, generating surge flooding, damaging waves, and coastal erosion in Florida from Cape Canaveral northwards. The worst surge damage was centralised around the barrier islands near St. Augustine, Florida, some low-lying back bay communities on these barrier islands received upwards of one metre of surge flooding in their homes. Some houses collapsed and others had to be condemned due to the safety risk. However, the extent and severity of Matthew's surge was less than that experienced along the Florida east coast in Hurricanes Frances and Jeanne in 2004.

Coastal and inland flooding

More damaging were the torrential amounts of rain that Matthew dropped across the southeastern United States, which triggered widespread flooding in both North and South Carolina. Ample tropical moisture from a record-warm western Atlantic, combined with a slow rate of storm motion and the development of a frontal boundary along the Carolina coast, generated rainfall totals in excess of 150 mm over the eastern half of the Carolinas, with rainfall totals in excess of 250 mm common in a swathe from Myrtle Beach, South Carolina, northeastwards to Norfolk, Virginia. The rapid rise of local rivers devastated local communities, and it would take weeks for water levels in this low-lying region to return to normal.

Hurricane damage less than expected

For the USA, initial loss estimates from the risk modelling community were in the range of US$ 1–4bn. Post-event reconnaissance trips by Munich Re to Florida and the Carolinas indicated that insured losses (excluding those covered by the National Flood Insurance Program, NFIP) would be well below the US$ 4.5bn insured loss (original dollars) from 2004's Hurricane Frances. Reports by Property Claims Services in early 2017 of a US$ 2.8bn insured loss from Matthew further validated this viewpoint. Claims to the NFIP are likely to add an additional several hundred million to this total. However, compared with the storms of 2004 and 2005, Matthew was a minor event for the United States, and was easily handled by the US insurance market.

A devastating domino effect

In 2016, just four years after the severe earthquake sequence that struck the Emilia-Romagna region in northern Italy, it was central Italy's turn to be hit.

Marco Stupazzini

Italy
Earthquakes 2016
Overall losses: **US$ 11bn**
Insured losses: **US$ 220m**
Earthquake losses in Italy since 2000:
Overall: **US$ 37bn***
Insured: **US$ 2bn**
(*in 2016 values)

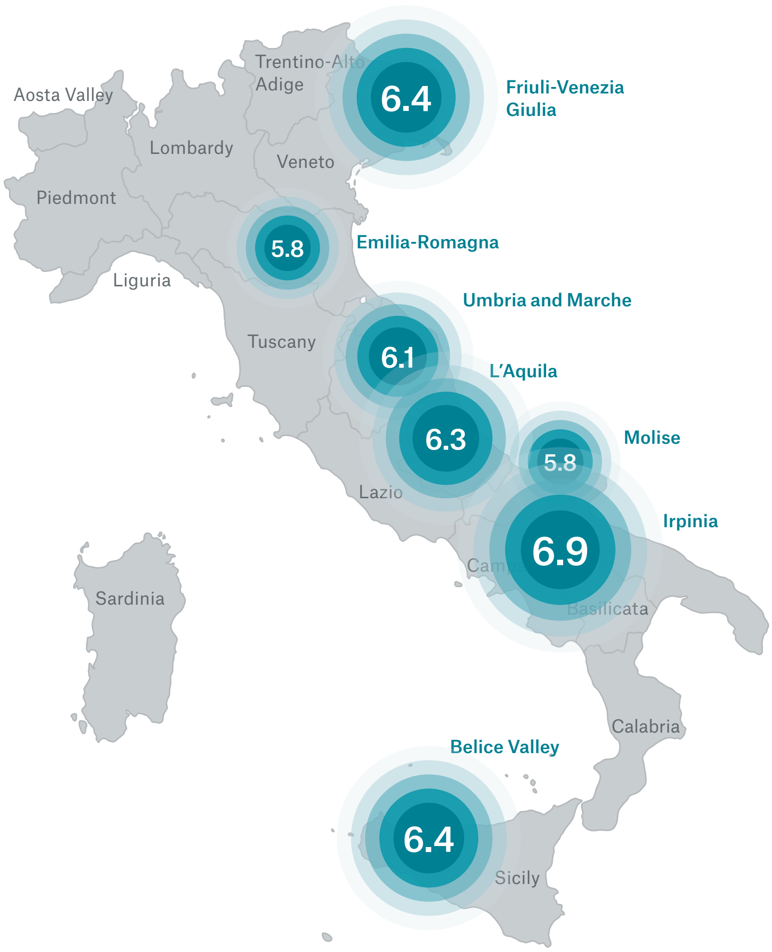
In the early hours of 24 August, the historic old town of Amatrice (with a population of some 2,500) and other villages in the Apennine Mountains in central Italy were struck by a magnitude 6.0 earthquake in which 299 people lost their lives. It was followed by a further (magnitude 5.9) quake on 26 October and a large number of smaller tremors that added to the destruction found throughout the region. The sequence peaked in Norcia on 30 October with a magnitude 6.5 earthquake, the largest in Italy for 36 years. The extensive evacuations that had taken place since the end of August and the fear of aftershocks are the likely reasons that no further lives were lost in this quake. By way of comparison, a 6.7 magnitude earthquake that struck the town of Avezzano, 100 km to the southeast, claimed the lives of some 30,000 people in 1915, while almost 3,000 died in the 6.9 magnitude quake in Irpinia, 250 km to the southeast, in 1980.

Hidden fault lines

Ross Stein of the United States Geological Survey (USGS) said that, since the L'Aquila earthquake in 2009, other tremors have followed like falling dominoes heading in a northwesterly direction. According to Stein, earthquakes in Italy tend to occur in groups or sequences, presumably because the underlying faults are under a million years old, making them relatively young in geological terms. For that reason, there is very little evidence on the surface that would allow geologists to map these faults. Most of them are therefore described as "blind faults". Despite these difficulties, the Istituto Nazionale di Geofisica e Vulcanologia has collected data on 300 georeferenced faults in its Database of Individual Seismogenic Sources (DISS). This information can be used to assess regional and national seismic hazards.

Italy's most powerful earthquakes of the last 50 years

Earthquakes cost Italy many billions of euros. Around €120bn in today's values was required to repair damage from the seven most costly quakes since 1968.



Costliest earthquakes in Italy by overall losses

Earthquake (M_W = moment magnitude)			Costs adjusted for inflation (in €bn, in 2014 values)
1968	M_w 6.4	Belice Valley	9.2
1976	M_w 6.4	Friuli-Venezia Giulia	18.5
1980	M_w 6.9	Irpinia	52.0
1997	M_w 6.1	Umbria and Marche	13.5
2002	M_w 5.8	Molise	1.4
2009	M_w 6.3	L'Aquila	13.7
2012	M_w 5.8	Emilia-Romagna	13.3

Source: Consiglio Nazionale Ingegneri (CNI)

The Italian government estimates losses from the 2016 earthquake sequence of €23.5bn (US$ 26bn). According to Munich Re estimates, the actual physical damage amounts to €10bn (US$ 11bn). Even today, insurance penetration in this part of Italy is very low for earthquake risk, in particular as regards residential buildings. The loss pattern once again highlights the fact that central Italy is characterised by the unfavourable combination of high seismic risk and large numbers of historic buildings, as demonstrated by the partial collapse in 2016 of the late-14th-century San Benedetto basilica in Norcia. In 1997, a magnitude 6.1 earthquake that struck the Colfiorito basin (approx. 30 km north of Norcia) caused widespread and severe damage. The arched ceiling in the Upper Basilica of Saint Francis in Assisi was one of the structures unable to withstand the shaking at that time. Reconstruction and restoration of the historic city centre is still ongoing in L'Aquila (50 km south of Amatrice), which was shaken by a magnitude 6.3 earthquake in 2009.

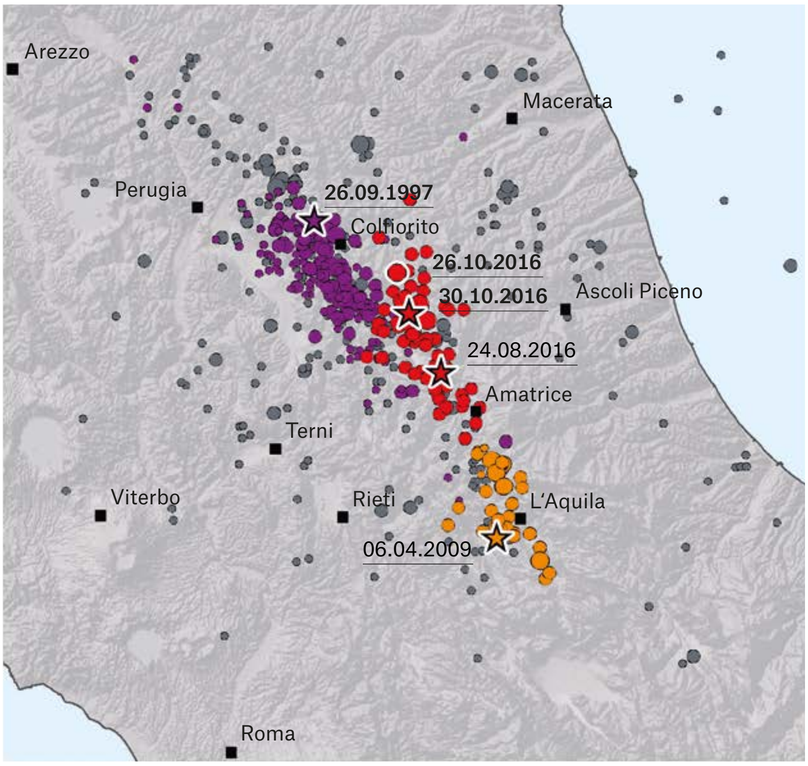
Costly reconstruction

In 2014, the Italian Consiglio Nazionale Ingegneri (CNI) presented a study on the costs of earthquakes, assessing data going back to 1968. It estimates that the country has spent approximately €120bn (in 2014 values) over the last 50 years or so on post-quake reconstruction. This equates to €2.4bn per year. It would cost just under €94bn to make Italy's entire private building stock more resistant to earthquakes. Although no level of investment can prevent occasional serious damage, it could at least help to save lives and reduce economic losses as, for example, in Norcia in the 30 October earthquake. Following the Amatrice earthquake, the Italian government launched the "Casa Italia" project. It is intended to enhance earthquake protection

Old buildings with no earthquake resistance of any kind often collapse like a house of cards.

The sequence of dominoes in central Italy

The epicentres of the earthquakes in the Apennines spread out in a line like a string of pearls. It is only a question of time before the next disaster occurs. The ideal conditions are in place, with a high level of risk in conjunction with a building stock that is old and unstable.



Magnitude
○ 3.0–3.9
○ 4.0–4.9
○ 5.0–5.9
☆ ≥6.0

● Amatrice and Norcia earthquake series in 2016
● L'Aquila earthquake series in 2009
● Umbria and Marche earthquake series in 1997
● Earthquakes in central Italy, 1997–2016

Source: Munich Re, based on USGS

throughout the country, and will require major efforts over the next few decades. Following the devastating Irpinia earthquake of 1980, the late Professor Giuseppe Grandori called for renewed efforts in this area. He pointed out that, if no systematic plan was put in place to retrofit buildings, a greater level of seismic safety would automatically be achieved over the years – since historic, non-retrofitted buildings would be gradually wiped out by earthquakes. We can only hope that the government is serious about investing in earthquake safety, because the statistics are clear: even if we do not know exactly where or when, further earthquakes are certain to strike.

Multi-fault rupture in Kiwi quake

In mid-November, New Zealand was hit by its strongest earthquake in decades. At least nine different faults ruptured but, despite the magnitude of the quake, losses were limited.

Marco Stupazzini

New Zealand
Earthquake 2016
Overall losses: **US$ 3.9bn**
Insured losses: **US$ 2.1bn**
Earthquake series in 2010/2011
Overall losses: **US$ 37bn**
Insured losses: **US$ 26bn**
Percentage of natural disaster losses caused by earthquakes since 2010: **96%**

On 14 November 2016, six years after the start of the earthquake sequence that devastated the city of Christchurch, New Zealand was again hit by a severe quake with a moment magnitude of 7.8. It was the country's strongest tremor since the Wairarapa earthquake back in 1855 (magnitude 8.2–8.3). The area hardest hit was between Christchurch and Wellington, in the northeastern part of New Zealand's South Island. In spite of the magnitude of the quake, just two lives were lost. The low population density in the epicentral region provides one explanation for this. Furthermore, New Zealand is known for its experience with earthquake-resistant structures, and has a modern building code that has been in force for many years.

According to the New Zealand Institute of Geological and Nuclear Sciences (GNS Science), the quake did not take place along a single fault. Instead, at least nine separate faults ruptured, some of which, like the Waipapa Bay fault, were previously unknown. The greatest displacement occurred along the Kekerengu fault, which was already known to geologists. The picture of one house that sat right on the fault (page 48, top) shows just how powerful the earth movement was, and how much it altered the landscape. The fault line now visible on the surface (page 48, bottom) is reminiscent of Hadrian's Wall, close to the border between Scotland and England, which once marked the northern limit of the Roman Empire.

The fault ruptured north of the epicentre, generating the strongest ground shaking in the village of Ward, with peak ground acceleration (PGA) of 1.3 times the acceleration due to Earth's gravity, "g". PGAs exceeded 0.2 g in parts of the capital, Wellington, and in Lower Hutt, while values were lower in Christchurch. In Wellington, the peak acceleration was similar to that generated by the Seddon earthquake on 21 July 2013 (magnitude 6.5), although this time an unusual damage pattern was observed: whereas low-rise buildings sustained only slight damage, mid-rise buildings suffered severe damage.

