TOPICS
GEO

Harsh winter

Normally snow-free areas of Japan were hit by heavy blizzards in 2014. Loss records were also blitzed. **PAGE 18**

Social media
Using the twittersphere to our advantage

Portraits
Floods, drought, storm and quake

Stationary weather
Is melting Arctic ice changing our summer weather?

Munich RE

EDITORIAL

Dear Reader,

In terms of natural catastrophes, 2014 was undoubtedly a year when the insurance industry was again able to breathe a sigh of relief. For the third year in a row, losses remained below the long-term average. There was only one instance, the devastating snowstorms in Japan, where insured losses exceeded US$ 3bn. The aggregate cost for insurers of the ten largest events was around US$ 17bn, while the ten largest overall losses came to US$ 46bn.
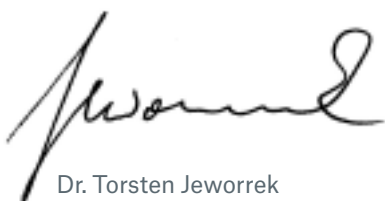
Another positive was that fewer lives were lost in 2014 than in any year since 1980, bar one. Tropical cyclones Hudhud in India and Hagupit in the Philippines could potentially have increased the number of victims significantly. In both cases, evacuation measures that were among the biggest in history managed to prevent the worst. It is promising to see that prevention measures are clearly having an increasing effect.

At the same time, it would be wrong to conclude any trend reversal based on the loss experiences of the last few years. At the start of the millennium, we also saw four successive years with relatively low loss amounts. This phase was promptly followed by the record loss years of 2004 and 2005.

Even though there were relatively low losses in 2014, there were still some exceptional events, which we analyse and evaluate in this issue of Topics Geo. We also examine the subject of how social networks can help to better assess the extent of a natural catastrophe and organise efficient relief. If we can succeed in using "swarm intelligence" from social media more effectively in future, it will open up entirely new perspectives for crisis and catastrophe management.

I hope that you find this issue of Topics Geo both interesting and informative.

Munich, February 2015

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

NOT IF, BUT HOW

Contents

IN FOCUS: The spread of social media offers new opportunities for crisis and catastrophe management, not least for the insurance industry.

6

CATASTROPHE PORTRAITS: The snowy winter in Japan was the insurance industry's costliest loss event in 2014. The wintry conditions caught many areas completely unprepared.

18

CLIMATE CHANGE: In 2010, a stable high pressure system hung over Russia for weeks on end, resulting in countless wildfires. Such persistent weather patterns are becoming more frequent.

34

NATCATSERVICE/RESEARCH: New research indicates that while the total number of tornadoes in the USA is not increasing, outbreaks of destructive multiple tornadoes are on the rise.

44

SURVEY
Exemplary management of climate risks at Munich Re

According to a study by the American sustainability organisation Ceres, Munich Re takes an exemplary approach to dealing with risks related to climate change. The ranking was compiled with the assistance of the National Association of Insurance Commissioners (NAIC). Ceres examined documents from 330 insurance companies operating in the USA, which represent 87% of the insurance market.

The experts assessed a range of indicators relating to the subject of climate change, including governance, risk management and investment strategy.

>> More information is available at: **www.ceres.org/resources/reports**

RENEWABLE ENERGIES
Comprehensive protection for green investors

The globally expanding market and the fast-paced development of technology for renewable energies also demand innovation from insurers. The Hartford Steam Boiler Inspection and Insurance Company can now offer a separate "Renewable Energy Insurance" product range, directed at developers, operators and investors.

It covers projects for wind energy generation, solar and photovoltaic systems, facilities for the production of biofuel or the use of biomass, hydropower plants and geothermal systems.

>> More information is available at: **www.hsb.com/renewable-energy-insurance**

IBHS
Progress in hail research

The US-based Insurance Institute for Business & Home Safety (IBHS) reports progress in research into hailstorms. As part of a multi-year project, 2014 not only saw a greater number of natural hailstones being measured than ever before, but also an improvement in hail detection, using what is known as polarimetric radar detection.

The IBHS project is intended to make the use of artificial hail more realistic in material and design tests, and also to improve the accuracy of hailstorm forecasts. Both will ultimately help reduce hail damage. Munich Re America, Inc. is one of the organisations providing financial support to the IBHS.

>> More information is available at: **www.disastersafety.org**

News in brief

Open earthquake platform launched
Following several years of preparation, the Global Earthquake Model (GEM) joint initiative has presented its OpenQuake platform. Its main purpose is to enable emerging and developing countries to assess earthquake risks better. Institutions, scientists and companies will have free access to the platform, which contains data records on loss susceptibility and exposure. Munich Re was a founding sponsor of the GEM and remains one of the main supporters of the project.

USA: Awareness of climate change increasing
Eight out of ten Americans are now convinced that the climate is changing. This is the result of the first Climate Change Barometer, which was published in 2014 by Munich Re America, Inc. Nowhere else in the world is the insurance industry and its clients as seriously affected by the growing number of natural catastrophes as in North America. 71% of Americans believe we need to focus more on renewable energies in order to slow down climate change. 63% of those interviewed stated that they had invested, or wanted to invest, in protection against the consequences of catastrophes. Almost half of the respondents are insured against the consequences of natural events. Over 1,000 US citizens were interviewed for the survey.

Follow us on Twitter! Munich Re has been active on social media for some years on the subject of geo risks. The Twitter account **www.twitter.com/MunichRe** gives notification of Group events, comments or publications. For in-depth reinsurance and nat cat topics, there is the channel **www.twitter.com/MunichRe_InFocus**.

UN applauds commitment to prevention in Australia

Australia has been badly affected by natural catastrophes in recent decades. The costs of such events have risen dramatically, simply because of economic growth and housing density. However, social willingness to invest taxes in preventive measures falls some way behind this development. In 2012, a group of Australian companies therefore formed the Australian Business Roundtable for Disaster Resilience and Safer Communities in order to inform people through publications and studies of the economic and social sense of having a good system in place for catastrophe prevention. Munich Re is one of the founding members of the Roundtable.

The Roundtable last year received encouragement from the UN Secretariat for Disaster Reduction (UNISDR). During a visit to the business alliance, the head of the secretariat, Margareta Wahlström, assured the Roundtable of her full support. At the Munich Re offices in Australia, the UNISDR head confirmed that the approach and objectives of the Roundtable were in full agreement with the strategy of the UN Secretariat. Wahlström applauded the members' commitment, their efforts in creating such an influential group and their lack of self-interest in achieving results. She plans to advocate the Roundtable's recommendations to the Australian government and other stakeholders. Wahlström also invited representatives from the Australian Business Roundtable to participate in the 3rd UN World Conference on Disaster Risk Reduction, which will be held in the Japanese city of Sendai in 2015.

The UNISDR serves as the focal point in the UN for the coordination of disaster risk reduction activities across the globe. One of the key functions of the secretariat is to help build disaster-resilient communities, and generally strengthen the international system for disaster risk reduction. Margareta Wahlström was appointed by UN Secretary General Ban Ki-Moon as the first Special Representative for Disaster Risk Reduction, and has extensive international experience in humanitarian relief operations in disaster and crisis areas. Munich Re has been working closely with the UNISDR and its predecessor organisation for decades.

The Australian Business Roundtable brings together a broad cross-section of Australian institutions, including Investa, Optus, Westpac, Insurance Australia Group, the Australian Red Cross and Munich Re.

>> More information is available at:
www.australianbusinessroundtable.com.au

Saving lives with the help of swarm intelligence

How quickly help arrives in a catastrophe region can mean the difference between life and death. The possibility of using social media to tap into the knowledge of as many people as possible on the ground offers completely new potential for crisis and catastrophe management. But many practical questions are still to be answered.

Be it a cyclone, a flood or an earthquake, people in need rely on prompt assistance. Survivors must be rescued, injured people require medical attention, and vital supplies like drinking water, food and emergency accommodation must be brought into the crisis region. Rescue teams always face the same questions. Where did the worst damage occur? Who is affected? How can we get to certain places? What are the major shortages? And, last but not least: What is the morale of the population like?

The spread of social networks and the availability of online map services are opening up entirely new ways of answering these questions. After all, what makes more sense than using the knowledge of local people to pinpoint where help is most needed? However, this assumes that it is possible to tap into the intelligence of the masses. The conditions to do this have never been better: worldwide, there are approximately seven billion mobile phones. Even in countries with low and medium incomes, nine out of ten people have a mobile phone. This means that, even in remote regions, people are able to send news of unusual events, share photos, and pass on status reports.

Of course, mobile phone networks can crash during major disasters. But in many natural catastrophes in recent years, mobile phones have provided valuable services, even when parts of the network have crashed. Plans by the American Federal Communications Commission to rapidly establish a functioning communications network in an emergency using

Power for mobile phones in the Philippine city of Rosario following the devastation of a typhoon: as sought after as food.

helium balloons or drones are still a vision of the future at this stage. Airborne radio stations could restore mobile phone and internet communications within just a few hours.

Mission 4636 saves lives

The first time that information from the swarm was used on a larger scale was after the earthquake in Haiti in 2010. Real-time posts provided aid organisations with valuable pointers that helped them assess the situation. The project "Mission 4636" was launched shortly after the quake. Those affected on the ground were able to send short messages to the toll-free number 4636. After the first week, Mission 4636 was already receiving more than 1,000 SMS per day, and over 80,000 short messages were received overall. They were assessed worldwide by Creole-speaking volunteers on an online micro-tasking platform. While the original idea had been to collect reports on missing people to facilitate targeted searches, the network was very quickly being used to handle requests for help, provide information on medical emergencies and offer logistical support for hospitals. Using the data submitted, helpers were able to focus systematically on the worst-affected regions and provide help to the people there.

The enormous potential that social media can develop in a catastrophe was illustrated two years later with Hurricane Sandy. When the hurricane made landfall in October 2012 on the US East Coast, internet data traffic in the region doubled in a very short space of time. Within the first 24 hours, a million short messages on the subject of the hurricane were posted on Twitter, Facebook was deluged with posts about Sandy, and ten images per second relating to Sandy were uploaded to Instagram. Needless to say, standard crisis communications using telephone, radio and TV were unable to keep up. The people affected and aid workers did phone in with information, but this either did not reach the crisis team's situation centre, or arrived late. In turn, information from the authorities generally concerned the overall situation in the disaster area, or in particular subregions, and allowed no conclusions to be drawn about the situation at specific locations.

Complex processing of data

But how can the expertise of the masses from the many different channels in the social networks be used as quickly and efficiently as possible to filter out the important information and identify trends? It is clear that analysing the data manually, as was generally the case with Mission 4636 in Haiti, is much too time-consuming and labour-intensive. For that reason, researchers around the world are working to adapt systems to obtain the key information automatically. What is needed is a platform that can summarise the diverse mass of data and then provide them to the authorities or non-government organisations (NGOs) in a clearly organised form.

The rise of mobile phones
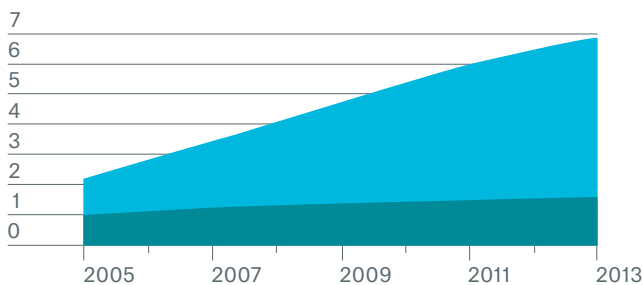
More and more people now own a mobile phone, even in emerging and developing countries.

Number of mobile phone contracts (in billions)

■ Countries with low to medium incomes
■ Countries with higher incomes

Source: ITU, 2013 (estimates for 2013)

First-hand information
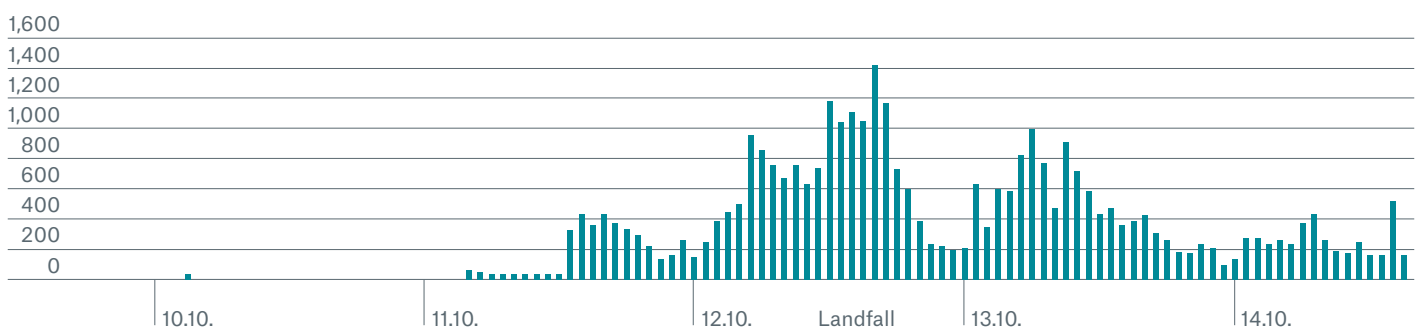
The number of tweets per hour relating to Cyclone Phailin in India peaked during its landfall on 12 October 2013. Up to 1,400 text messages an hour were posted and analysed as part of the forensic catastrophe analysis.

Source: CEDIM annual report 2013

Visual analytics is a promising approach for this, whereby the data is analysed and structured using special computer programs. Simply visualising the flows of messages gives a more precise picture of the situation on the ground: Where are people tweeting more frequently, and on which topics? Are there suburbs or streets that are particularly badly affected? Where are support measures most urgently needed? However, a "geotag" is required to ensure that visualisation provides reliable results. This gives precise information on the location the particular message is coming from. This can pose problems, since for data protection reasons, not all users automatically attach a placemark to their messages.

Online map services provide valuable assistance

This problem also arises with crisis mapping, which is the preparation of catastrophe maps using swarm intelligence. With this approach, known as VGI (Volunteered Geographic Information), information is collected in a structured form about the situation on the ground and then entered into the relevant web applications. One of these is the open source platform Ushahidi, which was developed in 2007 in Kenya, and allows both the affected people in crisis areas and humanitarian organisations to report in a straightforward way on crisis-related events. Using either SMS, e-mail or special web forms, anyone can share site-specific information about destroyed buildings, gaps

For some time now, well-functioning mobile phone communications have been considered essential for catastrophe response. Charging station in Ya'an City, China, after the earthquake in April 2013.

in aid provision, and the like. A group of volunteers then determine the GPS coordinates for the reported incidents and check the information for its reliability. When transferred to a map, this produces an overview that gives valuable pointers on the situation in the crisis region.