The ground was displaced several metres by the quake. The fault scarp, up to three metres high in some places, looks like a stone wall in the midst of the landscape.

The main reason for this phenomenon is related to the long-period ground motion components. On this occasion, they were significantly higher than would normally be expected for such a PGA value. This is understandable to a degree if one considers the magnitude of the quake and the northerly directivity of the radiation of energy. Nevertheless, the key question is why buildings of a particular size (ten to fifteen floors) proved so vulnerable to the tremors.

One positive aspect is that unreinforced masonry buildings that had been retrofitted for seismic events performed well in the quakes. Given the high insurance density and the proximity of towns and cities such as Blenheim, Wellington and Christchurch, all of which are found in potential damage zones, the insured losses – while significant – are much lower than those reported during the 2010–2011 Christchurch earthquake sequence.

Based on the present level of knowledge, it is impossible to say whether the likelihood of another large earthquake in the Wellington area has risen or fallen. It is perhaps worth noting that several major earthquakes have struck New Zealand since the 2009 Dusky Sound earthquake (magnitude 7.8) in Fiordland. This was also the case in the period between 1848 and 1942, when the country was hit by a number of earthquakes with magnitudes greater than 7.0. Despite this, it is impossible to forecast whether the next few decades will see greater seismic activity than in the period mentioned above. However, experience in New Zealand demonstrates that awareness of seismic risk, combined with the right provisions, is the only way to more effectively manage the risks posed by earthquakes.

NatCatSERVICE

Natural catastrophe expertise for risk management and research

Many decades of experience acquired in researching, documenting, analysing and evaluating natural catastrophes have made the NatCatSERVICE one of the world's most valued data sources for information on natural loss events. This unique archive provides comprehensive, reliable and professional data on insured, economic and human losses caused by any kind of natural peril.
Munich Re – **NOT IF, BUT HOW**

Start Analysis

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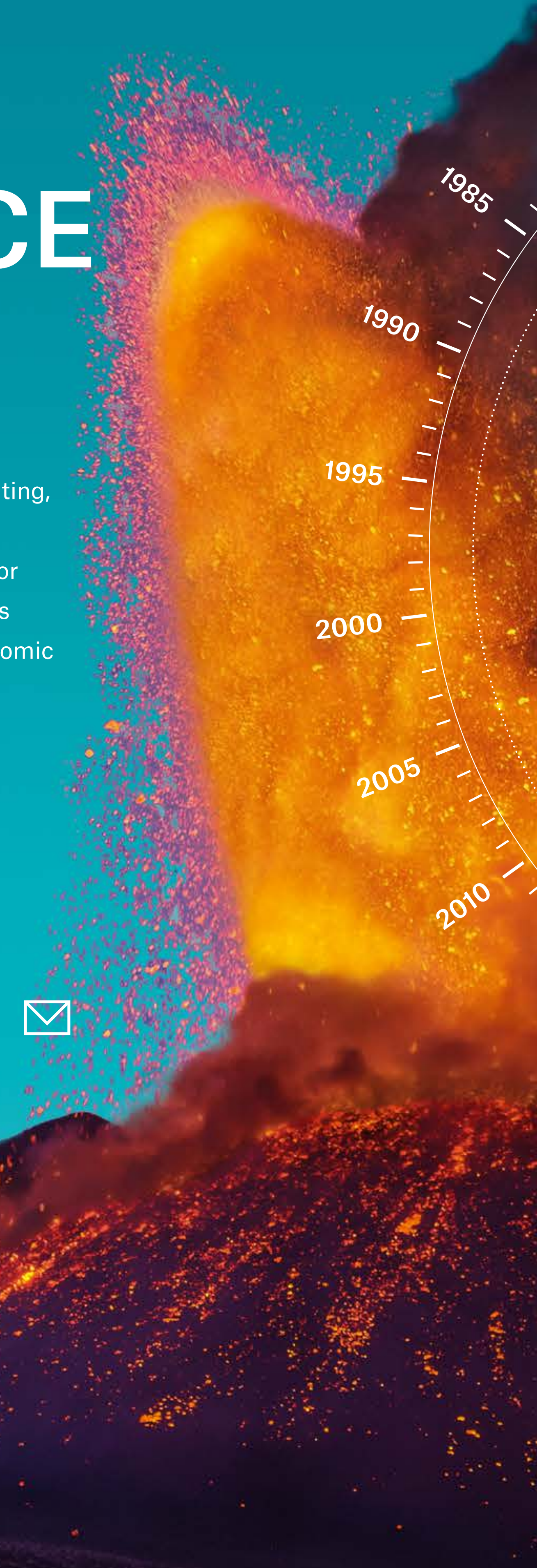


The NatCatSERVICE goes online

Petra Löw

The NatCatSERVICE is opening its archives. A new interactive online tool now offers information, analyses and statistics on the development of natural catastrophe losses over recent decades. This will make it even easier to get hold of extensive and detailed information from Munich Re on the whole spectrum of natural hazards and natural disasters.

For many years now, Munich Re has been offering extensive material on natural hazards and disasters, not only for risk managers in the insurance and finance industries, but also for research institutions and interested members of the public. We do this by making information available online in our comprehensive download library. In the area of Geo Services, NATHAN provides a worldwide overview of exposure zoning for earthquakes, windstorms, flooding and forest fires.

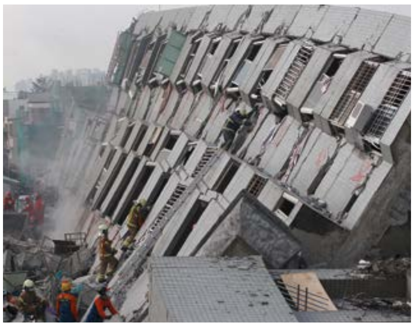
In addition to this information, the NatCatSERVICE now offers an interactive analysis tool. In future, it will be possible for users to produce their own analyses of loss data on natural catastrophes going back as far as 1980. The analysis tool presents the results in the form of frequency statistics, loss-amount diagrams, pie charts and tables. A download function enables the presentations to be comfortably downloaded in PDF format.

The main purpose of the tool is to display loss information and to make the material easy to use, and the NatCatSERVICE never stops working on its database methodology, for example inflation-indexing and normalisation of losses from historical events. Our focus is increasingly towards analysing the significance of loss events in specific regions of the world. The insights gained from such analyses can, for example, help countries take decisions on resilience measures needed in the aftermath of natural catastrophes, with the ratio of insured to uninsured losses a key factor. The worldwide distribution of losses shows considerable differences in the extent to which individual countries are in a position to cope with the burden of natural disasters (see pages 60 and 61).

>> Visit our website at www.munichre.com/en/natcatservice

The year in pictures

22–24 January
Winter storm: USA
Overall losses: US$ 550m
Insured losses: US$ 240m
Fatalities: 50



5 February
Earthquake: Taiwan
Overall losses: US$ 700m
Insured losses: US$ 370m
Fatalities: 117

March to December
Drought: Bolivia
Overall losses: US$ 450m
Insured losses: very minor
Fatalities: none

1 May–4 July
Wildfires: Canada
Overall losses: US$ 4,000m
Insured losses: US$ 2,900m
Fatalities: none

31 May–7 June
Severe storms, flash floods: Germany
Overall losses: US$ 2,000m
Insured losses: US$ 830m
Fatalities: 7

18 June–13 July
Floods: China
Overall losses: US$ 20,000m
Insured losses: US$ 520m
Fatalities: 237

24 August
Earthquake: Italy
Overall losses: US$ 5,000m
Insured losses: US$ 75m
Fatalities: 299

13–15 September
Typhoon Meranti: China, Philippines, Taiwan
Overall losses: US$ 3,400m
Insured losses: US$ 570m
Fatalities: 31

28 September–9 October
Hurricane Matthew: Caribbean, USA
Overall losses: US$ 9,700m
Insured losses: US$ 3,400m
Fatalities: 601

10–15 April
Severe weather, hailstorm: USA
Overall losses: US$ 3,900m
Insured losses: US$ 3,000m
Fatalities: none

14 and 16 April
Earthquakes: Japan
Overall losses: US$ 31,000m
Insured losses: US$ 6,000m
Fatalities: 69

16 April
Earthquake: Ecuador
Overall losses: US$ 2,000m
Insured losses: US$ 560m
Fatalities: 673

8–10 July
Typhoon Nepartak: China, Philippines, Taiwan
Overall losses: US$ 1,500m
Insured losses: minor
Fatalities: 87

15 July–12 September
Flooding, flash floods: India
Overall losses: US$ 350m
Insured losses: minor
Fatalities: 254

11–15 August
Flooding, flash floods: USA
Overall losses: US$ 10,000m
Insured losses: US$ 2,500m
Fatalities: 13

19–21 October
Typhoon Haima: China, Philippines
Overall losses: US$ 950m
Insured losses: minor
Fatalities: 16

13 November
Earthquake: New Zealand
Overall losses: US$ 3,900m
Insured losses: US$ 2,100m
Fatalities: 2

7 December
Earthquake: Indonesia
Overall losses: US$ 100m
Insured losses: very minor
Fatalities: 104

Source: Munich Re NatCatSERVICE

The year in figures – Global

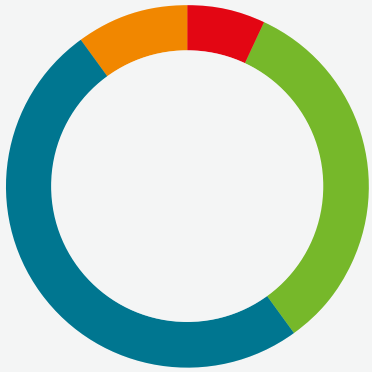
After three relatively moderate years, the overall loss amount in 2016 climbed to US$ 175bn, a level last seen in 2012. Once overall losses since 1980 are adjusted for inflation, 2016 comes in as one of the ten costliest years on record. North America and Asia had to bear particularly high claims burdens, making up 84% of the overall loss amount. The worldwide loss amount borne by insurers came to US$ 50bn, making 2016 the fifth-costliest year for the industry since 1980. The average insured loss for the last ten years is approximately US$ 45bn, and US$ 34bn for the last 30 years. As with overall losses, North America and Asia also accounted for the bulk of insured losses. The trend of an increasing number of registered events worldwide has continued, which is primarily the result of improved reporting options. Munich Re categorised 750 events as relevant natural catastrophes and included them in the event statistics. This is significantly more than the average for both the last ten years (590) and the last 30 years (470). At approximately 9,200, the number of fatalities was much lower than the previous year's figure of 25,400, and also below the 10-year average of 60,600. So, with the exception of 2014, when there were 8,050 fatalities, 2016 saw the fewest fatalities in more than 30 years.

Number of events

Munich Re's NatCatSERVICE recorded around 1,900 loss events in 2016. Following last year's change to the threshold for inclusion in our statistics, 750 of these were classified as relevant, 130 (17%) of which were very severe and severe disasters. The remaining 83% were moderate and minor loss events.

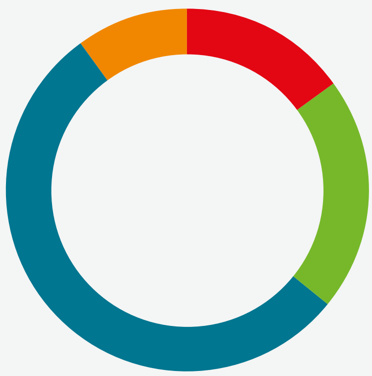
Distribution according to "peril groups" was markedly different in 2016, with significant changes in the figures for windstorms and floods compared with previous years. For example, 33% of all events recorded were meteorological events, some way below the long-term average of 40% for the period 1980 to 2015. By contrast, the number of hydrological events increased from 39% to 50%; in other words river flooding, flash floods and mass movement accounted for half of all relevant events worldwide in the past year. 7% of all events were geophysical. This matches the value of the previous year and deviates only slightly from the long-term average. 10% were climatological events. This also corresponds to the level of the last few years.

Events: 750
Percentage distribution



Geophysical events	7%
Meteorological events	33%
Hydrological events	50%
Climatological events	10%

Fatalities*: 9,200
Percentage distribution



Geophysical events	15%
Meteorological events	21%
Hydrological events	54%
Climatological events	10%

* Fatalities do not include famine victims or people missing

Source: Munich Re NatCatSERVICE

Fatalities

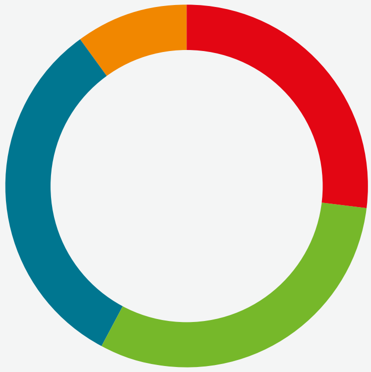
Almost 60% of the fatalities in natural catastrophes were in Asia. The countries mainly affected were China, India and Pakistan, where protracted rainfall led to extensive flooding that ultimately claimed the lives of almost 2,400 people. The two deadliest events of the last year were an earthquake in Ecuador in which 673 people died, and Hurricane Matthew, which caused tremendous damage in the Caribbean and the USA in late September/early October. Around 600 people were killed, most of them on Haiti. In Italy, 299 people died in a severe earthquake in August.