The Crisis Response Project from Google, which was set up in response to Hurricane Katrina in the USA, operates in a similar way to Ushahidi. The Google Crisis Map is also based on information obtained from crowdsourcing, but is directed more towards those seeking help than towards aid workers. The former can find information on evacuation zones, hospitals and police stations. Google also provides a special database that makes it easier to conduct targeted searches for missing people.

In the Philippines, crisis mapping proved to be a life-saving tool both before and after Typhoon Haiyan. People were able to monitor precisely in high resolution the probable track of the cyclone and determine which locations were at risk. Users on the ground also supplied crucial information, for example if bridges

had been destroyed, which roads were impassable, and which hospitals could still take in patients.

Crisis management team on the internet

With the crisis mapping for Typhoon Haiyan, invaluable assistance was provided by the standby task force, a network of over 1,000 volunteers spread across 70 countries. The task force is like a crisis management team on the internet, which comes together when required. It has taken on the task of trawling through the internet and social media for information following catastrophes and other events. Anyone with a computer who registers on the homepage can participate. For the volunteers, the standby task force operates as a flexible network, organising the work of its members and motivating them in their efforts.

The work of the standby task force is all the more important because virtually no aid organisation can afford its own social media emergency centre. One exception is the American Red Cross, which has been operating a Digital Operations Center (DigiDOC) since March 2012. It forms part of the Red Cross

Mapping of collective data
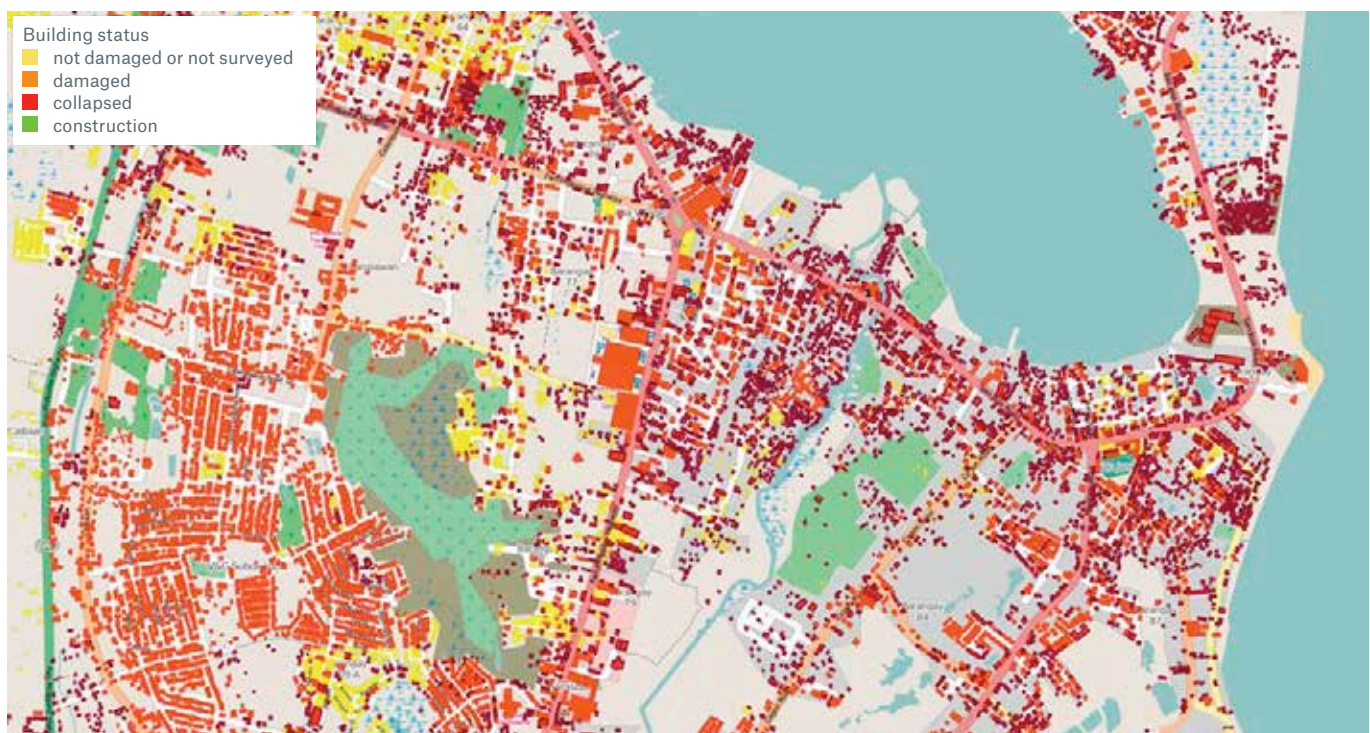
A map showing damage in the Philippine city of Tacloban after Typhoon Haiyan. Members of the non-profit organisation, Humanitarian OpenStreet-Map Team (HOT), had already mapped the housing stock after the region was categorised as at risk. HOT was then able to display the scale of the damage on the map using aerial photos and information from observers on the ground.

Source: OpenStreetMap tiles © OpenStreetMap contributors CC by-SA 2.0

National Disaster Operations Center in Washington D.C. and evaluates news from catastrophe regions on social media platforms. During Hurricane Sandy and in the weeks that followed, more than 2 million posts were monitored, with over 10,000 tagged and categorised. The organisation has also developed a series of apps that warn people at risk from forest fires, floods, earthquakes and windstorms, and which provide crucial information on shelters, etc.

Uniform norms and standards required

There is no doubt that social networks are a valuable tool for managing catastrophe situations. Since they are also useful for quickly determining the extent of damage, they are also of increasing value for insurers (see the following article on forensic disaster analysis). But these digital tools still provide only some of the many functions needed for comprehensive situation reports. Up to now, the mass of information and messages has been difficult to process because there are not many suitable ways of filtering it. For example, with the earthquake in Haiti, Ushahidi was only able to display around 3,500 individual items of information on the map. A further problem is the lack of data validation: Is the information correct, does it describe the situation in detail, and can it be connected to a precise location?

Uniform norms and standards would be helpful to exploit the full potential of this tool. What may prove to be a hindrance in this context is the range of different crowdsourcing platforms. While they all follow the same objective, they use different approaches and implementation mechanisms. For example, the Humanitarian OpenStreetMap project, launched in 2009, has set itself the further goal of assisting aid measures worldwide by coordinating the compilation, production and distribution of catastrophe maps. The biggest problem in connection with the use of information from social media remains the absence of standards for data collection. A proper framework needs to be established here to facilitate the flow of information between different platforms.

However, there is a good chance that the weaknesses of crisis mapping can be eliminated over the next few years. A forum for this has already been established in the form of the annual International Conference for Crisis Mappers (ICCM). Since 2009, representatives from leading development and media organisations have been meeting at this event with technology companies, software developers and scientists to initiate new projects and promote innovation in the field of humanitarian technology. In addition, the international network of crisis mappers (Crisis Mapper Net) provides valuable stimulus. It comprises over 7,000 members in more than 160 countries, and has good connections to more than 3,000 different institutes, including more than 400 universities.

Users on the ground also supplied crucial information, for example if bridges had been destroyed, which roads were impassable, and which hospitals could still take in patients.

Systematic research into causes

What conditions are most relevant for natural hazards to become catastrophes? Forensic disaster analysis can provide answers to this question. Supplemented by real-time information from social media platforms, this approach is perfectly suited to the rapid creation of reliable loss estimates in a crisis region.

Forensic investigation of disasters is a relatively young research approach, developed by the international research programme, Integrated Research on Disaster Risk (IRDR). The analysis here extends beyond the natural event itself to uncover the root causes of disasters through in-depth investigations.

Near real-time analysis to estimate losses

The Center for Disaster Management and Risk Reduction Technology (CEDIM), an interdisciplinary research institute founded by the German Research Centre for Geosciences and the Karlsruhe Institute of Technology, has adopted this research approach and added to it a component for near real-time analysis. Using modern monitoring and analysis techniques, the scientists involved focus on the diverse interrelations between technology, people and society. They search for the crucial factors that are most relevant for the extent of damage and use these to derive prevention measures. The near real-time component makes it possible to obtain information on the type, extent and consequences of a catastrophe within hours or days, and to track the course of a catastrophe. This component is important because the flow of information and user interest are normally greatest immediately after a catastrophe occurs.

As part of its research activities, CEDIM adopts and applies its own models and tools for rapid loss assessment. In addition, it evaluates information available from the internet via social networks such as Facebook, Twitter, YouTube or Flickr. Each active user of these networks is seen as a mobile virtual sensor. "Social sensors" like these offer decisive advantages over technical sensors, which only provide data for individual points and for just a few measurement parameters. They are mobile, collect a variety of information and can disseminate such information through various channels.

One disadvantage with the enormous quantity of information is that the data is frequently of a subjective character and of varying quality. To make the data of practical use for disaster management purposes, CEDIM launched the "Crowdsourcing" project. Its goal is to find suitable methods and procedures to filter the appropriate data from the mass of information and assign it to a specific event and particular location.

Sandy was the acid test

The CEDIM interdisciplinary forensic team has already analysed a number of disasters. These include the June 2013 floods in Germany, Cyclone Phailin, which swept across India in October 2013, and Super Typhoon Haiyan, which caused widespread devastation in the Philippines when it made landfall with the highest wind speeds ever recorded. In the latter instance, the CEDIM experts managed to make realistic assessments of the loss and the number of victims within just a few hours.

CEDIM was also active with Hurricane Sandy, which moved across the Caribbean to North America in October 2012. The forensic task force started its work immediately after the storm reached the US East Coast. The experts used the platform Twitter as an almost real-time component, collecting more than 5 million tweets and storing them in a database. The information was then filtered on the basis of keywords like hurricane, flood, damage, victim or power outage. About 3% of the tweets included geo-coordinates, which were then used for further evaluations. Since floods in urban areas are difficult to monitor, these eyewitness reports proved a valuable source of information. Tweets like "Sandy floods 63rd Street", "The Conestoga River still has a couple of feet before reaching the bank" and "Some may not have power but we all have phones connected", helped give an indication of what was happening on the ground. A good picture of the nature and scope of the damage thus emerged from the spatial and temporal distribution of the short messages.

The example of Sandy illustrated the potential for real-time analysis using the internet and social media. In conjunction with historical loss and event databases and suitable analysis tools, it was possible to make reliable statements on the extent of the loss within a short time. On 7 November 2012, roughly one week after the event, CEDIM presented estimates of direct and indirect losses for the states of Pennsylvania, New Jersey and New York that came very close to the actual figures. They were more precise than figures from professional risk modellers, although the latter were admittedly available somewhat earlier. In the conflict of interests between, on the one hand, obtaining loss information as early as possible, and on the other hand, uncertainty, each user has to weigh up which is more important. With forensic disaster analysis, through the evaluation of big data from social media, it is at least possible to put loss estimates on a broader footing shortly after an event has occurred.

The spatial and temporal distribution of tweets allows useful conclusions to be drawn about the course of a natural catastrophe. In the case of Superstorm Sandy, which struck the East Coast of the USA at the end of October 2012, the number of short messages increased in tandem with the intensity of the storm. Over the following days, the activity of Twitter users then gradually declined.

The illustrations show the number of tweets per 5 km x 5 km grid cell.

Source: CEDIM

⬜	0
🟦	1 – 2
🟦	3 – 5
🟩	6 – 7
🟩	8 – 10
🟩	11 – 12
🟩	13 – 15
🟩	16 – 17
🟩	18 – 20
🟩	21 – 22
🟨	23 – 25
🟨	26 – 30
🟨	31 – 35
🟨	36 – 42
🟧	43 – 52
🟧	53 – 62
🟧	63 – 75
🟧	76 – 90
🟧	91 – 152
🟥	153 – 635

Tweets during Sandy

28.10.2012
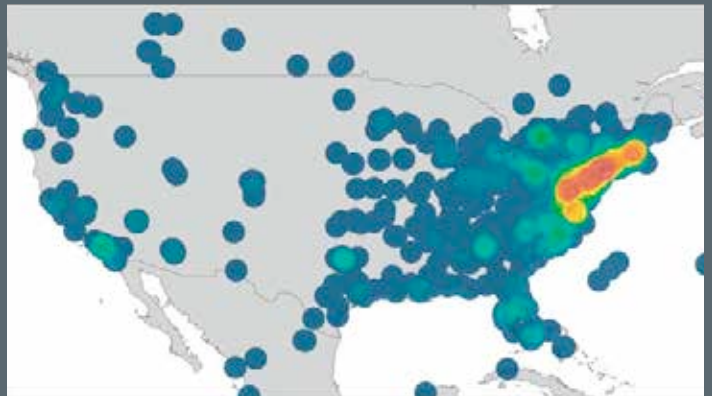
30.10.2012

31.10.2012

02.11.2012

Like looking for a needle in a haystack

With its forensic disaster analysis, the Center for Disaster Management and Risk Reduction Technology (CEDIM) has launched a new kind of interdisciplinary research. TOPICS GEO talked to project leader Stefan Hinz about the possibilities and limitations of mobile crowdsourcing for the analysis of natural disasters.

Since 2008, Dr. Stefan Hinz has been Professor of Photogrammetry and Remote Sensing at the Karlsruhe Institute of Technology (KIT). His main areas of research are developing methods for automated image and data analysis, including applications in the field of geoinformatics. Within CEDIM, he is project leader for research activities in the field of crowdsourcing.

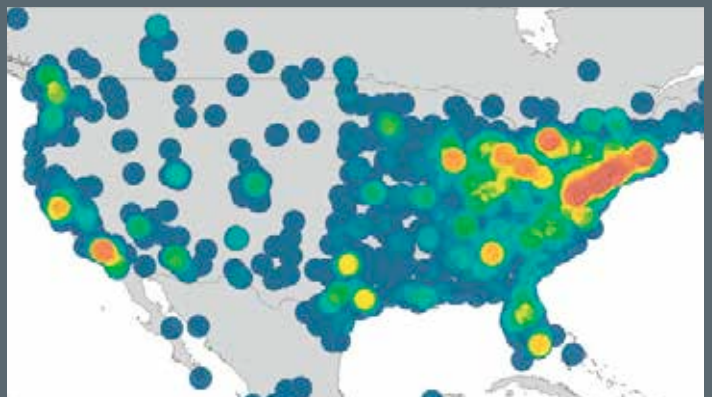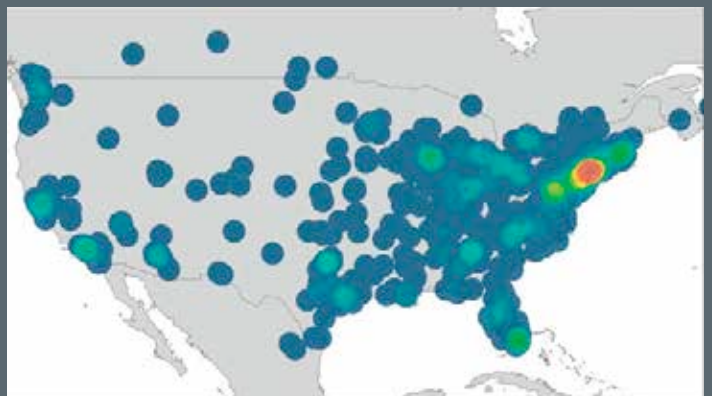### When did CEDIM first engage in large-scale crowdsourcing?