Losses

Of the US$ 175bn in overall losses, 27% came from geophysical events, including the costliest natural disaster of the year – the earthquake in Japan in mid-April, which struck close to the city of Kumamoto on the island of Kyushu. It resulted in an overall loss of US$ 31bn, of which the insurance industry bore US$ 6bn. Further claims burdens in the billions resulted from earthquakes in Italy and New Zealand. 31% of overall losses were caused by meteorological and 32% by hydrological events. Major contributors were floods in the USA, Europe, and in China. Along with the claims burden from Hurricane Matthew and the earthquake in Japan, they represent the five costliest events in 2016. 10% of losses are attributed to climatological events. Forest fires in Canada, months of drought in China and India, and winter losses in eastern Asia all left their mark. Overall, last year saw 32 events with losses of at least US$ 1bn. These include severe weather with hailstorms and flash floods in the USA and Europe, as well as typhoons in China, Taiwan and the Philippines. They were responsible for approximately 70% of the total loss amount.

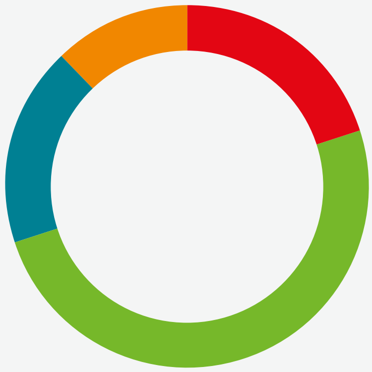
If insured losses are subtracted from overall losses, the insurance gap comes to US$ 125bn. Storms were responsible for half of all insured losses, with floods accounting for 18% and earthquakes for 20%, and droughts and other climatological events for 12%. 14 separate events each cost insurers US$ 1bn or more. They included the earthquakes in Japan and New Zealand, as well as four hailstorms in the USA. 62% of insured losses occurred in the USA, with only 21% in Asia, and 11% in Europe.

Overall losses: US$ 175bn
Percentage distribution



Geophysical events	27%
Meteorological events	31%
Hydrological events	32%
Climatological events	10%

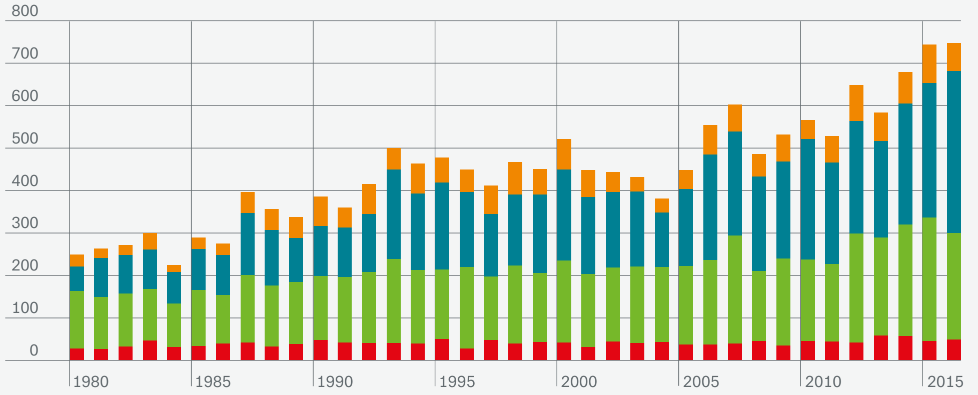
Insured losses: US$ 50bn
Percentage distribution



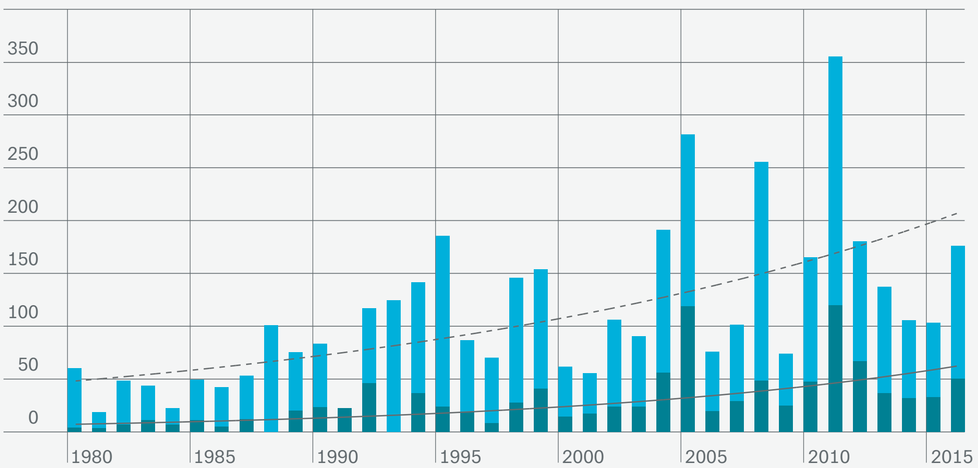
Geophysical events	20%
Meteorological events	50%
Hydrological events	18%
Climatological events	12%

Source: Munich Re NatCatSERVICE

Number of loss events 1980–2016

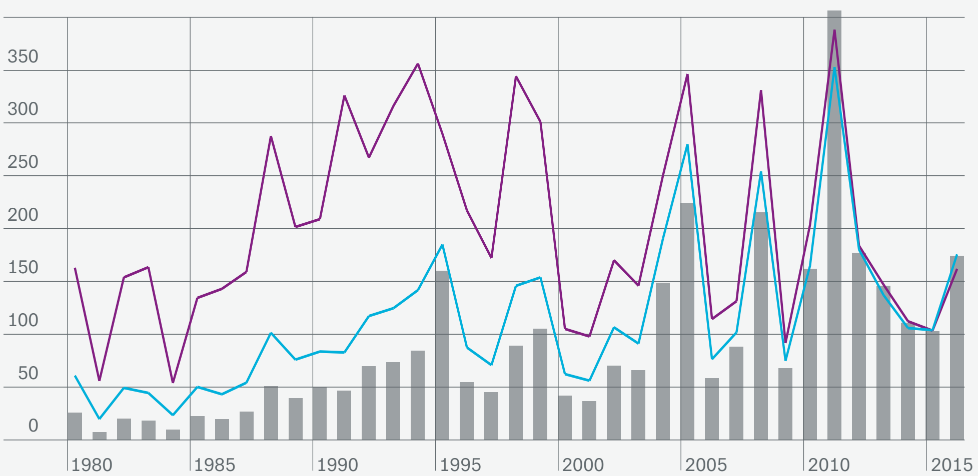


Overall losses and insured losses 1980–2016 (in US$ bn)



* Losses adjusted for inflation using the consumer price index (CPI) of each country and taking into account fluctuations in exchange rates.

Loss events worldwide 1980–2016



Adjusted for inflation using the consumer price index (CPI) of each country, and taking into account fluctuations in exchange rates against the US dollar.

Normalisation taking into account local changes in GDP measured in US$.

Source: Munich Re NatCatSERVICE

The year in figures – Regional

North America

The continent of North America, including Central America and the Caribbean, accounted for 22% of all loss events and 12% of all fatalities. This is in line with the long-term average. In terms of loss amount, however, there were slight deviations from the average. For example, 33% of overall losses and 60% of insured losses were recorded in North America, representing declines of 8% and 4% respectively. Overall losses came to US$ 52bn, of which US$ 29bn was insured. 13 events either reached or exceeded the billion-dollar threshold. The costliest disaster on the North American continent was Hurricane Matthew, which tore a swathe of destruction across the Caribbean and all the way up to South Carolina. Haiti was the worst affected, with almost 550 lives lost in this one event. The total number of fatalities exceeded 601, making the hurricane the world's second-deadliest event in 2016. In August, torrential rainfall caused flooding and flash floods in Louisiana and Mississippi. Overall losses amounted to US$ 10bn, of which around a quarter was insured. In the Canadian province of Alberta, large-scale forest fires raged from May to July, leaving in their wake damage amounting to US$ 4bn, of which US$ 2.9bn was insured. It ranks as the worst natural catastrophe in Canadian history.

South America

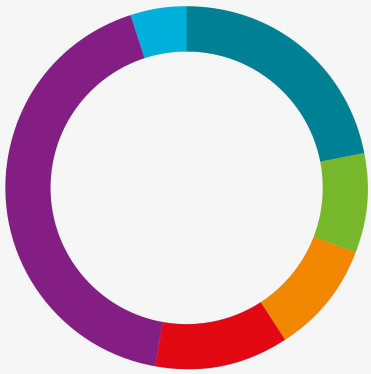
9% of global loss events were recorded in South America. They included the deadliest event of the year – an earthquake in Ecuador with 673 fatalities. The quake struck on 16 April, causing overall losses of US$ 2bn, of which US$ 560m was insured. The continent, and Argentina in particular, was also hit by severe floods. Overall losses came to more than US$ 1bn, with only a small portion insured. Bolivia suffered from a serious shortage of rainfall in 2016, resulting in drought losses for its agriculture of almost US$ 500m dollars.

Europe

Europe accounted for 10% of events, 5% of fatalities, 10% of overall losses, and 11% of insured losses worldwide. Particularly in terms of losses, 2016 therefore deviates from the long-term comparison since 1980. The averages are 3% for overall losses, and around 5% for insured losses. The overall loss from five catastrophes exceeded US$ 1bn in each case. The costliest events were the two earthquakes in Italy at US$ 5bn and US$ 6.5bn respectively. Europe was also gripped by severe storms for several weeks, which were assisted by a stationary weather pattern that remained over the continent for a protracted period. The outcome was extensive floods in France and severe flash floods in Germany. The accumulated losses came to US$ 6bn, of which half was insured.

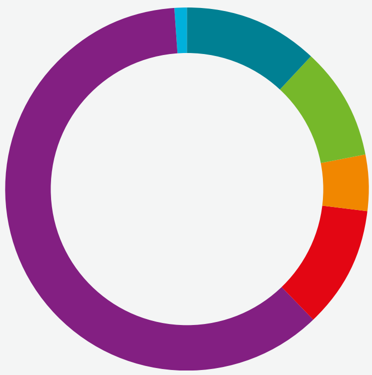
Loss events 2016
Percentage distribution by continent

Number of events: 750



North America, Central America, Caribbean	22%
South America	9%
Europe	10%
Africa	12%
Asia	42%
Australia/Oceania	5%

Fatalities*: 9,200



North America, Central America, Caribbean	12%
South America	10%
Europe	5%
Africa	11%
Asia	61%
Australia/Oceania	1%

* Fatalities do not include famine victims or people missing

Source: Munich Re NatCatSERVICE

In June, a violent hailstorm passed over Germany and the Netherlands. It caused an overall loss of US$ 1.9bn. Here too, almost 50% of the loss was insured.

Africa

A total of 90 relevant loss events were recorded for the continent of Africa. This corresponds to roughly 12% of global events. Weather-related disasters were the main loss events, with just four small earthquakes recorded that caused minor damage. Ethiopia was hit by extensive floods in April and May, while Sudan was also affected from June to September. In total, loss events in Africa in 2016 claimed the lives of over 1,000 people. This corresponds to 11% of all fatalities from natural catastrophes worldwide. 2016 was an extremely dry year in southern Africa, with drought losses in the millions. International aid was needed to provide sufficient food for the population.

Asia

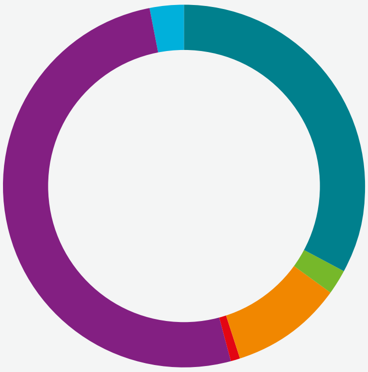
Asia suffered greatly from natural disasters in 2016 – 61% of all fatalities worldwide (some 5,000 people in total) and 51% of all losses. The year's two costliest events – the earthquake in Japan with losses of US$ 31bn and the floods in China with losses of US$ 20bn – were among the 11 events in Asia that exceeded the US$ 1bn mark. Overall losses from a total of 320 events came to US$ 87bn, with insured losses at only US$ 10bn, accounting for 20% of all insured losses worldwide. This means that losses in Asia totalling US$ 77bn were uninsured.

Australia/Oceania

The region comprising Australia, New Zealand and the Pacific island states accounted for just 5% of loss events worldwide. This is in line with the long-term average. Around 90 people lost their lives. The most serious event occurred in New Zealand on 13 November, when an earthquake with a magnitude of 7.8 struck the province of Canterbury, with losses of US$ 3.9bn. Some US$ 2.1bn of this was insured. The region was also hit by tropical cyclones. For example, Cyclone Winston caused losses of around US$ 600m and 44 fatalities in Fiji. A winter storm struck the east coast of Australia. The accompanying storm surge and flash floods resulted in losses totalling US$ 500m, US$ 310m of which were insured.

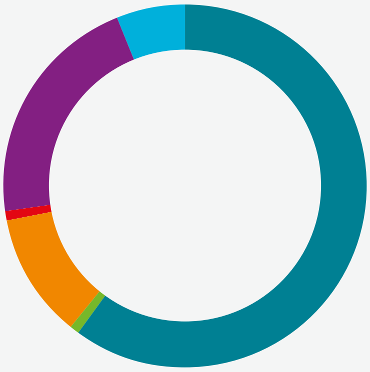
Loss events 2016
Percentage distribution by continent

Overall losses: US$ 175bn



North America, Central America, Caribbean	33%
South America	2%
Europe	10%
Africa	1%
Asia	51%
Australia/Oceania	3%

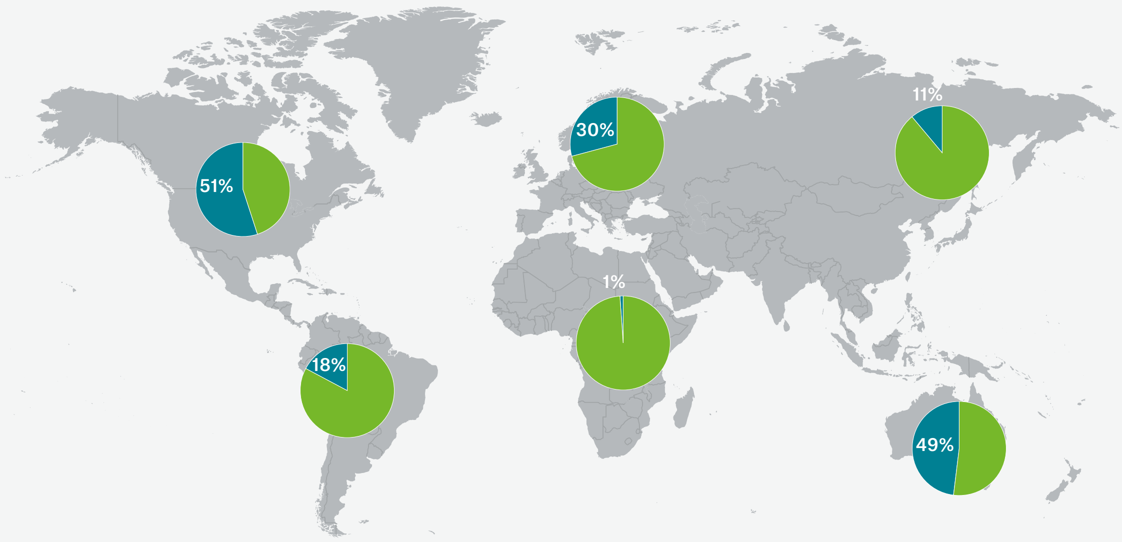
Insured losses: US$ 50bn



North America, Central America, Caribbean	60%
South America	1%
Europe	11%
Africa	<1%
Asia	21%
Australia/Oceania	6%

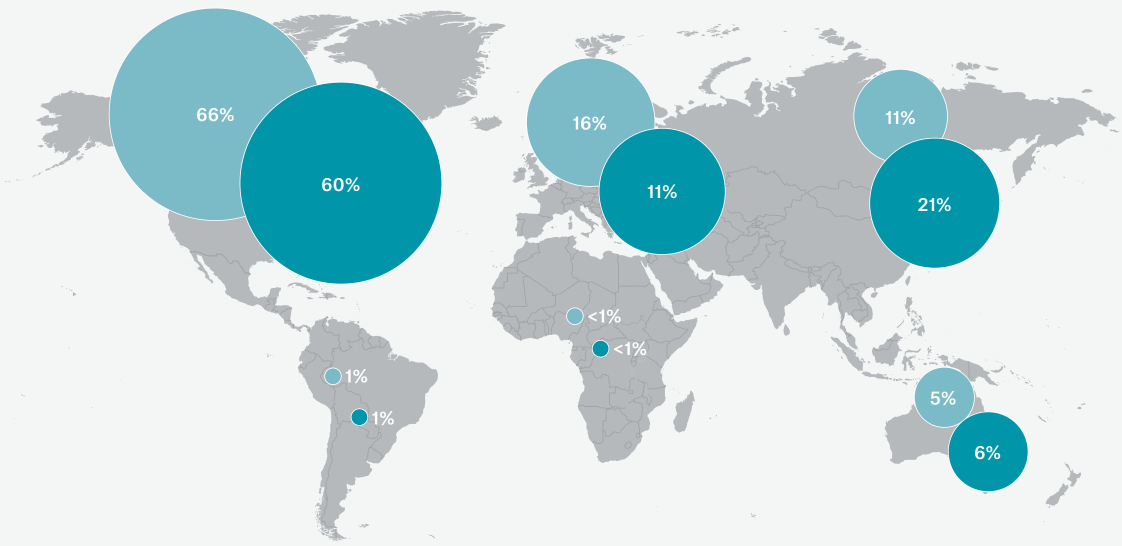
Source: Munich Re NatCatSERVICE

Loss events 2016
Insured losses as a percentage of overall losses for each continent



Uninsured losses
Insured losses

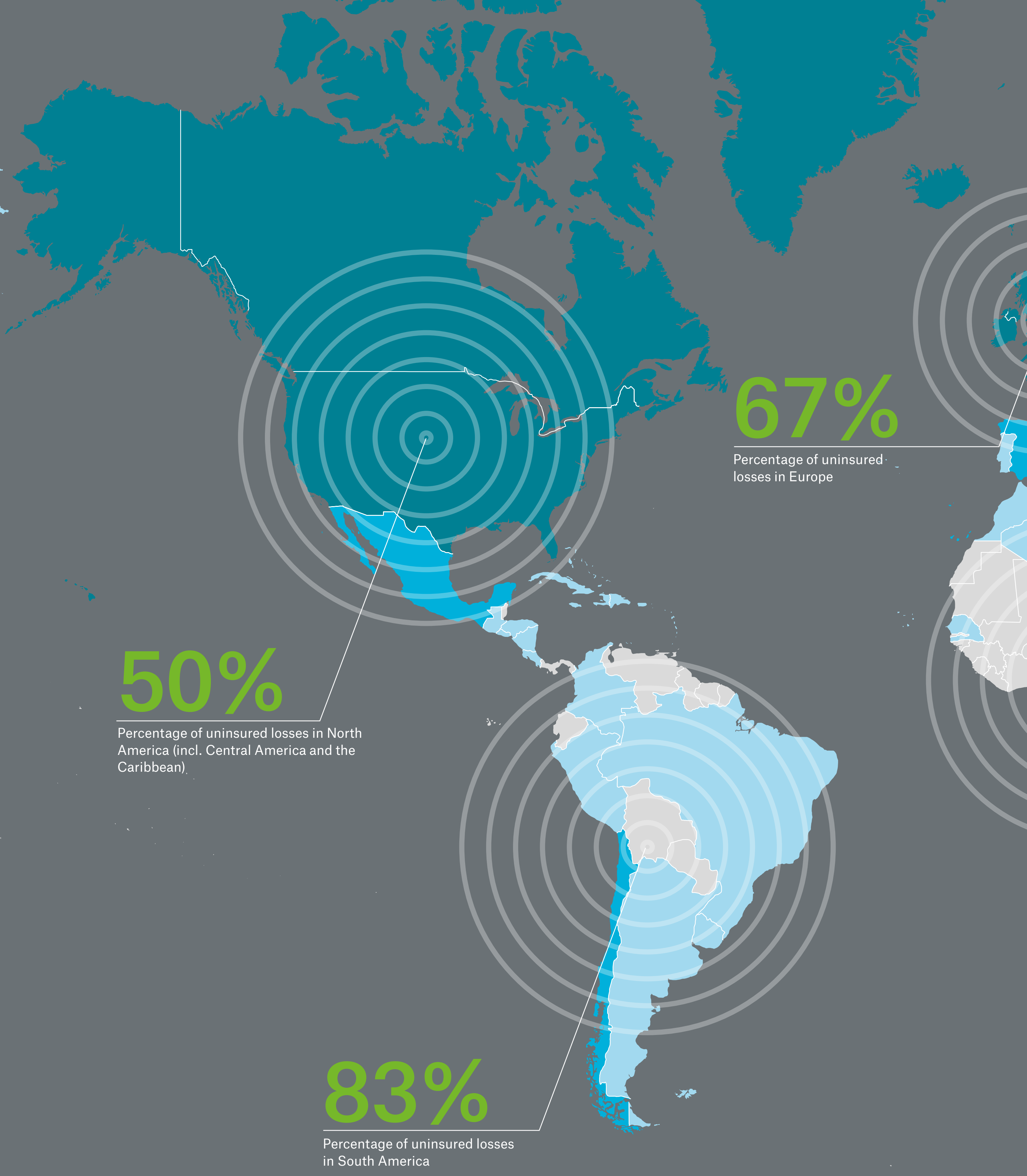
Loss events 2016 compared to 1980–2015
Breakdown of global insured losses by continent

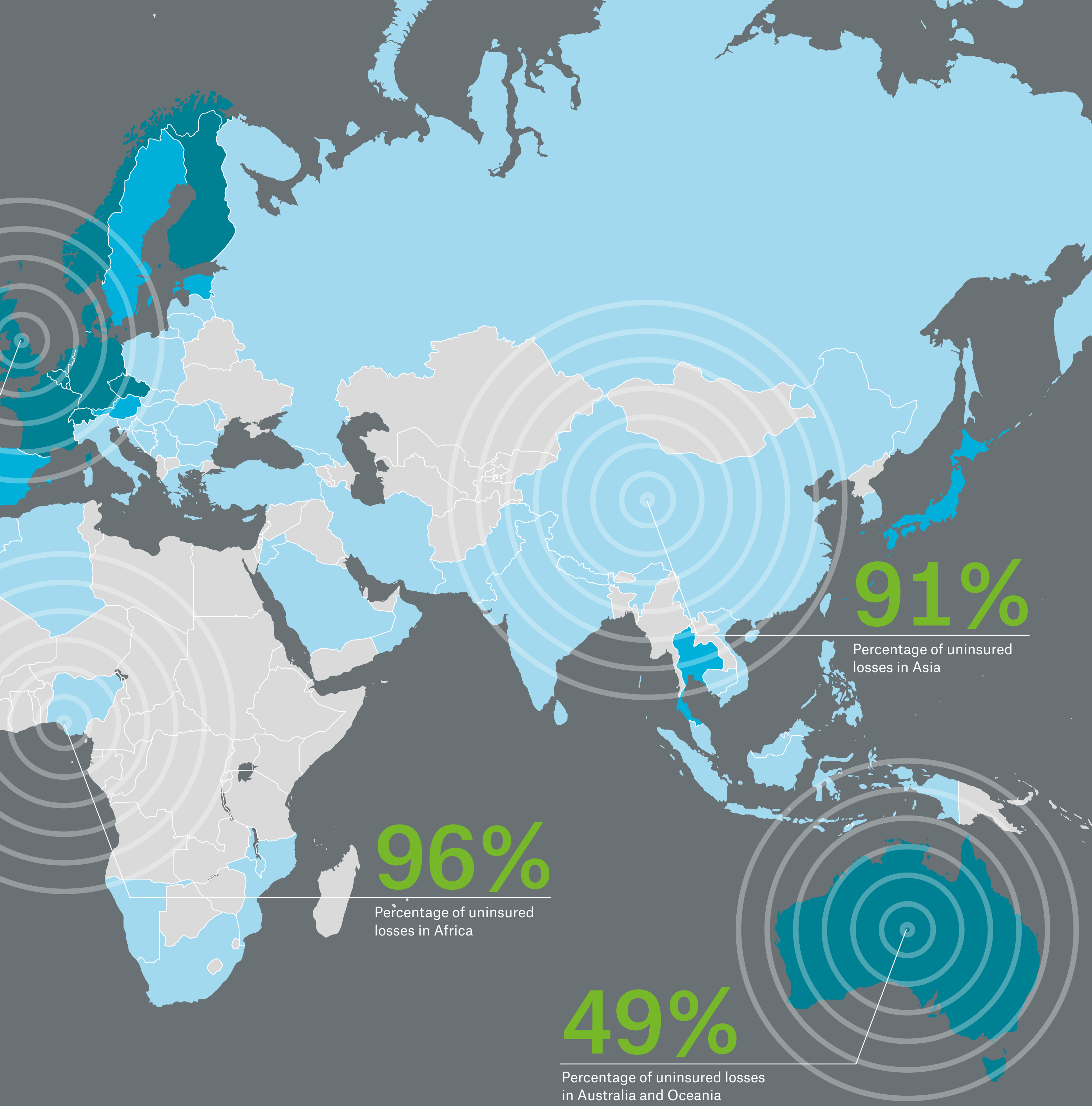


Insured losses 2016
Insured losses 1980–2015*

* Values adjusted for inflation using the consumer price index (CPI) of each country, and taking into account fluctuations in exchange rates.

Source: Munich Re NatCatSERVICE


67%
Percentage of uninsured losses in Europe
50%
Percentage of uninsured losses in North America (incl. Central America and the Caribbean)
83%
Percentage of uninsured losses in South America



Natural disaster loss events 2000 to 2016 Insured and uninsured losses worldwide

Nationwide level of insurance coverage, based on the ratio of insured to uninsured losses.