The phenomenon of mobile crowdsourcing first appeared just over ten years ago. That was when the first smartphones came onto the market, enabling every user to record specific data and provide them immediately in digital format. At CEDIM we have been using crowdsourcing to analyse natural disasters for around two years. We have been very impressed with the results, especially in terms of the speed of information provision. We can currently localise many disasters worldwide within the first three minutes after people are affected.

What are the biggest problems in terms of practical use?

You need to distinguish between purely technology-based and scientific challenges. On the technology side, the first task is to define practical, standardised interfaces. The difficulty here is that, depending on the operating system of the smartphone or the app used, the definition of data and attributes can vary greatly. In practice, finding solutions in this area requires a lot of time and effort, since it involves recording and processing millions of individual data submissions. From a scientific perspective, the challenge is to extract and correctly assess the relevance of a piece of information. Of course,

most users do not tweet or post images on the internet in order to help us evaluate disaster-related data. So we have to filter out the information that is most useful for our analysis from a mass of unstructured data. This can be like looking for the proverbial needle in a haystack.

Where is the search most productive? Are there particular social networks that you prefer?

We are forced to concentrate on particular applications because otherwise our resources would simply not be sufficient. One of our favourites is the short message service Twitter. It is used worldwide and users respond to developments very quickly. Then there are also special apps and services, like Ushahidi or Google Crisis Response, that are used during natural disasters. The advantage with these is that the information you obtain is provided systematically, if only to a limited degree. This is because you need to have someone on the spot who is registered with the special service, and who distributes suitable information.

How do you go about analysing the enormous amount of data?

Since we cannot monitor all the information communicated, we initially restrict the selection of data on a regional basis. This is done automatically using algorithms, into

which we incorporate background information such as population density. One approach that has proved useful is to compile statistics over a longer period on how many reports are normally made on certain topics. Once this kind of background noise is defined as the normal state, special features are easy to spot. Using text analysis techniques, you can then determine whether a particular word, for example "storm", occurs more frequently than usual. In a second stage, you need to establish whether the anomaly is connected with a natural event, or whether a different reason is responsible.

How many different terms do you analyse on a regular basis?

Depending on the language, a targeted search is performed for between 20 and 50 specific words. Of course, this will depend on the level of specialisation, in other words on whether a term like hail is included in the list. The selection must not be too big, as otherwise

evaluation becomes more and more complex. Besides, our service at CEDIM does not focus exclusively on monitoring current events. As part of our research work, we try to refine the analysis and develop new versions that remedy past shortcomings.

What steps do you take when you identify an anomaly for a particular region?

Our work is actually done once we have ascertained, after analysing the online data, that a serious event is involved. An automatic e-mail alert is then sent to our cooperation partners. The local authorities and aid organisations decide what happens on the ground. That is not our role. However, we have also taken on the task of analysing the course of a natural disaster retrospectively. We want to identify certain causal links. For example: What effect did a landslide have on energy supplies in a region, and in turn, what repercussions did that have on the transport system? If we can identify how different factors in a disaster interact, we can prepare better for future events.

Many crisis managers are somewhat critical of crowdsourcing in terms of the data quality involved. Can big data and crowdsourcing really live up to their promised potential for crisis management?

It is very difficult to apply an absolute quality standard here because there is no reference available for it. For example, how do you define a 100% recall rate for crowdsourcing? But that does not have to be the decisive factor. The added value lies in obtaining key information more rapidly when a disaster occurs. So it's all the more important that the algorithms provide measures of quality and confidence about the identified information. At any rate, crowdsourcing has

more than proved its value overall, because you obtain data from many different sources, rather than from a single or just a few monitoring points.

How could norms and standards be harmonised to enhance the potential of big data?

We have to be realistic about this. The manufacturers of smartphones and the developers of social media platforms have commercial objectives. Crowdsourcing for humanitarian purposes is not very high on their agenda. That being so, we have to try to make the best possible use of what the market offers us.

What are the prospects for cooperation between different crowdsourcing platforms?

Such approaches are already being used in the science sector, although efforts at an operational level are still at a very early stage. We have found that relief organisations are happy to receive any information they can from crowdsourcing. But there is definitely a need for more active cooperation.

The general public has become much more aware of the topic of data protection. How can contributors to crowdsourcing be protected against data abuse?

That is a subject that is not just relevant for crowdsourcing. Many apps force the user to approve the use of certain data, such as their location or contact lists, even if these are not needed for the use of the app. Each person should have full control over their privacy. However, in reality things are a little different. After all, who is really sure what rights they have granted to the operator of an app? I think that this is a job for the politicians. They need to push for standardised regulations similar to those that apply for roaming within Europe. Greater transparency would certainly be an advantage for crowdsourcing. As a user, I can make a conscious choice once I know who would like to view which data.

If you venture a look ahead, how do you see mobile crowdsourcing developing over the next few years?

If you just consider the sophisticated algorithms that online retailers and advertising marketers are already using to analyse customer behaviour, we can expect major progress. If you extend these technological possibilities to crowdsourcing for natural disasters, substantial improvements could be achieved, especially in terms of the quality of information selection. Of course, politicians may scotch these developments on data protection grounds, in which case progress will certainly be less dynamic.

20 years of Topics Geo Natural Catastrophes

Records

US$ 210bn
2011 earthquake in Japan is the costliest loss event of all time.

US$ 62.2bn
Hurricane Katrina in 2005 produced the highest insured losses.

222,500
2010 earthquake in Haiti set a sad record – the highest death toll in the period 1980 to 2014.

2011
Costliest year for natural catastrophes, not only in economic losses but also for the insurance sector.

Source: Munich Re NatCatSERVICE

Fatalities

13
Asian countries were hit by the tsunami on 26 December 2004, claiming at least 220,000 lives around the Indian Ocean.

70,000
perished during the European heatwave of 2003.

140,000
died following Cyclone Nargis in Myanmar in 2008.

Percentages

88%
of all natural events worldwide were weather-related in the period 1980 to 2014.

40%
of the overall losses from 1980 to 2014 occurred in Asia.

64%
of the insured losses were incurred in North America (incl. Central America and the Caribbean) in this period.

1994
Earthquake in Northridge, California, floods in the southern Alps*
1995
Earthquake in Kobe (Japan) and Sakhalin (Russia), floods on the Rhine
1996
Floods in China, eruption of Vatnajökull volcano (Iceland), Hurricane Fran (USA) and flash floods near Biescas (Spain)

1997
Floods on the Odra (eastern Europe) and along the Red River (North Dakota, USA)
1998
Floods on the Yangtze and Songhua rivers (China), Hurricane Mitch (Central America), icestorm in Canada and cyclone in India
1999
Floods and landslides in Venezuela and earthquake in Izmit (Turkey)
2000
Floods in Mozambique, flash floods and landslides in the southern Alps and Typhoon Saomai (Japan)

2001
Floods after Tropical Storm Allison, Houston (Texas, USA) and earthquake in Gujarat (India)
2002
Volcanic eruption of Nyiragongo, (Congo), Typhoon Rusa (Korea) and the Elbe floods in central Europe
2003
Heatwave in Europe, wildfires in Portugal and earthquake at Bam in Iran

2004
Tsunami in the Indian Ocean and Hurricane Ivan in the Caribbean and the United States
2005
Hurricanes Katrina and Wilma (Caribbean and USA)
2006
Snow disaster in central Europe
2007
Winter storm Kyrill (north and central Europe) and Cyclone Sidr (Bangladesh)
2008
Cyclone Nargis (Burma) and earthquake in Sichuan (China)

2009
Black-Saturday bush fires in Victoria (Australia)
2010
Earthquake in Haiti
2011
Tsunami in Japan and floods in Thailand
2012
Hurricane Sandy (Caribbean and US East Coast)
2013
Typhoon Haiyan (Philippines)

* Pictures for each year from left to right

1994 · 1995 · 1996 · 1997 · 1998 · 1999 · 2000 · 2001 · 2002 · 2003 · 2004 · 2005 · 2006 · 2007 · 2008 · 2009 · 2010 · 2011 · 2012 · 2013

It was twenty years ago that the geoscientists at Munich Re first produced a detailed review of the previous year's natural catastrophes. Much of what was written in that rather succinct review can be found in today's issues of Topics Geo: an "increasing influence of climate changes [...] on the frequency and intensity of natural catastrophes" is identified in the 1995 issue, along with "exceptional increases in average global temperatures", which "increases the probability of windstorms, storm surges, tempests, floods and other extreme events". This basic tone has remained throughout the 20 issues that followed the first one. It is not just that the number of natural catastrophes studied over the decades has increased, for example due to the increase in population and assets, the spread of urbanisation and as a result of climate change, but that the impact of these events (as anticipated) has also become much greater and more costly. The series impressively illustrates how our understanding of the origins and effects of natural hazards and their impact on the insurance industry has grown.

The winter of 2013/14 in the northern hemisphere

Large parts of Japan were hit by catastrophic snowfall in February 2014, while the US suffered record low temperatures in December 2013. Meteorologically, these two winter events are probably connected.

Mark Bove and Eberhard Faust

The Arctic is dominated by a large, quasi-stable area of high pressure caused by sinking cold air. Surrounding this area of high pressure is the polar front, a region where cold, dry Arctic air interacts with warmer, moister air being advected poleward. The temperature and moisture gradients along the polar front cause extratropical storms to form along the boundary, and also give rise to the polar night jet stream that circles the North Pole, moving from west to east.

The strength of the polar night jet, as well as storms along the polar front, depend on the magnitude of the temperature and moisture gradients in the region. These gradients are typically at their strongest in the autumn, causing the polar night jet to intensify and impart additional vorticity, or spin, into the upper troposphere and lower stratosphere. This helps to form and contain a uniform mass of cold air over the North Pole, known as the polar vortex. The vortex acts to keep cold air in place at the pole. The stronger the vortex, the more likely Arctic air will remain there.

But as winter begins, the gradients along the polar front weaken, and the polar vortex cools and stops growing. As winter progresses towards spring, sunlight returns to the Arctic. Some of the light is absorbed by ozone in the stratosphere, warming up the upper atmosphere and weakening the polar vortex. The resulting destabilisation of the polar vortex allows for pieces of the Arctic air to move southward, resulting in cold outbreaks in the mid-latitudes.

Ice-breaking tugboat near Chicago in January. Even for the "Windy City", this winter was a hard one.

Other outside influences can also cause weakening of the polar vortex during the winter season. One such phenomenon is known as Sudden Stratospheric Warming (SSW). An SSW event occasionally occurs when a stationary area of high pressure develops, forcing cyclonic storms to move around it. These blocking patterns create persistent atmospheric flows that can produce large amplitude planetary-scale waves in the troposphere, particularly when moving over mountainous terrain. The energy and momentum of these waves propagates into the polar stratosphere, and act to destabilise the polar jet via a warming of the stratosphere. The stratospheric warming disrupts or destroys the polar vortex, which allows for pieces of the polar air to be pushed southwards.

In late 2013, a blocking pattern developed over the northeastern Pacific Ocean and persisted throughout the entire 2014 winter season. High pressure over this region generated high amplitude waves that destabilised the polar front jet, allowing for pieces of the polar vortex to stream southward across eastern North America. The same ridge caused Arctic air to flow into eastern Asia, resulting in severe winter storms in Japan, and produced anomalously warm and dry weather in western North America, leading to worsening drought conditions in California. At the same time, Europe experienced an unusually mild winter season.

The winter in Japan

Snow is not an unknown commodity in many parts of Japan, but the amount of snow seen in February in the heavily insured regions in and around Kanto was exceptional. The heavy snowfalls occurred between 6 and 9 February and 13 and 16 February and came from a similar weather pattern.

Initially, a trough-like loop of the high-altitude air flow moved across eastern China and, in the days after 6 February, to the northeast across Japan. This trough in the high-altitude air flow was connected to a low pressure area in the lower atmosphere, which accompanied the displacement of the trough off Japan's eastern coast to the northeast.

At the southern to eastern side of this low pressure area, warm, moist air from the Pacific was drawn towards the north at the same time that Japan lay under the Arctic air on the rear side of the low. Where the warm air met the cold air, heavy precipitation developed that fell as snow over Japan.

In Japan, heavy snowfall brought traffic to a standstill in many areas. The snow proved even more damaging for many roofs. In areas unused to such wintry weather, roofs could not withstand the sheer weight of the snow and collapsed.

On 8 February, Tokyo was already buried under 27 cm of snow – a height not measured since 12 March 1969 – when a second heavy snowfall from 13 to 16 February followed. The second weather pattern developed in much the same way as the previous snow event. The cold front's extensive snowfall reached southern Honshu on 13 February and the Tokyo region the next day. Snowfall was especially heavy on the east coast and in the Honshu mountains. On 16 February, there was 250 cm of snow in Tsunan and 43 cm in Fukushima. In Kofu (Yamanashi) the snow level reached 114 cm – the most snow ever recorded since record-keeping began in 1894.

The large volumes of snow brought traffic to a standstill over large areas of the country and cut off towns and villages. At least 16 people lost their lives; several hundred were injured, many of them in traffic accidents. Many parts of the area affected by the snowfall were without electricity. On 15 February, a major airline cancelled 350 flights; leading car production companies temporarily closed their factories.

Record losses for Japanese insurers

Private individuals were particularly affected by the collapse of their carports under the snow's weight. Commercially available carports in the particularly affected prefectures are normally designed to withstand a maximum snow load of 25 cm. Not only were parked cars and other items stored in the ports damaged, but snow falling from roofs and traffic accidents contributed to car insurance losses of about 22 billion yen (US$ 215m). Altogether, almost 66,000 losses were reported.

The snowfall also resulted in significant damage to roofs and gutters of residential property. Some 212,000 claims for insured damage were filed, with losses totalling 232 billion yen (US$ 2.26bn). If waterproof membranes under roof tiles had been damaged, the entire roof structure often had to be rebuilt. On top of this, the hefty demand for skilled tradesman significantly added to repair costs. Additionally, some factory buildings, warehouses, schools and gyms could not support the massive snowfall and collapsed either partly or entirely. In some areas, the snow's weight on the buildings was twice as heavy as the heaviest weight recorded from previous years. Production materials, stored goods and inventory were also destroyed when roofs collapsed.