- Uninsured countries
- Low level of insurance coverage (≤20%)
- Medium level of insurance coverage (≤40%)
- High level of insurance coverage (>40%)

The new NatCatSERVICE analysis tool

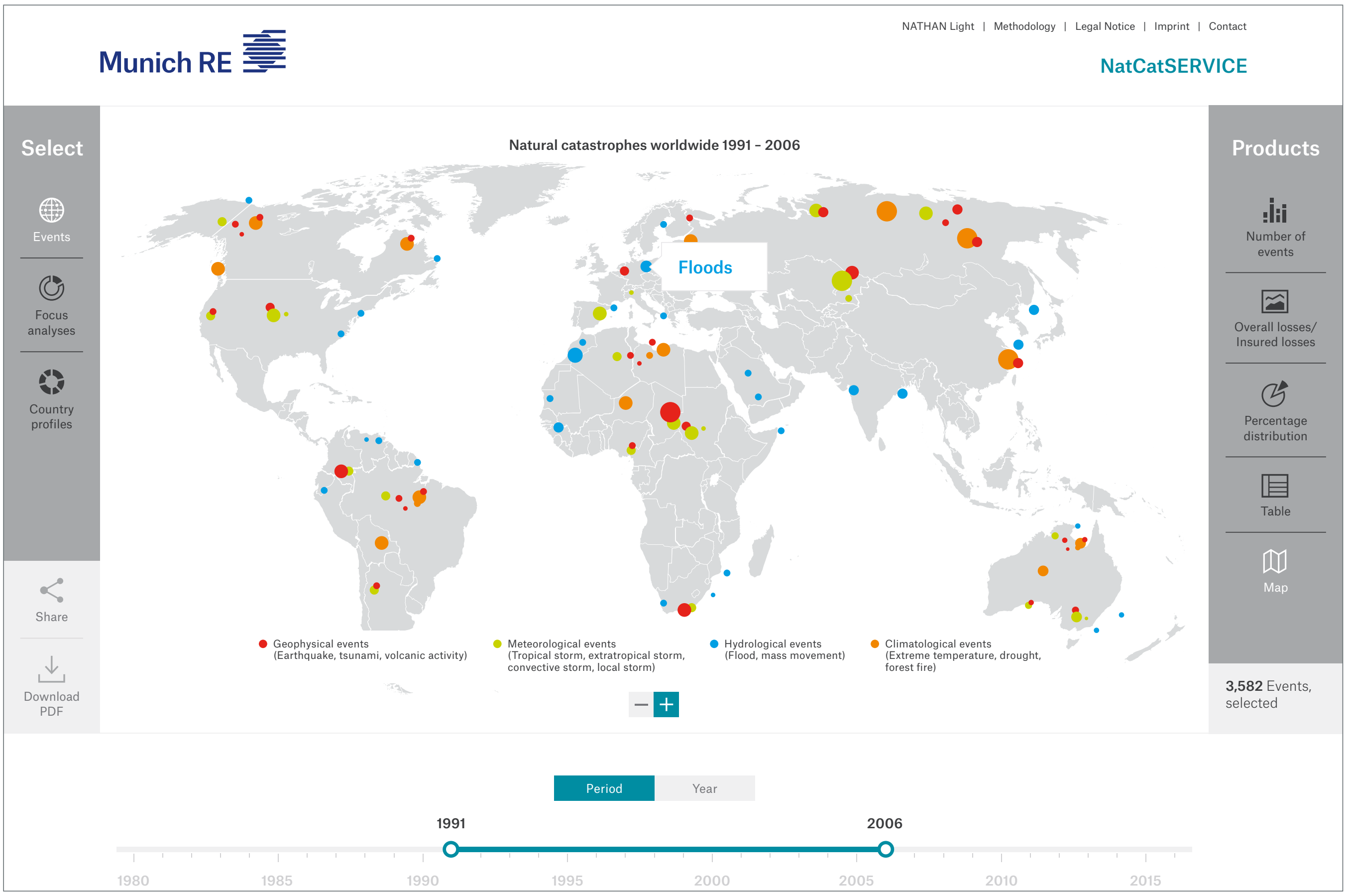
Petra Löw

For more than 30 years, Munich Re's NatCatSERVICE has provided comprehensive natural catastrophe expertise for risk management and research. Today, it is one of the most internationally recognised sources of information for the evaluation and analysis of natural disasters. You can now access this store of knowledge directly – using the online NatCatSERVICE analysis tool.

Since 1974, Munich Re has been systematically recording events and loss data from around the world. This unique natural hazard archive then developed into one of the world's most extensive databases on natural catastrophe losses, NatCatSERVICE. The database forms the basis for a wide range of information, tools and services for risk assessment. NatCatSERVICE is a reliable source of data, providing loss information on both current and historical events. Thanks to its detailed database structure, it can also offer many different types of analysis.

Up to now, a lot of information has been accessible from our download library. The NatCatSERVICE online tool now offers a variety of additional options for individual analysis, allowing users to filter the precise information that interests them. In developing the tool, special emphasis was placed on ensuring flexibility, ease of use and speed. The detailed view of the different assessments, including the world map, leads into a clearly structured representation with a variety of options.

Information for analysis is available from 1980 up to the present day, but you can also view shorter periods, down to individual years. In terms of geographical coverage, there is a choice between the global view and analyses for each continent. The temporal and regional coverage, and also the types of event, can be combined with one another in different ways. The tool also provides the option of creating hazard-specific evaluations. These include analyses of severe weather, winter storms, tropical cyclones and earthquakes, both worldwide and for individual countries. There are also data on aspects such as insurance penetration in different countries. The results can be shown in the form of frequency statistics, loss amounts and pie charts, as well as tables and maps, and can be downloaded as a PDF. Results from the analyses can be shared directly on social networks.



Source: Munich Re NatCatSERVICE

Structure of the user interface and elements of the tool

Select:

In the *Select* panel, you can find selection and filter options for three different views. Under the heading Events, you can choose one or more groups of event (geophysical, meteorological, hydrological, climatological). You also have the option of selecting either a global view or a view by continent. The *Focus analyses* provide hazard-specific information, e.g. on tropical cyclones worldwide or for the Atlantic only. *Country profiles* primarily provide analyses, such as income groups according to the World Bank definition, insurance penetration, or an analysis of global distribution of fatalities from natural catastrophes.

Products:

The *Products* panel contains all the possible analyses for the particular data selection. These include frequency graphs, loss amount diagrams, tables, percentage distributions and maps. The results can be downloaded as a PDF and shared on social networks.

Period/Year:

The time period is specified in the toolbar at the bottom. Options here range from an individual year to any period you prefer, but the maximum range is for all events from 1980 until the last complete calendar year.

Additional information:

Using the NatCatSERVICE analysis tool, you can switch directly to NATHAN Light for hazard analysis only.

You can download a PDF with a full description of the methods used in NatCatSERVICE.

Visit our website at www.munichre.com/en/natcatservice

New horizons opening up for geospatial risk management

Thomas Zerweck

The analysis of geospatial data is an important component of risk management, rating and loss assessment. Globally collated real-time data, high-resolution satellite images and 3D models are creating innovative analysis opportunities in a growing number of insurance fields.

Until recently, the only way geo-analysis could provide meaningful support for underwriting was with the aid of complex software and tools that required a high degree of specialist knowledge. Moreover, the sheer volume of raw data involved frequently proved a major stumbling block to the practical application of geoanalysis. Geodata are always big data – in the sense of enormous file sizes, and with a large amount of cartographic and attribute data. Analysing and visualising these data quantities within a reasonable time poses major challenges. Practical examples in this context include the several hundred gigabytes of data used for globally modelled flood areas for insurance portfolios.

But new technology options in the context of digitalisation are now allowing meaningful geoanalysis to be performed within a reasonable time. In this way, large quantities of data can be integrated into company-wide risk management and processed for every field in the insurance industry. Real-time data, high-resolution satellite images and 3D models enhance analysis capability, as do new big data and machine-learning technologies.

Big data and geospatial analytics

Munich Re created the “Data Lake” with the aim of maximising the use of our in-house data. It is a platform on which employees can combine and analyse data in any way they wish. The aim is to quickly and easily gain a greater understanding and develop new ideas from the data. The analysis is based on the big data framework, Hadoop, which offers reliable and scalable computing capacity by working through the processes more efficiently. This allows even petabytes of data (one petabyte is the equivalent of a million gigabytes) to be processed easily.

Tools based on Hadoop can also assist with geoanalysis. As part of a proof of concept, millions of ship-position data from the AIS (Automated Identification System) were analysed and combined to create a risk map for submarine infrastructure such as cables and pipelines (see map on page 65).

In-memory databases, in other words database management systems that use a computer’s main memory as a storage medium, are another mainstay for the rapid processing of large quantities of data. By switching to such a system, our popular client tool NATHAN, which is used for the portfolio analysis of natural hazards, was substantially expanded.

From data to information

Major advances have been made in recent years with data from satellites and drones. They are available in steadily better spatial and temporal resolutions, and additional spectral channels can provide further information. For example, after the earthquake in Pedernales, Ecuador, high-resolution aerial photographs were taken by drones and combined with satellite images to automatically estimate losses.

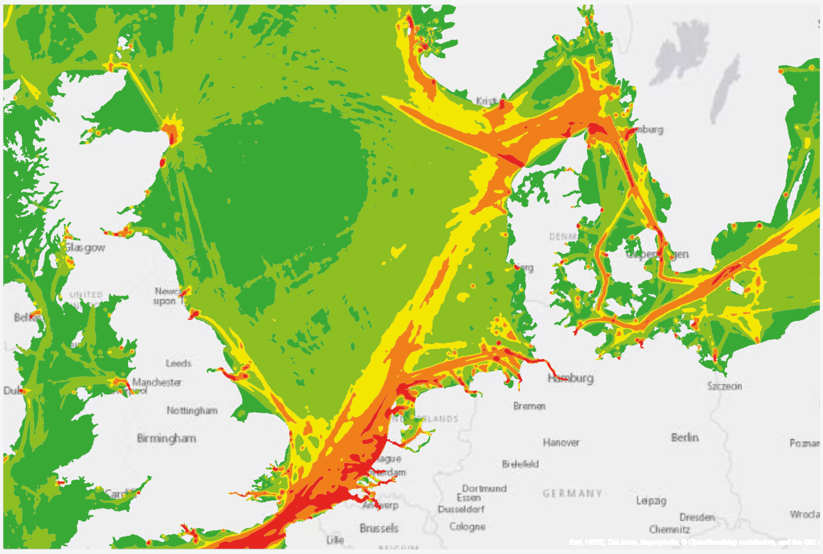
This market is opening up new opportunities for cooperation. In collaboration with Munich Re and the ESA (European Space Agency), SAP has developed a service to identify wildfire areas obtained from the automated analysis of satellite images. Real-time information like this, which can also be obtained from other sources (for example from sensors measuring seismic activity or wind strength), play a key role in the general assessment of a risk and in loss estimates. Institutions like the US National Oceanic and Atmospheric Administration (NOAA) or the United States Geological Survey (USGS), now provide information on the web via standard interfaces. This allows the predicted track of a hurricane, or the location and magnitude of an earthquake, to be integrated into in-house applications.

A further trend in the field of geoinformation is the use of 3D data. This could play a role in the future, particularly in the context of cities – the key terms here being smart cities and Building Information Modelling (BIM). Further applications would be needed to show the extent to which this might represent added monetary value for risk management purposes.

Tailored applications

Existing solutions such as Munich Re's NATHAN (Natural Hazards Assessment Network) Risk Suite already support the portfolio analysis of natural hazards. New functionalities

Hazard potential for submarine cables and pipelines in the North Sea and Baltic Sea. The main shipping routes can be clearly seen (green = low, red = high hazard).



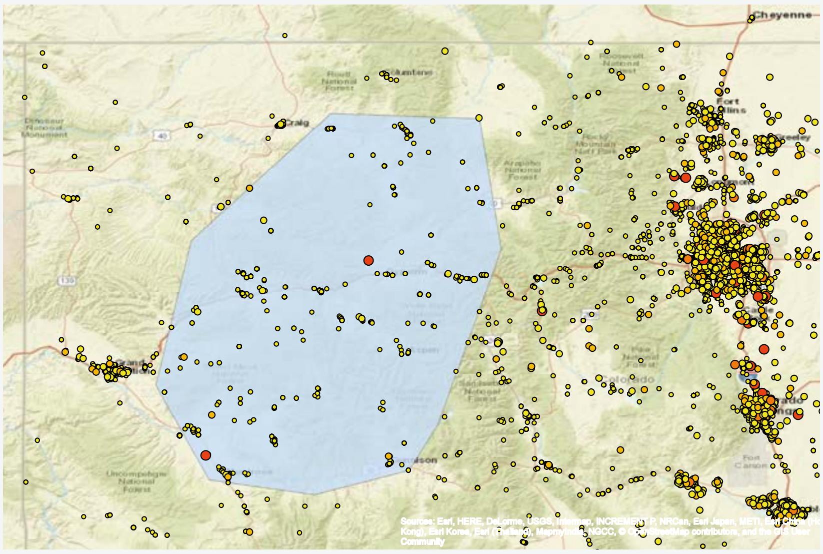
Source: Munich Re, based on AIS; background map: Esri

Indication of building damage. The change detection heat map for Pedernales (Ecuador), created from GeoEye-1 satellite data and drone images after the earthquake in April 2016, shows small changes (blue) and major changes (brown).

Source: Munich Re, based on GeoEye-1, Precision Hawk

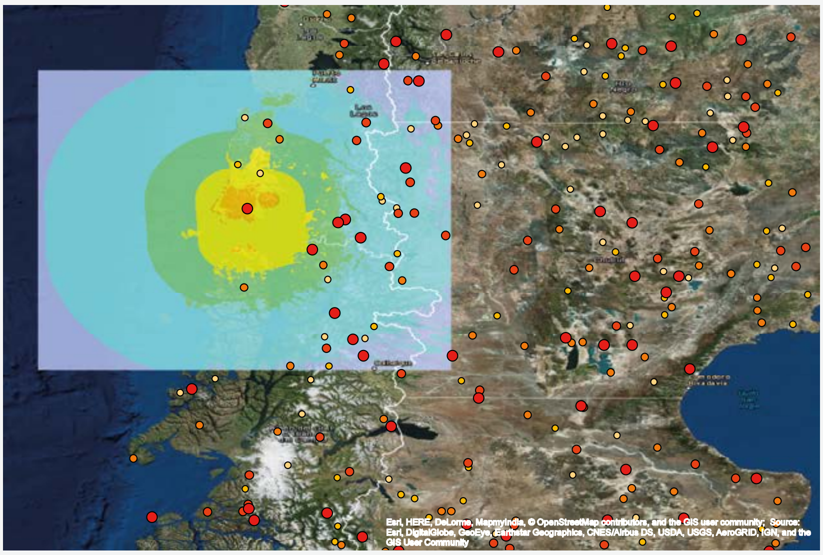
Exposure locations in combination with real-time data (yellow = medium, red = high sums insured)

a) Weather hazard information from the National Weather Service: "Heavy snow" (blue area) in the area of Phoenix, USA, on 29 December 2016, 6 p.m.



Source: Munich Re, based on NOAA/NWS/CPC; background map: Esri

b) Intensities of the earthquake in Los Lagos, Chile, on 25 December 2016 according to the Mercalli scale (yellow = II to violet = VII).



Source: Munich Re, based on USGS; background map: Esri

and content, however, always require the involvement of IT development, and therefore necessitate a certain lead time and available IT resources.

Munich Re launched the SAFIR (Spatial Analytics for Insurance Risks) platform to enable it to respond quickly and flexibly in future to individual requirements and provide tailored applications. This in-house solution gives the insurance expert an overview of the available data and applications, and new data can be supplemented and individual apps created without support from IT.

Is everything better when it is automated?

New technologies and data can improve risk management, and make it available faster with a focus on the individual situation – provided the data are understood and analysed correctly, and the results interpreted accordingly. However, despite all the enthusiasm for new technical possibilities, the importance of a critical, expert eye should not be forgotten. For it will be of little use if we simply evaluate more – and perhaps unsuitable – data using faster, but incorrect, methods of analysis.

Climate facts 2016

Eberhard Faust

2016 was the third year in succession in which average global temperatures set new records. As in the previous year, El Niño again played a part in this development, alongside continuing climate change.

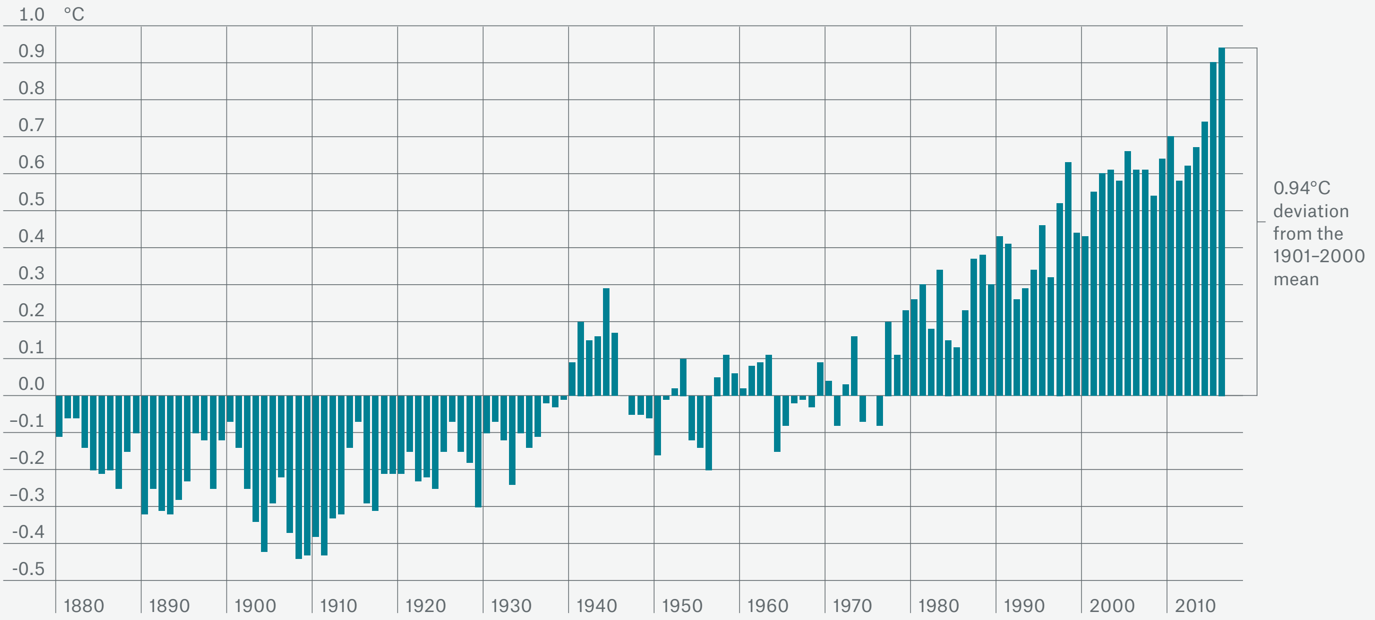
According to data published in January 2017 by the US National Oceanic and Atmospheric Administration, NOAA, the global mean temperature over land and ocean surfaces exceeded the 20th century mean of 13.9°C by 0.94°C, surpassing the previous record set in 2015 (0.90°C) by 0.04°C. The linear trend over the period 1880 to 2016 reveals an increase of 0.93°C. This is one of several methods used to determine the increase in temperature produced by climate change since the pre-industrial era.

The 2015 record was influenced by the strong El Niño phase in the tropical Pacific, which still had an impact on the global mean temperature in the first half of 2016. In addition, large sections of all of the ocean basins featuring above-average surface temperatures significantly contributed to the global temperature development. These areas included not only the Pacific off the west coast of the Americas, but also the western North Atlantic and large parts of the Western Pacific and the Indian Ocean. Of the land masses, regions in the high latitudes were of particular significance and have already experienced disproportionate warming over the last few decades. Regions in North America, Africa, South and Southeast Asia, and the eastern half of Australia also contributed to the increase in temperature.

The El Niño conditions and their lasting impact in the first half of the year also triggered drought phases, for example in northern South America and parts of Central America, as well as in the neighbouring Caribbean. Southern Africa, Ethiopia, eastern Australia, Indonesia, the Philippines and parts of India also experienced exceptionally dry conditions. Conversely, the northern half of Argentina, southern Brazil, Southeast China and southern parts of the USA saw greater precipitation than usual due to this phenomenon. In some areas, there was an abrupt change from dry to unusually wet conditions, coinciding with a shift to neutral and then to weak La Niña conditions in the second half of the year. These regions included the eastern half of Australia and Tasmania, as well as large parts of Indonesia, in particular Java and Sumatra. In South India, on the other hand, there was a shift to unusually dry conditions from September on, once again in line with the typical effects of the El Niño/Southern Oscillation (ENSO) phenomenon. Admittedly, the influence of the sometimes extremely varied partial periods is not evident in the annual average on the precipitation chart (see page 68).

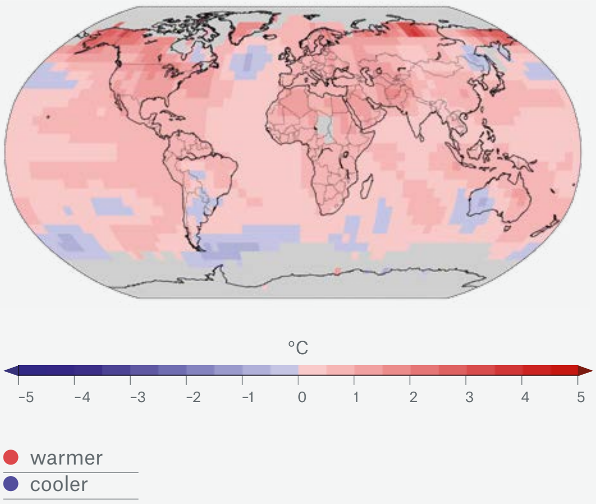
Deviation in global mean temperature from the 1901–2000 average

16 of the 17 warmest years were in the period 2001–2016

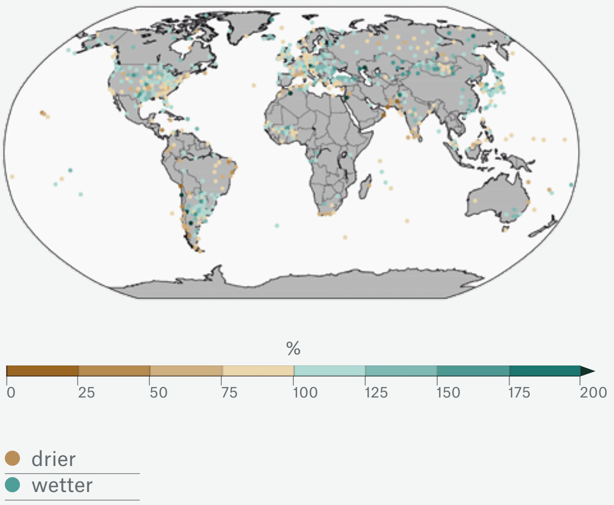


Source: Munich Re, based on data from the National Centers for Environmental Information/NOAA

Regional deviation of the 2016 mean annual temperature from the 1981–2010 mean



Regional deviation of the 2016 annual precipitation from the 1961–1990 mean

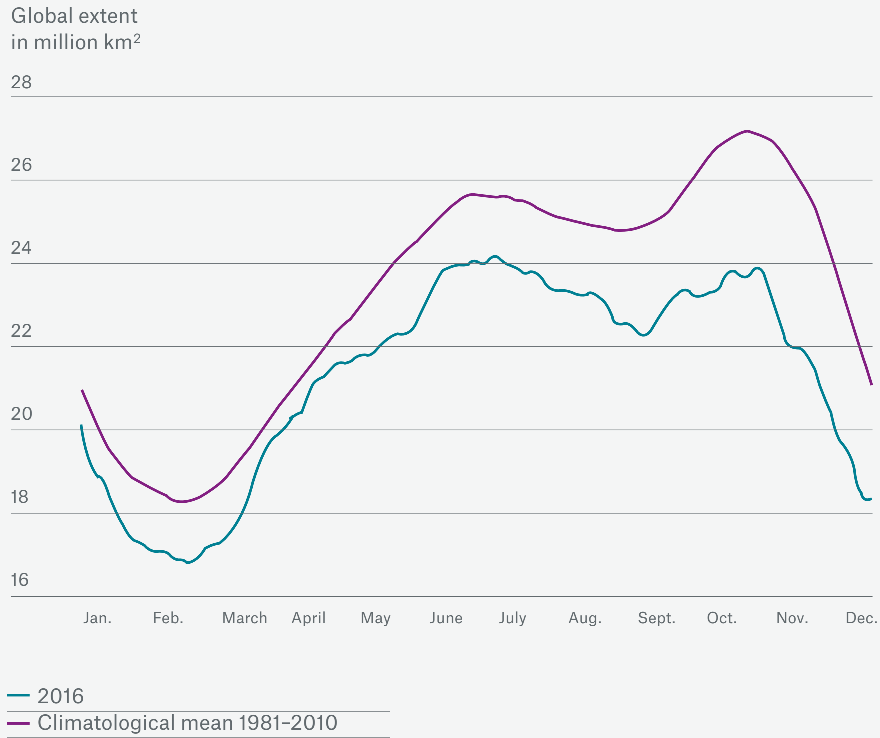


Source: Munich Re, based on data from the National Centers for Environmental Information/NOAA

As in the previous year, the maximum extent of Arctic sea ice in March 2016 marks the lowest value since satellite recordings began 37 years ago. The minimum recorded in September 2016 was the second-smallest area, along with an identical value measured in 2007. In seven months of the year, the extent of the ice was smaller than ever previously observed. From October on, warm North Atlantic air masses moved into parts of the Arctic, whereupon sea surface temperatures rose significantly. As a result, the extent of sea ice actually shrank in the middle of November, and was still significantly reduced in December. At the same time, sea ice in the Antarctic receded at an increasing rate from September. The main reason for this was probably abnormal wind fields in the Southern Ocean. As a result of these developments, the global sea ice extent (Arctic and Antarctic sea ice combined) fell to a record low, mainly in the second half of the year, and especially in the months of September, October, November and December. The precise climatological connections are still the subject of research.

In the same way as for 2015, the review of 2016 produced the important finding that the influence of El Niño over the first half of the year was clearly reflected in the temperature signal. In general, the fluctuations generated in the climate system always overlap the signal of climate change in every area. Research has shown that internal fluctuations in this overlap can produce decades-long phases with a less pronounced increase in temperature. After this, there may be "spring-back" effects, with phases characterised by a sharper increase in temperature. It is therefore more difficult to clearly identify climate change in individual years, or from the perspective of just a few years. Instead, we need to observe the long-term change since the 19th century. Once such a long-term perspective is taken, despite all the fluctuations in the increase behaviour, there have been no indications up to now of any long-term weakening in the increase in temperature. In fact, the most recent record years tend to indicate the opposite.

Global sea ice extent (Arctic and Antarctic) for 2016 and in the long-term mean



Source: Munich Re, based on data from the US National Snow and Ice Data Center

Rapid attribution: Is climate change involved in an extreme weather event?