Estimates for insured damage are over 320 billion yen (US$ 3.1bn), making these storms one of the most expensive for catastrophe damage in the Japanese insurance industry's history. This is typical "mass damage" resulting from an extensive accumulation of small and medium-sized losses averaging US$ 3,000 to 5,000 – similar to what one sees from a winter windstorm in Europe. In comparison, there were fewer large-scale losses. Industrial policies were hardly affected.
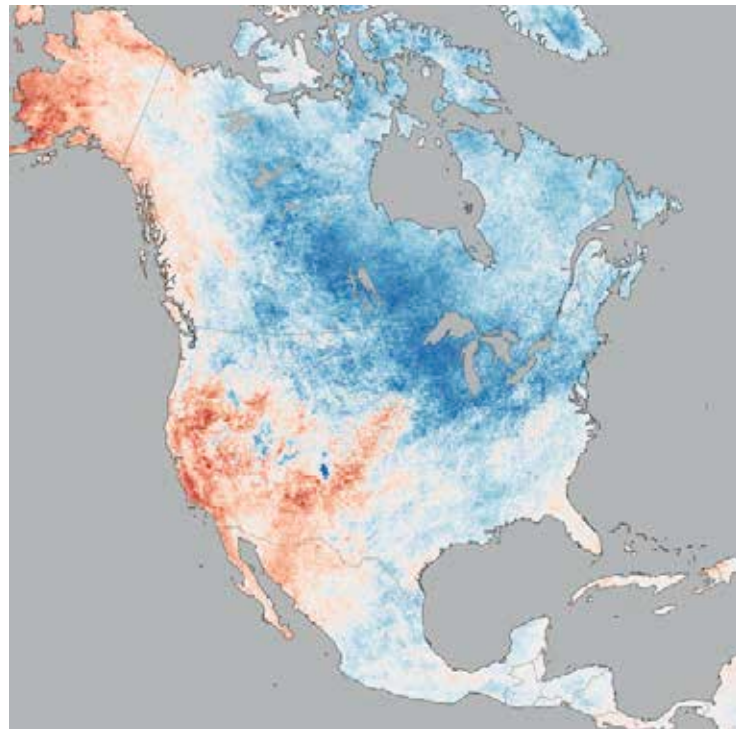
Land surface temperature anomaly (°C)

≤ –8   0   ≥ 8

Average temperature anomalies December 2013 to February 2014. Persistent atmospheric ridging over the Pacific brought warm conditions to western North America and unusually cold conditions to the east.

Source: NASA Earth Observatory

The winter in North America

Some parts of North America also battled bitterly cold temperatures, breaking records – some more than a century old – in a dozen states.

A series of frigid air masses surging south from the Arctic brought record cold temperatures to the eastern United States and Canada. The cold air also helped trigger the formation of several severe winter precipitation events, some as far south as the Florida Panhandle. Although cold air outbreaks are not uncommon during the North American winter, the unusually long duration and intensity of 2014's cold weather has spurred questions regarding the impact of anthropogenic climate change on winters in the region.

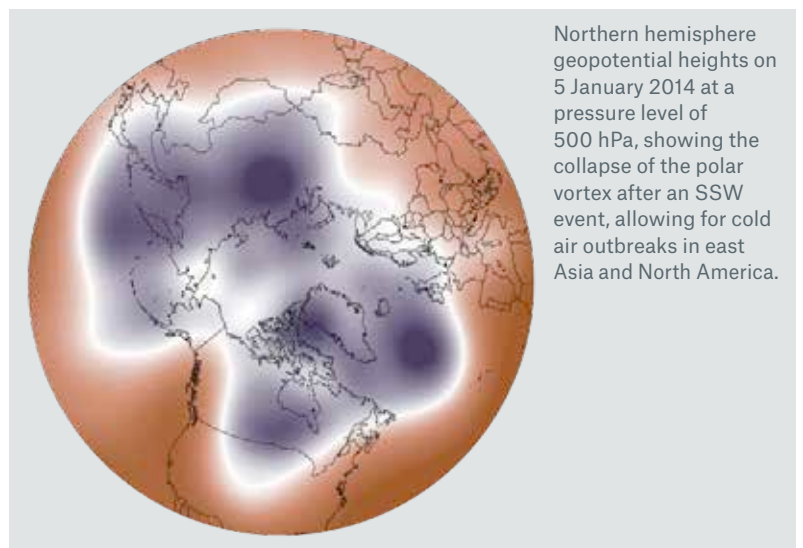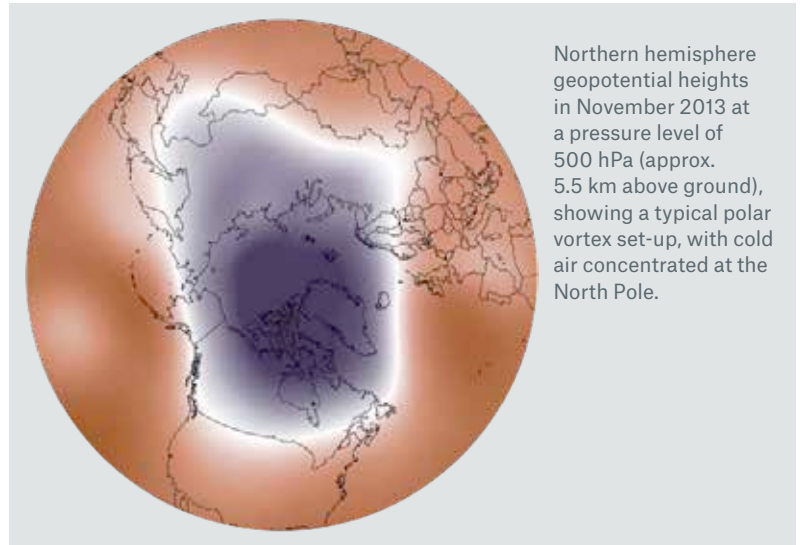Last winter produced two major Arctic air outbreaks over North America. The first occurred in early December 2013, causing unseasonably cold temperatures across the region, but quickly dissipated. The second outbreak, caused by an episode of SSW, started on 2 January and ushered in the coldest air of the season. Record low temperature observations, some dating back to the 19th century, were set in doz-

ens of cities over the next week, including Chicago, Detroit, New York City, Cleveland, and Atlanta.

Although temperatures moderated somewhat by mid-January, the persistent ridge over the northeast Pacific kept forcing Arctic air southward over eastern North America for the next three months, resulting in one of the coldest winter seasons in decades. Twelve states had three-month temperature averages that ranked among the ten coldest on record. New records were set for the lowest monthly average temperatures across many midwestern cities in February, and across New England and the mid-Atlantic regions in March. The prolonged outbreak also caused one of the largest freeze-over events of the Great Lakes in decades. Large icebergs remained in Lake Superior until late May, and their slow melt prolonged unseasonably cool temperatures near the lakes through the summer of 2014.

In all, the combination of extreme cold temperatures and several winter storm events caused an estimated US$ 2.3bn in insured losses, with economic losses of around US$ 4bn. The insured loss total for 2014 is the fifth highest total on record (adjusted for inflation), and almost double that of the 2009–2013 average, but still not extraordinary in comparison with other winter seasons over the past decade. The majority of the insured losses, US$ 1.7bn, stemmed from the January Arctic air outbreak. The majority of claims were due to frozen pipes bursting, resulting in water damage to buildings and personal property. The remainder of insured losses across the winter season were primarily associated with roof damage due to the weight of snow and ice, freezing rain events downing trees and power lines, ice damming on roofs, and automobile accidents due to slippery driving conditions.

Polar vortex

Northern hemisphere geopotential heights in November 2013 at a pressure level of 500 hPa (approx. 5.5 km above ground), showing a typical polar vortex set-up, with cold air concentrated at the North Pole.

Northern hemisphere geopotential heights on 5 January 2014 at a pressure level of 500 hPa, showing the collapse of the polar vortex after an SSW event, allowing for cold air outbreaks in east Asia and North America.

Geopotential height at 500 hPa (metres)

5,000   5,900

Source: NOAA Climate.gov

Insured property loss through winter storms in the US 1980 to 2014

US$ bn

■ Winter storms
— 5-year-average
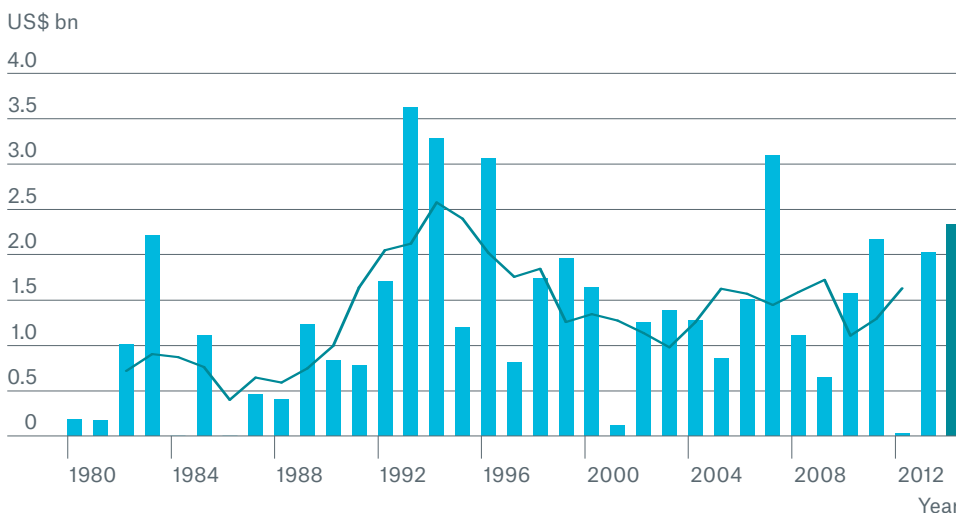
Despite the winter of 2014 being one of the coldest in decades in the United States, insured losses due to winter storms were well below record-setting levels and in line with those seen over the past 20 years.

Source: Munich Re NatCatSERVICE, PCS

Outlook

It is currently unclear whether anthropogenic climate change played any role in the severity and duration of the 2014 winter season across eastern North America. However, new research investigating links between climate change and the northern hemisphere winter give some indications that the Arctic polar vortex is more likely to become destabilised in a warmer world, potentially leading to more mid-latitude cold outbreaks.

There are several potential mechanisms being researched that could link our changing climate to more frequent cold air outbreaks. This first is that the Arctic has warmed dramatically over the past 100 years, and is now 3.5°C warmer than in the late 19th century. Since the development of a stable polar vortex relies in part on strong temperature gradients, the warming of the Arctic means that the gradient between polar air and warmer air to its south is reduced. This gradient reduction might lead to weaker polar vortexes in the future, which would increase the potential for pieces of the vortex to break off and enter the mid-latitudes.

The second potential mechanism is the dramatic drop in sea ice over the Arctic during early autumn. Recent modelling studies have shown that the dramatic loss of sea ice in the Arctic, particularly north of Scandinavia and Russia, may intensify atmospheric wave patterns that can weaken the polar vortex through SSW. Other research gives hints that persistent areas of high pressure in the North Pacific – like 2014's "Ridiculously Resilient Ridge", which lasted through most of the year and is linked to both the cold weather across eastern North America and the drought in California – may form more often in the current climate regime than in one without the anthropogenic greenhouse effect, giving a third mechanism for more Arctic air outbreaks in a changed climate.

It should be noted that all research noted here is preliminary, and it will take years of further research to determine what, if any, role anthropogenic climate change has on the frequency and severity of Arctic air outbreaks. But given the rapid changes being observed in the Arctic, it is likely that anthropogenic climate change will play at least some role in what to expect from winter seasons in the future.

Underwriting aspects

The snow damage in Japan clearly showed what a large effect a relatively small geographic shift in a weather pattern can have, for a country that is no stranger to weather phenonema like heavy snowfalls, when it hits an unprepared region. It remains clear that insurance purchasers need to buy coverage for precisely such events, and that it is the responsibility of the insurance industry to deal with the losses in a manner that is as efficient and uncomplicated as possible for the policyholders. Snowstorms along with wind, floods, hail, heavy rains, tidal waves (except for tsunamis) are covered in Japanese Cat XL contracts as well as in proportional fire treaties.

Despite winter perils being covered by most insurance policies in North America, insured loss potentials due to winter storms are typically not as severe as those from tropical cyclones and thunderstorm perils. For example, winter storm losses over the period 2009–2013 have averaged US$ 1.3bn per year, but losses from tropical cyclones and thunderstorms over the same time period have averaged US$ 7.7bn and US$ 15bn respectively. As a result, winter storms are often considered a secondary peril in the US reinsurance market, with Cat XL structures typically designed to protect against tropical cyclone or earthquake loss potentials. But despite this designation, winter storms still need to be considered by the underwriter assessing business risks.

OUR EXPERTS

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Winter in the British Isles: Water, water, water

In the winter of 2013/14, a succession of storms swept across the United Kingdom and Ireland, creating storm surges on the coasts that caused considerable damage. On top of this, many places experienced record rainfall, resulting in widespread and persistent flooding.

Tobias Ellenrieder

Two factors were to blame for the stormy, wet conditions: firstly, the North Atlantic jet stream assumed extreme proportions in terms of position and strength in the winter of 2013/14. Part of the reason for this was the cold snap that was experienced at the same time in North America. The prolonged and fixed position of the jet stream over the North Atlantic assisted a flow that continuously channelled low pressure systems over the British Isles. In addition, what are known as Atmospheric Rivers carried large quantities of moisture from the tropical Atlantic in the direction of Europe.

One storm surge after another

An area of low pressure had formed south of Greenland in early December 2013, intensifying rapidly on its path eastwards. This storm, named Xaver, produced hurricane-strength winds and storm surges on the east coast of Britain, as well as in the Irish Sea and on the North Sea coasts of mainland Europe.

At the beginning of 2014, winter storm Anne brought further storm surges to the North Sea coasts between France (Brittany) and Scotland. Worst affected were the counties of Devon and Cornwall in southwest England, where 130 buildings were damaged. The River Severn experienced increased tidewater (Severn Bore) from the storm surge, which led to flooding in Gloucestershire.

A storm surge also developed off the coast of Ireland during the storm that affected virtually the entire coastline. However, its impact was greatest in the south and west of the country. The city of Cork and surrounding areas were particularly hard hit. In Wales, many people were forced to abandon their endangered homes on Cardigan Bay.

February 2014: While giant breakers batter the town of Porthleven in Cornwall, large parts of the Somerset levels are submerged under water.

Just a few days later, Christina (also referred to as Hercules) was the next winter storm to hit Ireland. Its storm surge flooded large sections of the country's west coast, in particular the region between Galway and the mouth of the Shannon. Finally, in early February, winter storm Petra brought a further storm surge that wreaked the worst damage in 50 years along the south coast of England. Some sections of the railway line in Devon were washed away, while parts of Cork in Ireland flooded once again.

Inland areas also affected

If the focus at the start of the 2013/14 winter storm season was on storm surges, the emphasis over the following weeks shifted to floods in inland areas. In addition to high wind speeds, storm surges and high waves, the succession of low pressure areas also brought vast quantities of rain. Increased groundwater levels also caused problems in many places.

By mid-December 2013, the soil in many regions was already extensively waterlogged. The additional rain around New Year triggered numerous flash floods and caused smaller rivers to burst their banks. In Somerset, the floods persisted for several weeks, covering several thousand hectares of farmland and affecting 600 homes.

At the start of February, following yet more rain, larger rivers like the Avon, Wye and Teme also became swollen. On the Severn, the longest river in the UK, the water levels registered at Worcester were higher than in the disastrous summer of 2007. Gloucester and Tewkesbury were also hit by the floods, along with many other smaller towns.

On the River Thames, more than 2,400 buildings flooded in the counties of Berkshire and Surrey. The Greater London area was spared, basically because the Thames, being a tidal river, has a much greater discharge capacity and also because the masses of water can be controlled by the Thames Barrier.

Scale of damage

The floods in the winter of 2013/14 in the United Kingdom and Ireland caused overall economic losses of US$ 1.5bn. As well as residential buildings, household contents, commercial and industrial premises, infrastructure and agriculture were also affected. Insured flood losses came to US$ 1.1bn in the UK alone. Almost 19,000 claims were made to insurers, two-thirds of them from homeowners and business people. The losses were much smaller than the record figures from the summer of 2007, the reason being that the floods on this occasion were mainly confined to the flood plains and less densely populated areas.

Record rainfall

The winter of 2013/14 in the United Kingdom and Ireland was the stormiest in at least 20 years. From mid-December to mid-February, a total of twelve major winter storms swept over the region. In the south of England, January was the wettest on record since 1910. There are even indications that the levels of rainfall in England and Wales were the highest in almost 250 years. In southern England, 1961 was the last occasion when it rained on so many days of the year. In many parts of Ireland too, the winter of 2013/14 was the wettest since records began.

Most river levels, on the other hand, did not set new records. But what was remarkable was the duration of the floods. The combined outflow from British rivers was the highest since records began in 1961. In London, the Thames Barrier was raised a record 50 times. This was not only to protect against storm surges, but also to relieve the swollen Thames. By way of comparison, since its completion in 1984 the barrier had previously only been activated 124 times.

Overall, the winter of 2013/14 once again demonstrated that it is not only single extreme events that can cause high economic and insured losses. Even several successive events that are moderate in themselves have dire consequences.

OUR EXPERT

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Floods in the Adriatic

In May 2014, the western parts of south-eastern Europe experienced the heaviest rainfall since records began almost 120 years ago. In some cases, ten times the monthly average fell, and local amounts of 300 millimetres were recorded in the space of just 48 hours. Flash floods, landslides and river flooding claimed the lives of 86 people and caused economic losses of more than US$ 3bn.

25 people were drowned in the Serbian town of Obrenovac after the Kolubara river burst its banks.

Wolfgang Kron

Intense rainfall and floods are nothing unusual in the Adriatic region, but the events in the spring of 2014 were extreme. An area of low pressure, extending to high altitude and fed with warm, moist air masses from the Mediterranean, had formed in the region in mid-May. The principal rainfall zone lay between Banja Luka and Belgrade. Over several days, it rained so heavily in parts of Serbia, Bosnia-Herzegovina and Croatia that some places received a third of their average annual rainfall. In the mountainous regions, this was followed by thousands of landslides and debris flows, while in the river valleys flood waves formed that inundated villages and towns.

Damage to buildings and agriculture

In the three countries affected, tens of thousands of houses were destroyed or damaged, with Serbia and Bosnia-Herzegovina hardest hit. Hundreds of kilometres of roads, railway lines and several bridges were damaged or destroyed in the floods. Energy and water supplies were disrupted in places. There was also enormous damage to farming areas, and it will be years before the agricultural sector, so important for these countries, will be able to recover from the disaster.

Worst affected was the Serbian town of Obrenovac, which lies at the confluence of the Kolubara and Sava rivers southwest of Belgrade. 90% of the town was left under water, in some areas several metres deep, after the river level had rapidly risen by seven metres. All of the 25,000 inhabitants had to abandon their homes. In the Drina valley in western Serbia, the town of Krupanj was cut off from the outside world for three days. In Sabac, further north on the Sava, army units just managed to prevent a dyke from breaking; the resulting deluge would probably have flooded the entire town. Once the flood wave on the Sava had reached the River Danube in Belgrade, the worst was over. The Serbian capital itself was spared serious damage.

Coal production falters

Serbia generates a large percentage of its electricity from domestic coal, two-thirds of which comes from open-cast mines in the Kolubara region. The Kolubara river flooded some mines completely, some partially, with the result that coal production came to a standstill. The country's power stations were then forced to cut back production by almost half, leaving 110,000 people temporarily without electricity. Added to the material damage of around US$ 250m in the energy sector was a further US$ 400m in business interruption losses. The overall losses from the floods in Serbia are likely to be US$ 1.5bn, equivalent to 3.5% of the country's GDP. An additional 2% can be added to this figure for indirect losses.

Areas of the Balkans affected by flash floods, landslides and floods in May 2014.

Source: Munich Re, based on data from ECHO, EC-JRC

■ Affected
■ Severely affected

At US$ 1.7bn and 9.5% of GDP, losses were even greater in Bosnia and Herzegovina. The main disaster area was in the valley of the Bosna river. 43,000 residential buildings were flooded, 1,950 were destroyed, and 130,000 people had to find temporary shelter. Here too, energy and water supplies were severely disrupted. A major hazard was also posed by the countless landmines left over from the Bosnian war. Rescue efforts were seriously hampered by concerns about explosive devices that had been swept from the soil.

Comparison with the 2013 floods in central Europe

There are remarkable similarities with the previous year's floods in central Europe. These include the high level of soil moisture at the start of the rains, and a stationary low pressure system, whose rain intensity was enhanced by mountain ranges (see Topics Geo Natural Catastrophes 2013). However, despite all the parallels, there was one crucial difference: despite the fact that, at approximately 100 mm, the average rainfall in the region affected in May 2014 was significantly lower than in central Europe in 2013 (over 200 mm), the consequences were more serious this time around. This suggests that Germany, Austria and the Czech Republic have much more effective flood protection systems in place than their poorer southern neighbours. In addition, deforestation, river training and the uncontrolled growth of unauthorised settlements in exposed areas – sometimes of an appalling construction quality – all contributed to the scope of the loss. Notwithstanding the high financial burden involved, reconstruction in the different countries does present an opportunity to remedy some of the structural deficits.

Insurance issues

In spite of the high economic losses in some instances, insured losses in all three countries were extremely modest, at around 2%. The reluctance of private households to purchase insurance may well be because many people in the region have more pressing problems than protecting themselves against natural hazards. Educating people about the sense and purpose of insurance cover and introducing compulsory insurance for certain risks (similar to the Romanian insurance pool PAID) could improve matters. Nevertheless, it is doubtful whether people in the region can protect themselves efficiently against natural hazards using only their own resources. General measures are needed to protect against floods, and these are predominantly tasks for the public authorities. The respective governments therefore have an obligation to make greater efforts to minimise the extent of damage in future floods.
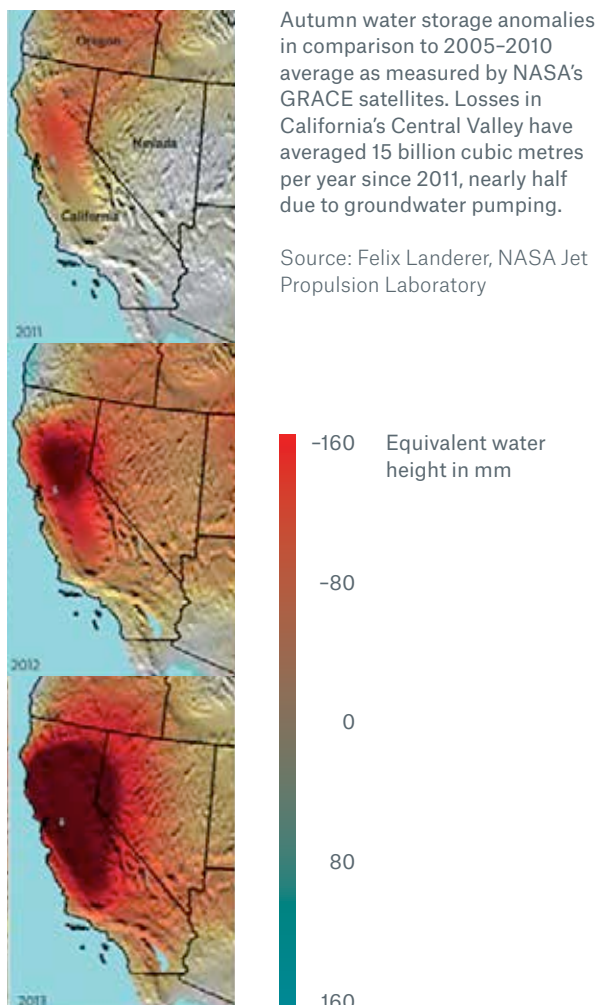
OUR EXPERT

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Record drought in California

California experienced its hottest and fourth driest twelve-month period on record through the end of October, which left nearly 82% of the state in extreme or exceptional drought conditions, up markedly from 11% just one year prior. The escalation of the drought, which began in 2011, prompted the declaration of a drought emergency by the state's governor and a federal natural disaster area declaration for all 58 California counties.

Water storage is shrinking

Autumn water storage anomalies in comparison to 2005–2010 average as measured by NASA's GRACE satellites. Losses in California's Central Valley have averaged 15 billion cubic metres per year since 2011, nearly half due to groundwater pumping.

Source: Felix Landerer, NASA Jet Propulsion Laboratory

Equivalent water height in mm

−160

−80

0

80

160

Andrew Moore

The climate across California is characterised by dry summers and wet winters, with more precipitation falling across the northern parts of the state and in the mountains. Most of the annual precipitation falls from storms rolling in off the Pacific Ocean as the jet stream shifts south from October through April.

The severity of the 2014 drought was caused by an atmospheric pattern dubbed the "Ridiculously Resilient Ridge" that kept the jet stream and associated Pacific storms well north of California for most of the winter wet season. While recent research is inconclusive as to whether anthropogenic climate change contributed to this persistent pattern, several studies on the event have concluded that an expansive area of warmer than normal ocean surface water centred in the northeast Pacific played a significant role.

Impact on agriculture

The state snow survey in early April, representative of the peak accumulation for the season, found only 32% of average snow accumulation statewide. The final May survey showed the limited snowpack rapidly melting down to only 18% of normal. Downstream, the state's seven largest reservoirs were holding 25% of their capacity and only 42% of their average storage at the beginning of November, down from 68% one year prior.

California is the number one agricultural producer in the United States, providing nearly half of the nation's fruits, nuts and vegetables, and generating US$ 42.6bn in revenue. The 2014 drought caused the greatest absolute reduction in water availability for the industry in history, driven largely by a deficit of available surface water of nearly 37% of the sector's total annual water usage. Estimates of the economic toll on the state's agricultural industry are US$ 1.5bn in direct losses, and US$ 2.2bn total economic losses. The losses could have been much worse were it not for the ability of groundwater pumping to replace nearly 75% of the surface water deficit and save most of the more profitable, permanent crops.

Pumping groundwater to dampen drought effects has been ongoing in California since as far back as the late 19th century, though its recent escalation has raised sustainability concerns. Combining research completed by the United States Geological Survey with NASA satellite data shows that the average rate of groundwater depletion in the state's Central Valley agriculture region accelerated from an average of 1.5 billion cubic metres a year from 1961–2000 to 3 billion cubic metres a year from 2003–2010, to over 7 billion cubic metres a year from 2011–2014, or over 85% of the annual public water consumption.

Increased groundwater pumping also has a significant economic and environmental toll. Its impact is estimated to have to cost California agricultural interests an additional US$ 454m in 2014, while the practice over time has resulted in land subsidence of up to 10 metres in areas of the Central Valley, and has reduced water tables by over 30 metres in places, causing many wells to dry up. The mounting costs combined with the uncertainty around future climate conditions and an enhanced recognition of the state's groundwater dependence prompted California to pass legislation on groundwater usage in September – ending its status as the last western US state without any groundwater regulation.

No clear trend for precipitation

A review of statewide average annual temperature and precipitation data since 1895 does not show any clear trend for precipitation, but does show an accelerating positive trend in temperature. Absent any increase in precipitation, rising temperatures favour more periods of drought in the state as the extra heat increases evaporation and favours earlier snowmelt. This temperature-driven trend towards increasing drought conditions is evident in the time series of the Palmer Drought Severity Index for the state since 1895.

While climate model projections show strong consensus of continued warming in California through the 21st century, there is less consensus on future precipitation trends across the state. In a warming climate, most models suggest an increase in moisture available to Pacific storms as the warming air is able to carry more moisture. A majority of projections show the polar jet stream trending north, leaving southern California drier with less frequent storms, while there is greater uncertainty on precipitation trends for northern California.

A weak El Niño and a weakening and eastward shift in the anomalously warm ocean surface water in the northeast Pacific has ended the reign of the "Ridiculously Resilient Ridge" and brought slightly above-average precipitation across California through the first half of the winter of 2014/15. However, even as there has been some easing in local drought conditions, the extreme deficits in ground and surface water caused by the recent drought are likely to cause problems into the foreseeable future.

Lake Oroville, a gigantic reservoir northeast of San Francisco, shown in a photo from August 2014 when its storage volume was down to 32% of capacity.

OUR EXPERT

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Cyclone Hudhud rages over India

A powerful cyclone caused substantial damage on the east coast of India in mid-October. Following Cyclone Phailin, Hudhud was the second severe event to strike the region since 2013. The damage to infrastructure, buildings and crops runs into the billions.

Doris Anwender

Cyclone Hudhud reached the east coast of India on 12 October 2014, achieving wind speeds of between 170 and 215 km/h. It was initially classified as a tropical storm in the Andaman Sea on 8 October. Hudhud rapidly gained in strength because of the warm ocean and only slight differences between the wind streams at low and high altitudes. On 10 October, the India Meteorological Department (IMD) classified it as a "very severe tropical storm" over the Bay of Bengal. This classification corresponds to wind speeds of 124 to 232 km/h, averaged over a one-minute period. Hudhud reached its maximum intensity of 215 km/h shortly before making landfall near the city of Visakhapatnam (Vizag) between 6.30 and 7.30 a.m. (UTC) on 12 October.

Second severe event since 2013

This port city, with a population of more than two million people, is an important economic centre in the region. Wind speeds of between 170 and 180 km/h were measured in the area, with gusts peaking at as much as 195 km/h. Hudhud rapidly weakened to a tropical storm, as it tracked inland, but still triggered torrential rain as it passed. Meteorological observations of Hudhud ended on 14 October, as it moved away over the state of Uttar Pradesh in the north of the country in the form of a low pressure system.