Eberhard Faust

Research into extreme weather and climate change is making progress. It is now possible to quickly quantify the degree to which the intensity or frequency of certain events is influenced by man-made climate change.

Why is it important to rapidly establish whether – and to what extent – an extreme regional weather event is now more likely as a result of climate change? Take as an example the extreme rainfall and flooding that France experienced in 2016 on the Seine and Loire. If climate change has already verifiably increased spring rainfall in these regions, more events of this kind can be expected in future as global warming continues. Such events could lead to damage in the billions – especially in the Greater Paris area.

Correct attribution critical for risk management

The requirements for public risk management here are different to those for an exceptional one-off event without any trend. Attribution to climate drivers can have direct practical consequences: the earlier climate change can be identified as being involved in a natural catastrophe, the stronger the incentive for authorities to implement suitable adaptation measures.

It is much more difficult to attribute a single extreme weather event to its drivers shortly after its occurrence than, for example, the increase in global mean temperature that has taken place over many decades. With a set of global climate models, it is possible to attribute the warming to human-influenced climate change by way of a virtual experiment. A link is probable if the warming can only be reproduced when, in addition to natural drivers (historical volcanic eruptions and solar variability), the observed changes in greenhouse gas and aerosol concentrations, as well as land-use changes, are applied to the models. When the natural forcing variables alone are applied, excluding anthropogenic factors, the models do not arrive at the observed increase.

Weather extremes as one-off events

What works for a variable such as global temperature, which is averaged over time and space, is of little use in the case of weather extremes, which are sporadic as regards time and place. Such weather extremes can be seen as unique events in terms of their individual meteorological causes and course so that, strictly speaking, it is not possible to derive information on frequencies or on any changes to the frequencies. However, the use of abstraction can help in this instance: all the events that produce intense precipitation are first pooled in one category. If the statistical series for events in this category is sufficiently large, we can check whether the associated distribution of rainfall – for example the return periods for high values – has altered significantly over time.

Coastal areas suffer more than most from the increase in extreme weather events.

By this means it cannot be determined whether the observed changes are the result of climate change as opposed to natural climate variability. Such evidence can be provided in the form of a climate model experiment, as illustrated with the 2016 spring floods in France. In this case, two distributions of the three-day rainfall amounts are generated for the regions in question: one of them for a virtual, pre-industrial climate not influenced by climate change, and the other for the climate we have today. To obtain a statistically sufficient database, the climate models generate the distributions over and over again, and the results are then pooled. This also makes it possible to average out natural climate variability influences found in the climate model runs. The procedure ensures that climate change is the only thing determining the difference between the two distributions. Furthermore, the procedure is repeated with many different climate models, instead of just one.

More extreme precipitation events on the Seine and Loire in future

It is evident that the three-day rainfall amounts in the spring of 2016 in France were rare events in the present-day climate. They occur roughly every hundred years in the Loire region, and are even more unusual in the Seine basin. Nevertheless, the different climate models produce consistent and thus robust results. They show that, because of climate change, the probability of regional events of at least the same intensity as 2016 has increased by factors of 2 (Loire) and 2.3 (Seine) in comparison with a world without climate change. They also show that the probabilities of less extreme events have also increased as a result of climate change. The fact that these enhanced probabilities can be attributed to climate change means that such events will occur even more often in the future.

Such attribution studies of selected weather extremes such as heatwaves, droughts and intense precipitation have been conducted regularly since 2011, generally on the basis of models. At the end of the year subsequent to the event, these studies are published in special supplements to the Bulletin of the American Meteorological Society. Climate change was found to have influenced the frequency or intensity of 65% of the more than 100 events studied so far, while no influence could be demonstrated for 35%. This illustrates how climate change is already having a significant impact on extreme events.

Because of the time lag factor, however, these studies fail to meet the reasonable criterion of rapid attribution mentioned above. For this reason, for a few years now, articles containing an attribution analysis have been submitted to specialist journals within a few weeks of an event (rapid attribution) – the study on the floods in France outlined above, for example, was online just three weeks after the event. A further recent example is the torrential rain and flooding that occurred in August 2016 in Louisiana, particularly in the Baton Rouge area, where one place experienced just under 650 litres/m^2 of rain over a period of three days. A little over three weeks after the event, a study (van der Wiel et al., HESSD, 2016) appeared online, stating that an extreme event of this kind now occurs roughly every 30 years in the central Gulf Coast region of the USA, and has become more frequent by a factor of at least 1.4 as a result of climate change. Similar studies have also been published for a number of heat and extreme precipitation events in recent years (see table on page 73).

Normalised losses alone not indicative enough

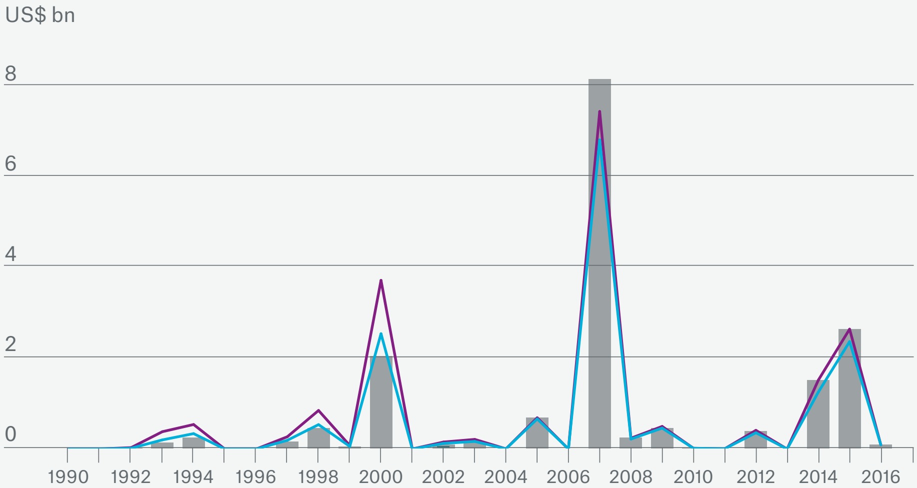
Rapid attribution analysis as described above is useful for informing risk management about the type and scale of the change in hazard activity and creates an incentive to improve adaptation efforts while the event is fresh in the minds of the relevant authorities. In the case of major events in a particular region, such analyses could help to identify a long-term driver of losses that is not clearly identifiable from the time series of normalised losses. This is because such a trend would only become apparent over a much longer observation period. Major

catastrophes such as river floods remain rare events in many countries, affecting different regions, exposures and vulnerabilities over the decades.

One such time series does not per se disclose the causes of the different normalised loss amounts involved. These might be able to tell us something about the different regional exposures or efforts to protect against flooding, but might not at first hint at changes due to climate change. This is illustrated by the normalised losses of the great flood disasters in the United Kingdom since 1990 (see chart). All the major losses in this time sequence, in other words the events in 2000, 2007, 2014 and 2015, represent affected exposures that may partially overlap but which are also distinct from one another. It is only when we look at the attribution studies that we see that climate change has already influenced the probability of all of these events. They are 1.4 to 2 times more frequent than they would be in a world without climate change.

To foster rapid attribution studies, Munich Re participates as a stakeholder in the European research initiative EUCLEIA (European Climate and Weather Events: Interpretation and Attribution). EUCLEIA is developing an operational system for climate attribution with particular focus on Europe. The causes of changed event frequencies and/or intensities need to be identified as early as possible in order to take the appropriate steps. Besides early identification of trends in hazards and losses, the main implication for the insurance industry is the continued support for corresponding efforts to improve prevention.

Flood events in the United Kingdom 1990–2016
Overall losses: original, adjusted for inflation, and normalised



Overall losses in original values
Overall losses adjusted for inflation*
Normalised overall losses*
(*in US$, in 2016 values)

Source: Munich Re NatCatSERVICE

Selection of recent specialist publications on the (rapid) attribution of climate cause

Loss event	Losses			Meteorological return period (at present)	Role of climate change
	Overall (original):	Normalised:	Insured (original):		
August 2016: Extreme precipitation and floods in Louisiana, USA[1]	US$ 10bn	US$ 10bn	US$ 2.5bn	Approx. 30-year event (central Gulf Coast region 29–31N, 85–95W)	Increase in probability by a factor of at least 1.4
May/June 2016: Intense precipitation and floods in France[2]	€2.2bn	€2.2bn	€1.2bn	Approx. 100-year event (Loire). Return period >>100 years (Seine)	Increase in probability by factors of approx. 2.3 (Seine) and 2.0 (Loire)
Winter (December) 2015: Intense precipitation and floods in northern England/southern Scotland during Storm Desmond[3]	£0.88bn	£1bn	£0.6bn	Approx. 100-year event	Increase in probability by a factor of approx. 1.4
July 2015: Heatwave in Europe[4]	€30m	€30m	–	3-day temperatures at start of July: De Bilt/NL (3-year) Madrid/ES (5-year) Mannheim/D (30-year) Beauvais-Tillé/F (3-year) Zurich/CH (13-year)	Increase in probability by a factor of at least 2
Winter 2013/14 (January 2014): Heavy rainfall and floods in England/Wales[5]	£0.9bn	£0.94bn	£0.7bn	Approx. 100-year event in southern England	Increases in probability: - intense precipitation factor approx. 1.4 - 30-day peak Thames discharge factor approx. 1.2 - properties at risk of flooding (Thames) increase by 1000
July 2007: Extreme summer rainfall and floods in central England/Wales[6]	£2bn	£2.4bn	£1.5bn	5-day rainfall in July: return period approx. 10–30 years	Increase in probability by a factor of at least 2
October–November 2000: Heavy rainfall and floods in England/Wales[7]	£1.5bn	£3.7bn	–	Discharge (rivers) approx. 10-year (modelled)	Increase in probability of discharge: factor >1.2 to >1.9