Following Cyclone Phailin, Hudhud was the second severe event to strike the region since 2013. This marked the end of a relatively quiet phase that had

lasted since 1999. In that year, two cyclones, just 300 km apart and with wind speeds of over 200 km/h, struck the coast of the states of Andhra Pradesh and Odisha. With one in 2014 and two in 2013, the number of landfalls on the Indian subcontinent was more or less in line with the general average since records began in 1891.

Hudhud caused serious damage, with extreme wind speeds, heavy rain and a storm surge. Several Indian weather stations recorded rainfall in excess of 100 mm in the space of 24 hours. Data from the research satellite of the Tropical Rainfall Measuring Mission (TRMM) show that the heaviest rainfall was in the coastal region close to where Hudhud made landfall. The highest totals were 200 to 250 mm. At 3.5 metres, the extent of the storm surge remained relatively moderate. This was due to the fact that the continental shelf falls away sharply near the coast and the terrain is elevated. Several settlements and the runway of Andhra Pradesh's largest airport in Vizag were flooded. The cyclone also damaged the roof and the interior of the airport, with the result that numerous flights had to be cancelled and operations put on hold for several days. Both the electricity and communications networks were temporarily disrupted. Damaged cars, uprooted trees and thousands of hectares of ruined plant stocks and devastated areas of agricultural land also contributed to the scale of damage. The Vizag Steel factory, the largest public employer in Andhra Pradesh, was forced to shut down production for almost a week.

Effects felt as far north as the Himalayas

Thanks to warnings issued by the Indian Meteorological Service, a total of 700,000 people, 500,000 of them from Andhra Pradesh alone, were brought to safety. The government's efficient evacuation measures are the hard lessons learned from the experience of 1999, when a destructive cyclone struck Odisha, and over 10,000 people lost their lives. Despite the extensive preparations this time around, 84 people were killed, with 50 fatalities in Andhra Pradesh. Hudhud's impact was even felt in the distant Himalayas. Tongues of moist air masses stretched from the cyclone inland towards the high mountain ranges, intensifying the monsoon rains there and triggering severe blizzards. The unexpected early start to the winter brought avalanches in Nepal and northern India, claiming the lives of 43 trekkers.

Even though Hudhud was less severe than Phailin, the economic loss was considerable, not least because the cyclone took a heavy toll in the city of Vizag. The total direct economic costs in India are estimated at US$ 7bn, with insured losses of US$ 530m. Even though this amount represents just a fraction of the overall loss, it reflects the growing insurance density in India. In spite of the significant rise in insurance penetration among farms and smallholdings in India in recent times, the losses from crop insurance were minor.

Calls for an insurance pool

In light of the accumulation of catastrophes this year and last year (Kashmir also experienced heavy floods in September 2014), calls have redoubled for a pool insurance system for natural catastrophes in India. This would allow claims to be settled promptly and the economy to be stimulated again without delay. Reconstruction would generally progress more rapidly, ensuring that additional loss drivers such as business interruption would have very little potential to develop. The local population would also benefit, since they could get on with their lives much more quickly.

Houses destroyed at Visakhapatnam
on the east coast of India.

OUR EXPERT

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Napa Valley: Strongest earthquake in California for 20 years

Even though it only caused relatively minor damage, the earthquake at the end of August 2014 in the Napa Valley sends out a clear warning for the Greater San Francisco Bay Area.
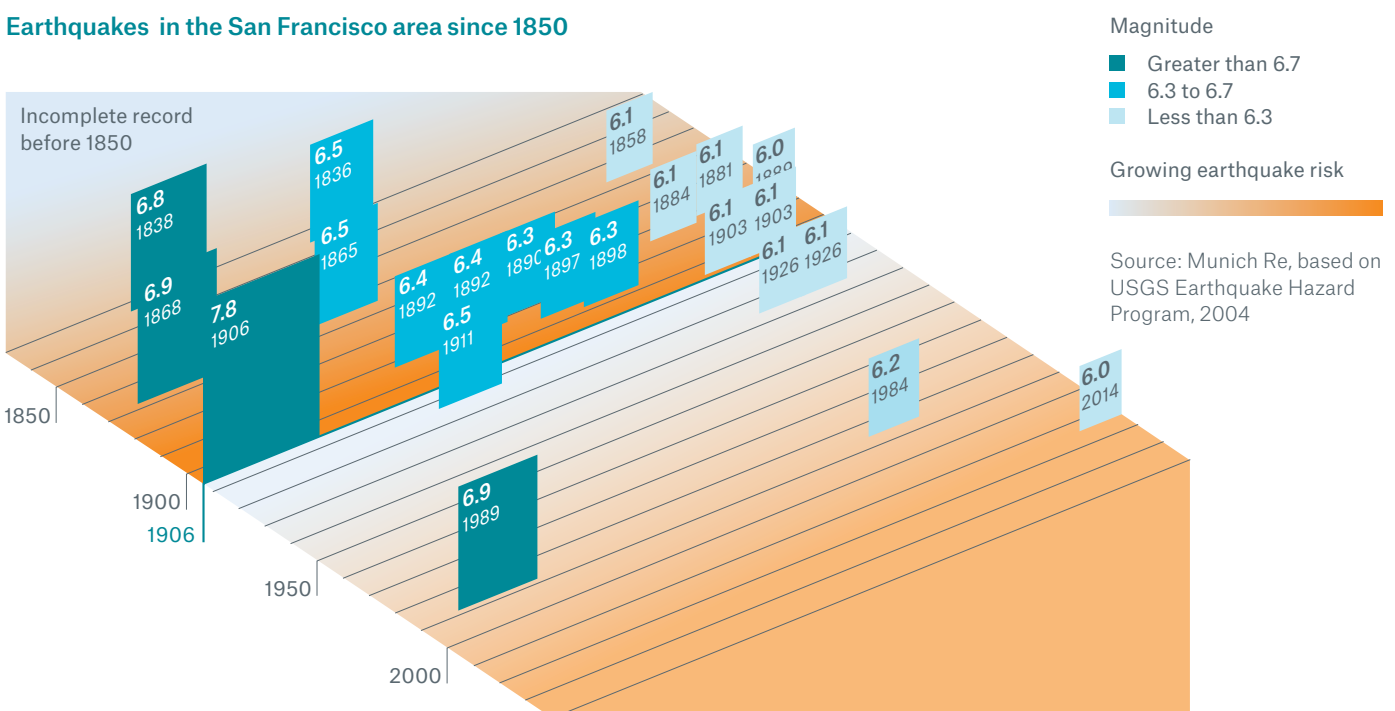
Martin Käser

The quake struck on 24 August at 3.20 a.m. and registered a magnitude of 6.0 according to the United States Geological Survey. Its hypocentre was at the southern boundary of the town of Napa, northwest of the town of Vallejo, at a depth of roughly 11 km. The tremors were felt 100 km away, and lasted between 10 and 30 seconds depending on the location. Close to the epicentre, peak horizontal acceleration measured 5 m/s^2, which corresponds to an intensity of IX on the Macroseismic Intensity Scale.

Napa lies within a highly exposed, 70 km-wide zone that has several known faults forming part of the greater San Andreas fault system. Along this rupture zone, the Pacific plate in the west is sliding in a northwest direction against the North American plate in the east at a rate of approx. 6 cm each year. The quake occurred between two of the best-known active fault systems, the Hayward-Rodgers Creek fault and the Concord-Green Valley fault, but could not be clearly assigned to any previously known fault.

Severe damage to older buildings

The earthquake claimed the life of one person, while some 250 people escaped with injuries. There was severe damage to 170 buildings, with slight damage to a further 1,000 buildings. In Napa, it was older buildings in particular, some of them listed in the National Register of Historic Places (library, post office, Alexandria Hotel, church) that suffered serious damage despite the fact that they had previously been retrofitted for greater earthquake safety. The quake also left its mark on roads and affected electricity and gas connections, with supplies to more than 70,000 households temporarily disrupted. Fires broke out in several places, but were quickly brought under control despite the ruptured water pipes. According to Property Claim Services (PCS), insured losses are estimated at US$ 150m. Munich Re estimates the total economic loss at many times higher, at around US$ 700m.

Earthquakes in the San Francisco area since 1850

Incomplete record before 1850

Magnitude	
■	Greater than 6.7
■	6.3 to 6.7
■	Less than 6.3

Growing earthquake risk

Source: Munich Re, based on USGS Earthquake Hazard Program, 2004

Winegrowers also affected by the quake

The Napa Valley is one of the most important wine-growing regions in the USA. One special aspect was therefore the damage to the many vineyards in the region. Over 100 businesses were affected. As well as damage to buildings and wine-producing machinery, growers were also lamenting the loss of their wine stocks. The local community of winegrowers estimates the total damage at about US$ 80m. Many businesses were anxious to prevent their losses becoming public knowledge because of concerns about negative headlines.

State of emergency facilitated prompt federal aid

A short time after the quake, the authorities in California declared a state of emergency for the Napa region. This allowed rapid financial assistance from Washington to flow into the region. Assistance was badly needed as hardly anyone in this area is insured against earthquakes: the insurance density in both the private and business sectors is less than 5%. The main reason for this is the high insurance premiums in many parts of California, with enormous deductibles of more than 15%, and also the lack of government support for earthquake covers.

Earthquake situation in the San Francisco region

The region around San Francisco has a history of major earthquakes. If one looks at the period since 1850, the number of events with a magnitude greater than 6.0 noticeably decreased following the devastating 1906 quake (see diagram). Seismologists believe that the quake at that time helped to substantially reduce the tectonic stresses in the region. But over the last 100 years, seismic energy from tectonic loading has been building up again.

In 2008, experts estimated a 63% probability of a 6.7 magnitude earthquake or greater striking the Greater San Francisco Bay Area by the year 2036. A recently published study on seismic hazard produced a similar assessment. It expects a much stronger quake than the one in Napa in the near future, although it is impossible to predict the location and magnitude with any great accuracy. Tremors in the San Francisco Bay Area pose a particular risk. Experience has shown that artificial landfills used to reclaim land, such as those frequently found on coastlines, suffer a disproportionate level of damage in quakes because the uncompacted material amplifies the ground motion. In addition, if the soil is saturated with water, there is the further risk of liquefaction.

Conclusion

After more than two decades of unusual seismic calm in the San Francisco region, the Napa quake of 2014 was the most serious event since the Loma-Prieta quake in 1989. On that occasion, the tremors came from a magnitude 6.9 quake south of San Francisco. A total of 68 people were killed and there were economic losses of US$ 10bn, of which US$ 960m was insured. The Northridge quake in 1994, with a magnitude of 6.7, was located much further south in the Greater Los Angeles area. This claimed the lives of 61 people and produced losses of US$ 44bn (US$ 15bn in insured losses). In this context, the Napa quake of 2014 is a sharp wake-up call, showing that California, and the region around San Francisco in particular, has to be prepared for further and even larger earthquakes.
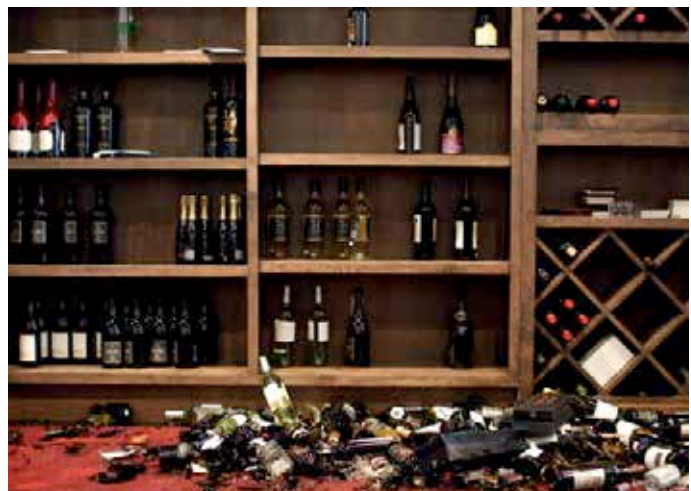
Shattered bottles after the earthquake in the wine-growing region of Napa Valley.

OUR EXPERT

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Are stationary weather patterns increasingly responsible for summer weather extremes?

The latest research findings strongly suggest a link between the higher frequency of persistent weather patterns, extreme weather events and the warming of higher latitudes due to climate change.

Eberhard Faust

Over the last few decades, weather conditions in the northern hemisphere that hardly change for days or weeks at a time have been responsible for many extremes in summer temperatures and precipitation (see TOPICS Geo Natural catastrophes 2013). These include heatwaves in North America (1983, 1984, 2011, 2012), Europe (2003, 2006, 2010), and severe floods in Europe (1997, 2002, 2013) and Pakistan (2010). Current research findings indicate that the clearly increased frequency of fixed or stationary weather patterns is connected with the excessive warming of the Arctic region (Coumou et al., 2014). In order to understand this connection, one must first look in more detail at the characteristics of these weather patterns.

In the mid-latitudes, the spatial position of large areas of high and low pressure, and their movement, is determined by the jet stream, a band of strong, high-altitude winds that loops and meanders around the globe. For example, a low pressure area that channels cool air masses from higher latitudes southwards and ensures rainfall lies under a half wave extending towards the equator (trough). In contrast, a high pressure area can be found below a half wave facing towards the pole (ridge), and this produces high temperatures and drought in summer.

The effects of melting polar ice in summer are felt far beyond the Arctic.

Quasi-stationary weather patterns

According to analyses by Coumou, Petoukhov and other scientists, under certain conditions the waves in the fast upper air flow (the jet stream) can undergo resonant amplification in summer, and become virtually stationary. Because the upper air flow also determines the position of areas of low and high pressure, this produces local conditions of persistent heat/drought or precipitation. These effects accumulate and can assume extreme proportions. A schematic comparison between a non-resonantly and a resonantly amplified weather pattern clearly illustrates the characteristics.

Non-resonant summer weather pattern

Under normal conditions, with non-resonant waves in the upper air flow, there is no evidence of exceptionally large amplitudes. There is also no particularly distinct structure of two corridors in the upper air flow. The wave pattern shifts from west to east and underlying low and high pressure areas are swept along with it. The illustration is for the period 25 July to 8 August 2008, which was not one of the months with resonance features.
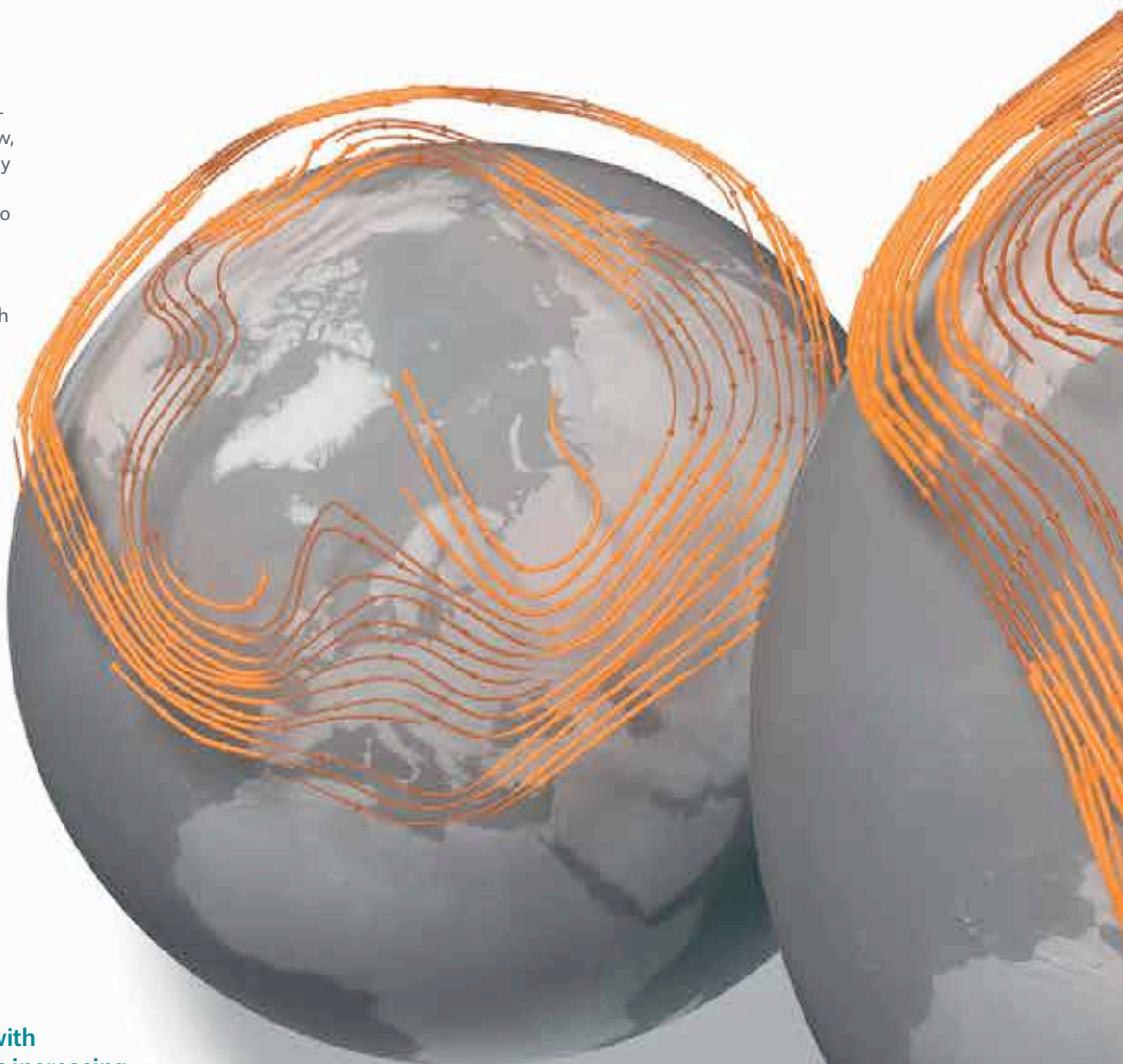
**Number of summer months with persistent weather patterns is increasing**
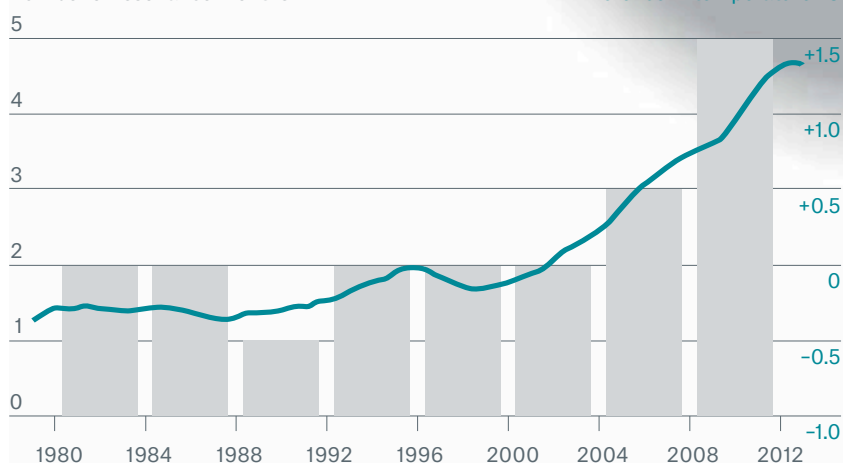
Number of summer months (July, August) with predominantly resonant characteristics according to Coumou et al., 2013, in four-year periods between 1980 and 2011 (bar and left axis). Smoothed development of the anomalies of the mean temperature in the high latitudes (>65°N) and the rest of the northern hemisphere (<65°N) (blue curve) – the Arctic has been warming rapidly since around 2000.

Source: Munich Re, based on Coumou et al., 2014

Resonantly amplified weather pattern

Exceptionally large wave amplitudes are found in resonantly enhanced waves in the upper air flow. In addition, a structure of two corridors forms (sectionally at least) in the upper air flow, one close to the pole and one further to the south. The weather configuration remains virtually stationary under these conditions. The large-amplitude wave ridge over Russia illustrated here protrudes towards the pole in the rough shape of a capital Greek omega (Ω). Together with the two short wave troughs at its western and eastern ends, it forms what is known as an omega block, frequently characterised by large amplitude. Shown here is the average over the period 25 July to 8 August 2010, which was one of the months with predominantly resonant characteristics.

H

L
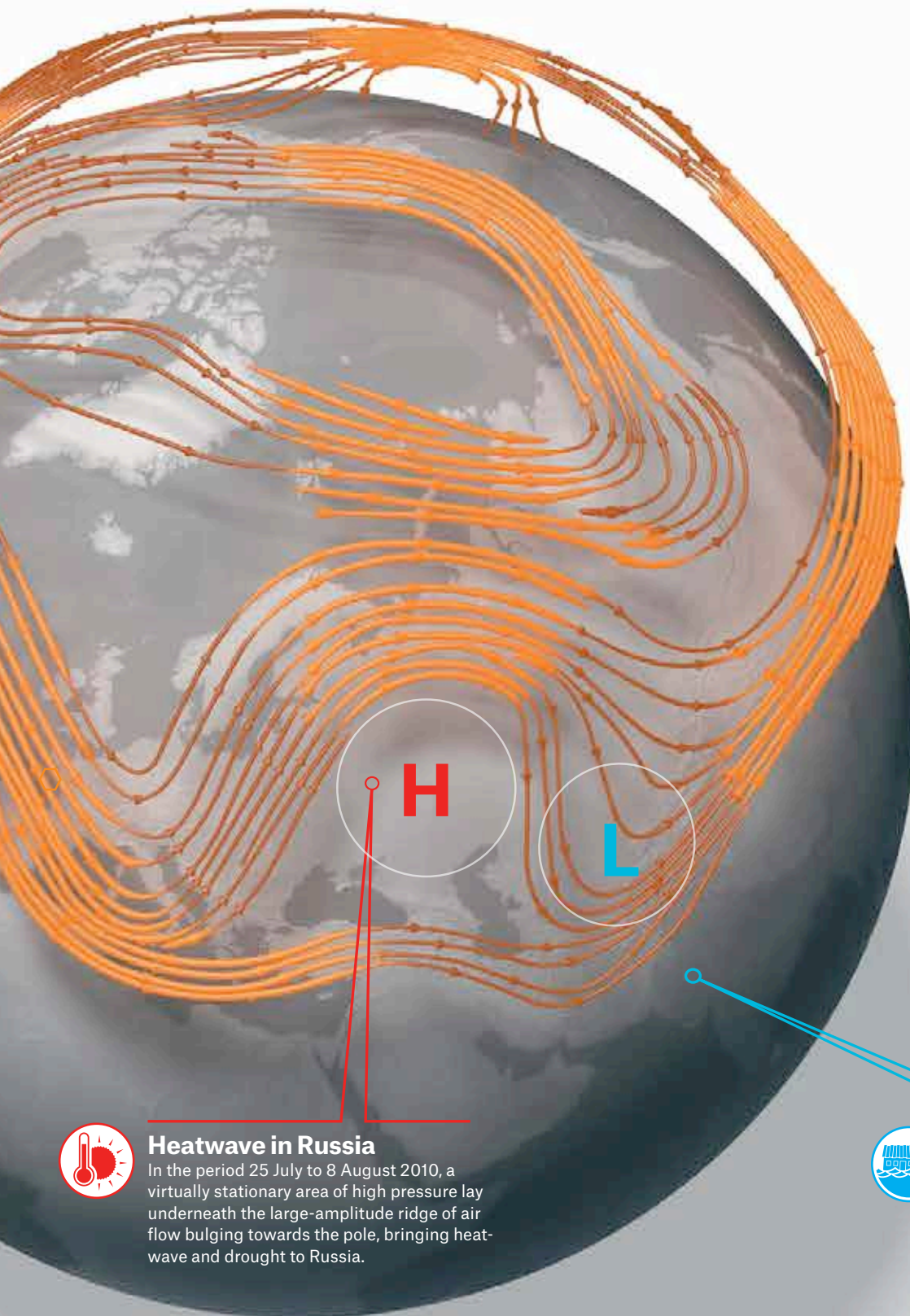
Jet stream speeds

Low   High

Source: Munich Re, based on fields of geopotential height and vector wind (300 hPa level), averaged over the periods 25 July–8 August 2008, and 25 July–8 August 2010, NCEP/ NCAR Reanalysis, Earth System Research Laboratory, Physical Science Division, NOAA.

Heatwave in Russia
In the period 25 July to 8 August 2010, a virtually stationary area of high pressure lay underneath the large-amplitude ridge of air flow bulging towards the pole, bringing heatwave and drought to Russia.

Floods in Pakistan
A trough extending towards the equator resulted in low air pressure activity close to the surface and rainfall that caused high water levels and floods in Pakistan.

Under normal circumstances, the wave bands, consisting of between six and eight individual waves (pairs of ridges and troughs) move around the northern hemisphere in a west-to-east direction. Researchers led by Dim Coumou and Vladimir Petoukhov have now discovered that these wave bands can enter a state of resonant amplification. One precondition for this is that sections of the strong high-altitude winds split into two strands flowing in parallel at approximately 45°N and 70°N. This means that the amplitudes of the waves increase and their movement from west to east stalls to such an extent that they can be considered quasi-stationary (see illustration on pp. 36/37). This generally occurs in the summer months in the northern hemisphere. At this time, the atmospheric circulation is already weaker than in the winter half of the year due to the lower differences in temperatures north of the equator, so that, on average, the waves move more slowly.

Amplified by accumulation

It is likely that the effects from rainfall or heat/drought intensify if an area of high or low pressure remains over a region for a longer time. Researchers were actually able to show that the duration and intensity of rain increased in months with predominantly resonant wave formations. On the other hand, high temperatures also occurred more frequently than in months without resonant amplification. In contrast, when individual days were studied, it was found that rainfall was no higher or more widespread, so that the effect must primarily be due to an accumulation over time.

At the same time, extreme weather characteristics, and occasionally loss events, do not simultaneously result under all waves during a resonant phase. For example, in certain regions, there is only a dependency between increased wave amplitude and heat, whereas in others the link can only be identified for drought or high amounts of precipitation (Screen and Simmonds, 2014). So there are additional factors that contribute to preferential regional correlations with extreme weather characteristics. This limits the loss accumulation aspect across the entire wave band.

Regime shift around the year 2000

In the period since 1980, it is striking that resonance months in the middle of summer (July/August) have occurred much more often over recent years (see graph on p. 36). There appears to have been a regime shift around the year 2000. This coincides with a phase shift in Arctic warming: until the end of the 1990s, the rise in temperature in the high latitudes was equal to that throughout the northern hemisphere. However, from the start of the new millennium, the air in Arctic latitudes (>65°North) warmed at a much faster rate (Arctic amplification). This

reduced the average difference in temperature between the polar region and the equator, which also caused a drop in the strength of high-altitude winds. This effect on its own slows the movement of the wave pattern. There is also the fact that, under these conditions, the high-altitude winds are more likely to divide in sections into parallel strands – an essential precondition for the development of resonant waves.

Based on the research findings, it is therefore reasonable to assume that climate change, which is responsible for the intense warming of the high latitudes, is also beginning to change the atmospheric circulation of the mid-latitudes. It is reducing the differences in temperature and pressure between high latitudes and mid-latitudes, with the result that more frequent quasi-stationary weather patterns occur. Under such conditions, heat or drought and rain can assume extreme forms.

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OUR EXPERT

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Natural catastrophes

The weather has gone crazy – What are the potential causes?

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People in virtually every part of the world believe that the weather has changed over the last few decades. Weather patterns that used to be reliable, like dry and rainy seasons, but also hot and cold spells, have become more unpredictable. The winter of 2013/14 was a good example of this: on the one hand, it was almost non-existent in central Europe, whereas Japan and the eastern regions of North America experienced record low temperatures and snowfalls. In Japan, last winter produced one of the most costly natural catastrophes of the year worldwide.

In some regions, changed weather patterns like these overlap and overcompensate for the global trend towards steadily higher temperatures. So it is quite understandable that cartoonists were asking what had happened to global warming during the January cold snap in the USA. But a very different picture presented itself across the Atlantic in Europe. The winter there was much milder than would have been expected even in the context of global climate change.

What is striking about the last few years is that extreme weather conditions have persisted for longer periods, in many cases for weeks at a time. Pronounced waves in the jet stream are to blame for this. The jet stream is a band of strong west winds that flow from west to east at higher altitude. It separates cold Arctic air masses from warm subtropical ones. Atmospheric disturbances can produce oscillations in the stream. What happens then is that Arctic air masses push far to the south in what

are known as troughs (bulges to the south). Conversely, what are known as ridges (bulges to the north) transport subtropical air masses in the opposite direction. As the result of dynamic processes, areas of low pressure form in the troughs and areas of high air pressure in the ridges. The greater the amplitude of the jet stream, the more extreme are the weather conditions that develop within it.

As a rule, the troughs and ridges move in the same direction as the jet stream's prevailing wind direction, in other words from west to east. As a result, lows and highs alternate over a region over the course of several days. However, several studies suggest that the jet stream has remained stationary more frequently in recent decades. The waves in the band of strong wind remain over a region for periods of up to several weeks. In areas influenced by the troughs, large quantities of rain accumulate, while in summer, heatwaves and droughts affect the areas influenced by the ridges. All this would be unremarkable if the meteorological parameters were averaged over the latitude.

There is currently intensive discussion among climate researchers about whether the changed weather patterns of the jet stream are a consequence of climate change, and in particular of the rapid melting of snow and sea ice in Arctic latitudes. But a lot of research will still be needed before any clear connection can be established. Nevertheless, the phenomena described indicate that a relatively small change in global mean temperature may be all that is needed to disturb weather patterns that have been typical up to now, and to trigger regional weather extremes. This underlines once again how important it is for insurers to be familiar with the results of the latest research and, where necessary, to incorporate them into their risk models.