- Rapid attribution of climate cause
- Non-rapid attribution of climate cause

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Source: Munich Re

Topics Geo – 50 major loss events 2016

Nr.	Date	Loss event	Country/ Region	Deaths	Overall losses US$ m	Insured losses US$ m	Explanations, descriptions
1	6–11.1.	Wildfire	Australia	2	110	50	>700 km² burnt. >180 houses destroyed. 1,000 power poles, 44 transformers, power lines damaged, 7,000 customers without electricity. >30 km² of pine plantations destroyed. Losses to agriculture, livestock killed.
2	Jan.–Dec.	Drought	Djibouti, Ethiopia, Somalia, Uganda				Food insecurity, wells dried up, low water levels in reservoirs. Losses to agriculture, livestock killed.
3	Jan.–Aug.	Drought	Thailand, Vietnam		1,200		Low water levels in lakes/rivers. Thousands of km² of crops (rice, wheat, orchards) damaged/destroyed.
4	20–27.1.	Winter damage	China, Japan, Taiwan	10	1,500		Frost, heavy snowfall, snow accumulation, freezing rain. 6,300 homes damaged/destroyed. Water pipes damaged/destroyed. Air, rail, road traffic affected, accidents. Crops damaged.
5	29–31.1.	Winter Storm Marita (Gertrude)	Norway, UK		160	120	High wind speeds, gusts up to 170 km/h, heavy rain, flash floods, landslides. Several houses, schools, hotels damaged. Road, rail, ferry traffic disrupted.
6	5.2.	Earthquake	Taiwan	117	700	370	Mw 6.7. Numerous buildings and bridges damaged/destroyed. Power outages, hundreds of thousands of customers without electricity. Industrial park affected, business interruptions.
7	6–10.2.	Winter Storm Ruzica (Imogen), storm surge	France, Germany, UK		220	160	High wind speeds, heavy rain, high waves up to 19 m, floods. Houses, schools, vehicles damaged. Rail tracks, roads damaged/blocked, weather-related accidents. 29,000 customers without electricity.
8	15–21.2.	Cyclone Winston	Fiji	44	600	50	Cat 5 cyclone. Wind speeds up to 230 km/h, gusts up to 325 km/h, torrential rain, flash floods, storm surge, high waves. 30,000 homes, schools, hospitals damaged/destroyed. Two ports, wharves, jetties damaged. Crops up to 100% destroyed, severe losses to sugar industry. Evacuated: 59,000.
9	Mar.–Dec.	Drought	Bolivia		450		Water shortages, lack of drinking water. >2,000 km² of crops destroyed (soy, maize, sunflower, sorghum, chia, vegetables, fruits). >60,000 cattle killed. Affected: >720,000.
10	5–17.3.	Flash floods	USA	7	1,600	560	Homes and businesses damaged/destroyed. Boats damaged. 40,000 customers without electricity.
11	10–29.3.	Floods	Pakistan	141			Torrential rain (57 mm/24 h), flash floods, landslides. >1,000 homes damaged/destroyed. Communication lines downed. Wheat crops damaged. Injured: >120.
12	17–19.3.	Hailstorm, severe storms	USA		1,200	920	Tornadoes, high wind speeds, heavy rain. Houses, commercial buildings damaged. Zoo facilities damaged, animals killed. >50,000 vehicles damaged. Fire damage at oil field equipment site.
13	23.3.	Hailstorm, severe storms	USA		2,300	1,700	Thunderstorms, tornadoes, high wind speeds, hail up to 3 cm in diameter, heavy rain, lightning. Hundreds of homes (esp. windows, roofs), 50,000 cars damaged, 5,000 of them at car dealerships.
14	April	Floods	Afghanistan, Pakistan	211			Extreme rains, thunderstorms, landslides. Thousands of homes damaged/destroyed. Water supply affected, shortage of drinking water. Crops, orchards damaged, livestock killed.
15	Apr.–May	Heatwave	India	700			High temperatures up to 45°C. Rivers, lakes, reservoirs dried up. Heat-related diseases.
16	Apr.–May	Floods	Ethiopia	100			Heavy spring rains. 1,000 homes damaged/destroyed. Construction sites damaged. Roads and bridges damaged/destroyed. Crops destroyed, >1,000 cattle killed. Affected/displaced: 490,000.
17	10–15.4.	Hailstorm, severe storms	USA		3,900	3,000	Thunderstorms, high wind speeds, gusts up to 110 km/h, hail up to 11 cm in diameter, torrential rain. Thousands of homes damaged. >110,000 vehicles damaged.
18	14/16.4.	Earthquake	Japan	69	31,000	6,000	Two earthquakes M_w 6.2 and M_w 7.0. 7,900 houses and public buildings destroyed, >141,000 damaged. Airport severely damaged. Hundreds of thousands of customers without electricity, gas and water. Automobile plant shut down. Evacuated: 294,000.
19	16.4.	Earthquake	Ecuador	673	2,000	560	M_w 7.8, landslides. 280 schools, 2 hospitals, five-storey hotel destroyed, >35,000 buildings, houses, shopping malls damaged/destroyed. Injured: >6,200, evacuated/displaced: 80,000, affected: 720,000.
20	16–19.4.	Flash floods, severe storms	USA	9	2,000	1,000	Torrential rain (300 mm/24 h), thunderstorms. 7,000 homes damaged or flooded. 30,000 vehicles damaged. Power lines downed, >140,000 customers without electricity.
21	1.5–4.7.	Wildfires (Fort McMurray Fire)	Canada		4,000	2,900	5,900 km² burnt. >1,900 residential buildings destroyed. Numerous vehicles/mobile homes burnt. Gas stations exploded. Oil-sand production shut down, a quarter of the country's oil production halted. Evacuated: >88,000.
22	27–30.5.	Flash floods, severe storms	Germany, France, Netherlands	8	1,400	850	Dozens of houses, businesses, public buildings damaged/destroyed. Bridges destroyed, highways, roads, railways blocked. Automobile plant flooded, production suspended. Crops damaged/destroyed.
23	30.5–8.6.	Floods	France	5	2,400	1,300	Rivers (Seine, Loing, Yonne) burst their banks. Numerous towns and villages flooded. Thousands of buildings and businesses damaged. Power outages, 25,000 customers without electricity. Farmland, vineyards destroyed.
24	31.5–7.6.	Flash floods, severe storms	Germany, Belgium, Switzerland	9	2,200	1,000	Torrential rain, rivers burst their banks. Thousands of houses damaged. Basements, underground car parks flooded. 9,000 customers without electricity.
25	Jun.–Sept.	Floods	Sudan	171			Heavy seasonal rains. >22,000 houses destroyed, >18,000 houses damaged. 200 water engines damaged, water supply disrupted. Outbreak of diseases. Affected: >200,000.
26	Jun–Aug.	Drought	China		3,000	1,100	High temperatures. >30,000 km² of cropland damaged. Livestock affected.
27	3–7.6.	Winter storm, flash floods	Australia	5	500	310	Heavy rain (280 mm/24 h), high waves up to 14 m. 100 farms, >200 homes/businesses flooded. Wharf damaged, ports closed. Power outages. >228,000 customers without electricity.
28	18.6–13.7.	Floods	China	237	20,000	520	Heavy seasonal rains. Rivers burst their banks. 147,200 houses destroyed, >390,000 damaged. >5,000 km² of cropland destroyed, >20,000 km² damaged, livestock killed. Affected: >60 million.
29	22–24.6.	Hailstorm	Netherlands, Germany		1,900	1,000	Hundreds of vehicles damaged. Solar panels destroyed. Damage to greenhouses and agriculture.
30	Jun.–Jul.	Flash floods	Nepal	122	15		Heavy seasonal rains, mudslides, glacial lake outburst. >1,500 houses destroyed, >3,200 homes and schools damaged. Telecommunication towers, transmission lines damaged.
31	Jul.–Sept.	Floods	India	184	160		Madhya Pradesh. Heavy seasonal rains (southwest monsoon). >20,000 houses/dwellings destroyed. Highways, 4,500 km of roads, 12 bridges damaged. Thousands of square kilometres of crops damaged/destroyed.
32	8–10.7.	Typhoon Nepartak (Butchoy)	China, Philippines, Taiwan	87	1,500		Cat 5 typhoon. Wind speeds up to 215 km/h, torrential rain, high waves up to 14 m. 23,000 homes destroyed, 22,000 damaged. Power and communication lines downed. 5.4 million customers without electricity.
33	15.7–12.9.	Floods	India	254	350		Bihar. Heavy seasonal rains (southwest monsoon). >4,200 villages affected. Evacuated: >1.6 million.
34	18–21.7.	Floods	China	164	4.500	80	Rivers burst their banks. >126,000 houses destroyed, >250,000 houses damaged. Great Wall of China damaged. Power outages. Evacuated: >500,000, affected: >14.7 million.
35	19.7–31.8.	Floods	Bangladesh	106	150		Heavy seasonal rains, rivers burst their banks. >280,000 homes damaged/destroyed. >500km² of crops, esp. rice, jute, sugarcane damaged/destroyed. Displaced: >40,000, affected: 4.2 million.
36	2–6.8.	Hurricane Earl	Mexico, Belize, Guatemala	54	250		Cat 1 hurricane. Floods, landslides, storm surge. >10,000 buildings severely damaged, public buildings, businesses damaged. Damage to infrastructure. 63,000 customers without electricity.
37	11–15.8.	Floods	USA	13	10,000	2,500	Torrential rain (>760 mm/48 h). 60,700 houses damaged/destroyed, 6,000 businesses, schools damaged. >100,000 vehicles damaged/destroyed. >53,000 customers without electricity. Affected: 70,000.
38	24.8.	Earthquake	Italy	299	5,000	75	M_w 6.0. >290 historic buildings damaged. Hospitals, schools damaged/destroyed.
39	29–31.8.	Typhoon Lionrock, floods	Japan, China, North Korea, Russia	157	1,500		Cat 4 typhoon. Entire villages washed away. >40,000 buildings damaged/destroyed. 6 bridges, numerous roads damaged. Water supply affected. Outbreak of epidemical diseases.
40	31.8–4.9.	Hurricane Hermine	USA	3	600	270	Cat 1 hurricane. Thunderstorms, tornadoes, heavy rain, high waves. >190 homes destroyed, >4,500 damaged, businesses destroyed. Roads blocked. Rail and air traffic affected, ferry services suspended.
41	13–15.9.	Typhoon Meranti (Ferdie)	China, Philippines, Taiwan	31	3,400	570	Cat 5 typhoon. 7,200 buildings destroyed, >61,000 homes damaged. Power grid damaged, >3.2 million customers without electricity. 900 km² of cropland damaged. 20,000 trees uprooted.
42	27–28.9.	Typhoon Megi	China, Taiwan	32	1,100	60	Cat 3 typhoon, high wind speeds, heavy rain. Rivers burst their banks. >1,200 homes destroyed, >10,000 damaged. Thousands of vehicles damaged. 4 million customers without electricity.
43	28.9–9.10.	Hurricane Matthew, storm surge	USA, Bahamas, Haiti	601	9,700	3,400	Cat 5 hurricane, storm surge, heavy rain, high wind speeds. Haiti: 200,000 houses, >500 schools, >70 hospitals, churches, roads, bridges, >400 km² of plantations (coffee, coconut) damaged/destroyed. Bahamas: Numerous houses, businesses, hotels, port facility, power grid severely damaged. USA: Thousands of houses, harvest (pecans, cotton) damaged. >1.9 million poultry and hogs killed.
44	16–19.10.	Typhoon Sarika (Karen)	China, Philippines	3	800		Cat 4 typhoon. 5,600 homes damaged, 1,000 destroyed. Damage to forestry (rubber trees) and aquaculture. Roads, bridges damaged or blocked. Trees, telecommunication, power lines downed.
45	19–21.10.	Typhoon Haima (Lawin)	China, Philippines	16	950		Cat 5 typhoon, storm surge. Dykes breached, dam gates damaged. 200,000 houses damaged/destroyed. Water facilities damaged. Air, rail traffic affected, ferry services suspended. Affected: >1.6 million.
46	26/30.10.	Earthquake	Italy		6,500	140	2 powerful earthquakes M_w 5.9, Mw 6.6. Villages cut off, hundreds of houses, churches, historic buildings damaged/destroyed. Highways and roads damaged. Thousands of customers without electricity.
47	13.11.	Earthquake	New Zealand	2	3,900	2,100	M_w 7.8. Landslides. Several buildings destroyed, hundreds damaged. Port facilities and cranes damaged, port closed. Telecommunication, power lines downed.
48	23.11–13.12.	Wildfire	USA	14	1,200	850	Forest and brush fires, >60 km² burnt. High wind speeds, continuous exceptional drought conditions. >2,100 homes, businesses, hotels, apartment complexes destroyed. 12,000 customers without electricity.
49	7.12.	Earthquake	Indonesia	102	100		M_w 6.5. >11,000 houses, 10 government buildings, >160 shops, >140 mosques, 33 schools, university, hospital damaged/destroyed. Power supply interrupted.
50	12.12.	Cyclone Vardah	India	24	1,000	200	Wind speeds up to 140 km/h, strong gusts, heavy rain. Homes, factories, vehicles, ships damaged/destroyed. Millions of customers without power. Crop damage to rice, banana, papaya.

Topics Geo – World map of the 50 major loss events 2016

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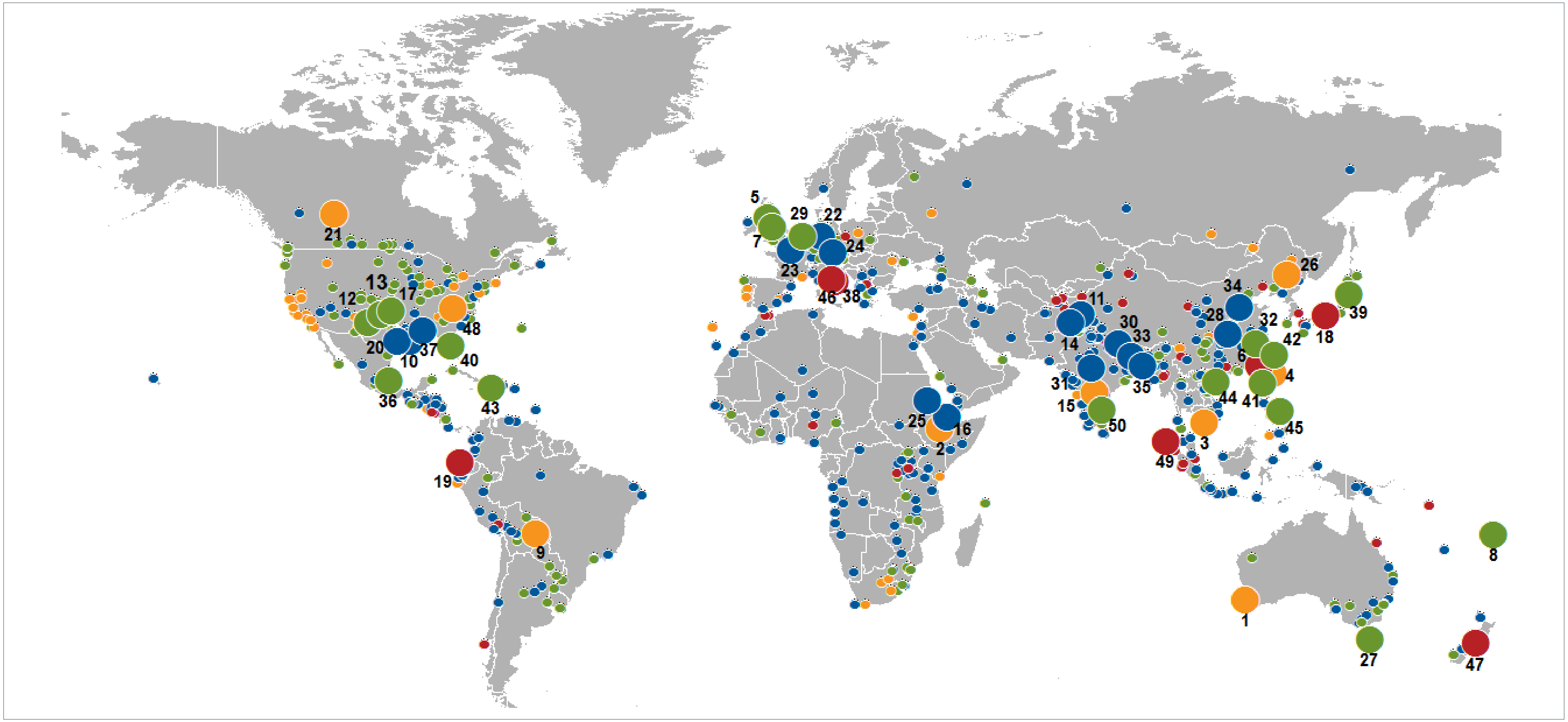

1,060 natural hazard events, thereof

50 major events (details overleaf)

- **Geophysical events:** Earthquake, tsunami, volcanic activity
- **Meteorological events:** Tropical storm, extratropical storm, convective storm, local storm
- **Hydrological events:** Flooding, mass movement
- **Climatological events:** Extreme temperatures, drought, wildfire

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