The changes in weather patterns that have already been demonstrated, and which cause strong fluctuations in rainfall and temperatures in many places, call for new approaches in risk management. These include improved flood control, more efficient use of water resources, and warning systems for risks that are sensitive to heat. Weather insurances and multi-peril covers for agriculture will increase in importance as a means of cushioning losses in income. Munich Re has the necessary expertise in this area and can offer the appropriate products.

Facts, figures and background

No year since 1880 has been as warm as 2014. It is highly probable that a first tipping element was reached in the global climate system with the incipient instability of the West Antarctic ice sheet, thereby heralding its irreversible disintegration. As a result, sea levels will rise significantly over the long term.

Ernst Rauch and Eberhard Faust

According to data published in January 2015 by the US meteorological agency NOAA (National Oceanic and Atmospheric Administration), 2014 was the warmest year since NOAA's data records began in 1880. The global mean temperature for land and sea surfaces was approximately 0.69°C higher than the global average in the 20th century. However, 2014 was only 0.04°C higher than the previous record annual average temperatures recorded in 2005 and 2010. It was much too warm in large parts of Europe and Africa and periodically in Australia. Even the unusually severe cold snap in February and March in the USA and Canada was unable to slow down the global increase in temperature. In the latter countries, deviations from the long-term mean were measured that in some cases were as much as -5°C. This clearly shows that no conclusions can be drawn from regional temperature observations about global annual mean temperature.

It was the highest ever sustained sea surface temperatures measured from June through December that were solely responsible for the classification as the warmest year worldwide. The increase in the global annual mean temperature over land areas did not set any new records. Nevertheless, the temperatures for each month were within the range of the ten warmest years since 1880.

West of the USA and Brazil too dry

Despite heavy regional rainfall, the year overall (land data only) was excessively dry. In comparison with the NOAA reference period (1961–1990), there was markedly less rain in the west of the USA and in parts of Brazil. Both regions had already been affected by drought in the previous years, and California has been suffering for several years from a lack of rainfall. In contrast, it was much too wet in the first half of the year, especially in the UK and in southeast European regions (Adriatic), which were affected by flooding. In summer and autumn too, exceptionally high rainfall occurred around the Mediterranean and in many parts of the Balkan states. In November/December, heavy rainfall on the US West Coast at least brought

temporary relief from the drought. In all probability, the heavy rain was due to the developing El Niño event. This naturally occurring weather phenomenon, which is driven by fluctuations in sea surface temperature in the equatorial eastern Pacific, occurs at intervals of several years. It frequently changes the overall weather patterns in certain regions such as the west of North America and produces increased rainfall there.

The global sea level reached a new record in 2014. The trend of an accelerated increase over the past two decades is continuing unabated. For example, an annual increase in the global average of over 3 mm per year was observed between 1993 and 2014, which was almost twice the secular trend of 1.6 mm per year in the 20th century. On a regional level, however, there was a substantial variation over past decades in the change in sea level due to geotectonic and meteorological influences. For example, sea levels fell in the South Pacific, sometimes by more than 5 mm, while at the same time, water east of the Philippines rose by up to 10 mm.

Collapse of the West Antarctic ice sheet

The prevailing opinion among climate researchers is that "tipping elements" with serious irreversible consequences cannot be ruled out if the global average temperature increases by more than 2°C compared to pre-industrial levels. Potential tipping elements in the earth's system include melting ice, ocean current systems and supraregional ecosystems. A common feature of all three is that relatively small external disturbances are enough to trigger self-accelerating processes that lead to a new state of the system. Based on the current status of research, the following are examples of conceivable tipping elements as climate change progresses: the disappearance of Arctic sea ice, loss of the Greenland ice, thawing of Arctic permafrost soils, attenuation of the Atlantic thermohaline circulation, changes in the Indian monsoon, shift in the west African monsoon, or the irreversible destabilisation of the West Antarctic ice sheet.

Regional anomalies of the 2014 mean annual temperature compared with the 1981–2010 mean


°C −5 −4 −3 −2 −1 0 1 2 3 4 5
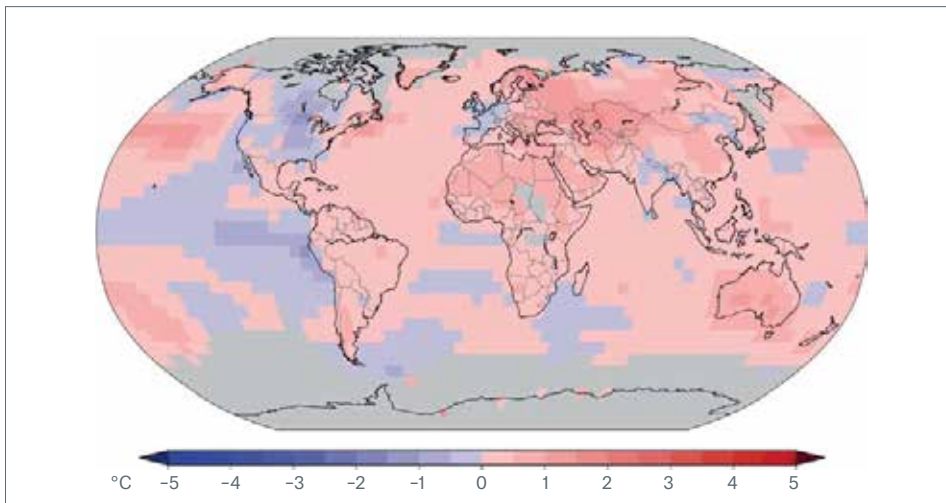
With the exception of eastern North America and parts of central Asia, nearly all land areas of the world were warmer in 2014 than the reference period. However, what made 2014 the warmest year since 1880 were the sustained highest sea surface temperatures ever recorded from June through December.

■ Warmer
■ Colder

Source: NCDC/NESDIS/NOAA

Regional anomalies of annual precipitation in 2014 compared with the 1961–1990 mean

% −100 −80 −60 −40 −20 0 20 40 60 80 100
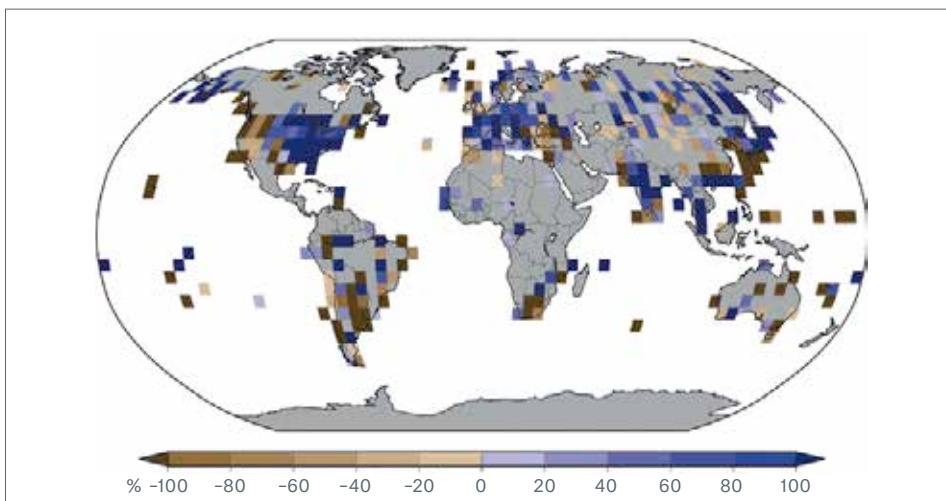
Although parts of Europe, South America, and the eastern USA received above-average precipitation in 2014, overall the year was too dry.

■ Drier
■ Wetter

Source: NCDC/NESDIS/NOAA

Deviations of the global annual mean temperatures from the 1901–2000 average
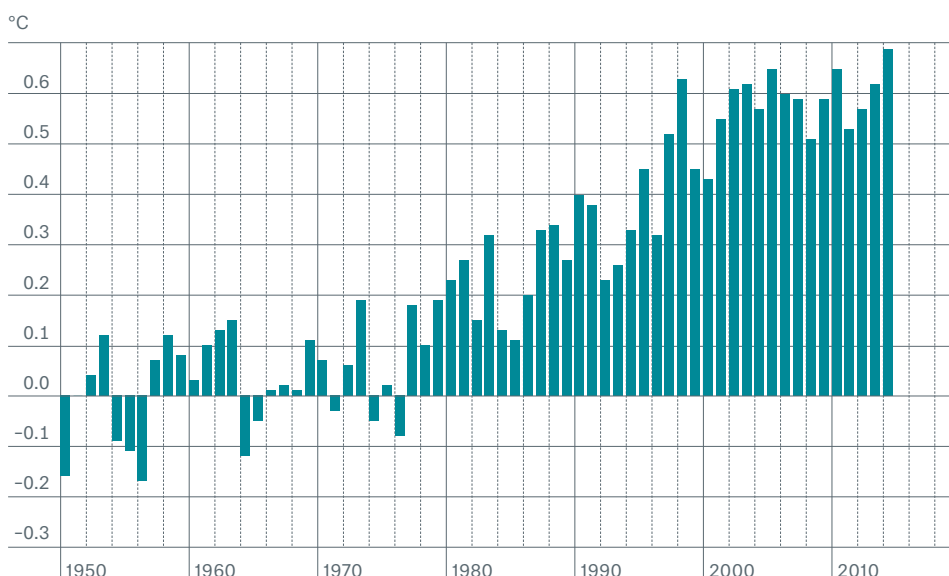
The 14 warmest years in the observation period 1880 to 2014 have all been since 1998. The time series commences in 1880; the period shown here is 1950 to 2014.

Source: Munich Re, based on NCDC/NOAA

Tipping elements
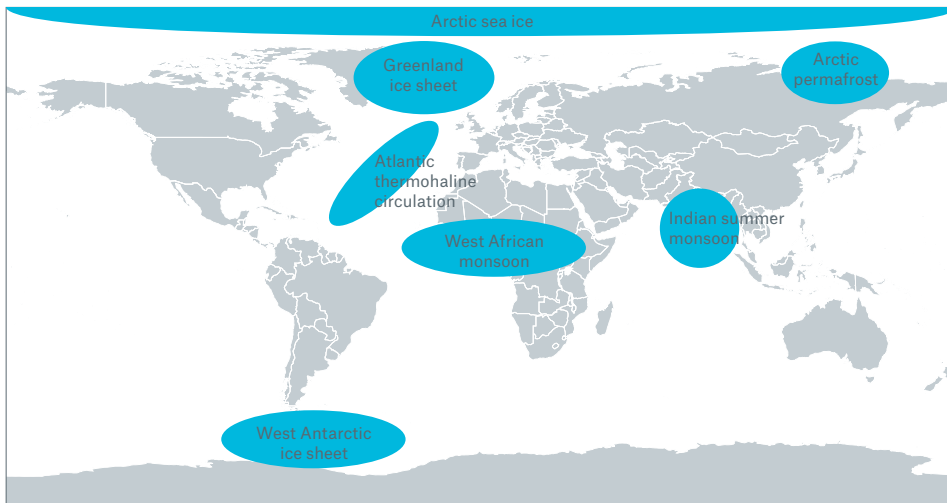
Based on the status of climate research, even small external disturbances are enough to trigger self-accelerating processes in some regions of the world that lead to a new state of the system. This especially applies to melting ice, ocean current systems and large-scale ecosystems.

Source: Munich Re, based on Potsdam Institute for Climate Impact Research, adapted from Lenton et al., 2008

This sheet is a mass of ice several thousand metres thick that, like the Greenland ice and the East Antarctic ice sheet, rests below sea level on land. The mass of ice is subject to a permanent process of flowing and calving in the direction of the sea. What is known as the grounding line marks the point where the mass of ice no longer rests on land, but instead floats in the sea. If the ice sheet melts, the grounding line withdraws landwards. Because the ground falls away in the West Antarctic region, an increasing volume of seawater is flowing in. The course of the ice withdrawal is unstable and the flow of the ice into the sea accelerates in a self-reinforcing process: this is because the further into the interior the grounding line moves, the lower the braking effect on the ice from friction against the supporting ground. Loss of the West Antarctic ice sheet, probably extending over a period of centuries, would increase global sea levels by more than three metres.

Whether the irreversible destabilisation of the West Antarctic ice sheet can be clearly attributed to anthropogenic climate change cannot be proven conclusively at this time. However, this development does show just how vulnerable even large-scale elements of our earth system are to external changes. All in all, it would appear obvious that, in an increasingly warm world, there is a greater likelihood of other areas in the Antarctic exceeding similar types of tipping points: Wilkes Basin in East Antarctica being a prime candidate.

Tropical cyclones

In the Atlantic, a much lower number of storms developed than the mean of the warm phase of the Atlantic Multidecadal Oscillation (AMO) since 1995. There were eight named storms in 2014, of which six reached hurricane strength and two grew to severe hurricane strength (Saffir-Simpson Hurricane Wind Scale SSHWS 3–5). There were 15 named storms on average over the period 1995–2013, with eight hurricanes and 3.5 severe hurricanes. The meteorological reasons for the low level of activity were principally dry air above the tropical Atlantic in the period July to September, intermittent above-average strong vertical shear winds in the Caribbean Sea, and sea surface temperatures that were significantly cooler than the warm phase average in the first months of the season. Descending air over the western tropical Atlantic also resulted in stabilisation of the atmosphere, which counteracted convection.

Only Hurricane Arthur caused losses in the USA. Its winds and storm surge hit North Carolina as an SSHWS category 2 storm on landfall, and the rainfall it carried with it extended as far as New England. Thanks to strict building regulations, however, and a relatively young building stock in North Carolina, only slight damage occurred. Two separate hurricanes, Fay and Gonzalo, hit Bermuda in the space of just a few days in October as an SSHWS category 1 and SSHWS category 2 storm respectively. Gonzalo in particular caused damage to houses, airport facilities and other infrastructure.

Some of the meteorological factors in the Atlantic mentioned above, which tend to hamper hurricane development, correspond to the typical influence of the (beginning) El Niño phase (see above and pages 58/59). Likewise typical for El Niño periods, meanwhile, was the exceptionally high level of hurricane activity in the eastern North Pacific. With 22 named storms, the tally for the season was well above the long-term average of 16.5 storms for the period 1981 to 2010, while in terms of hurricanes and severe hurricanes (SSHWS categories 3–5), there were roughly twice as many storms as the long-term average (16 versus 8.9, and 9 versus 4.3). Together with 1990 and 1992, the 2014 season holds the record for the most hurricanes since 1970. The meteorological factors for this high level of activity included above-average sea surface temperatures, a moisture content that was greater than average in the middle troposphere of the main development region, and from July on, substantially reduced vertical wind shear in many regions.

On 14 September, Hurricane Odile made landfall at the southern end of Baja California as an SSHWS category 3 storm, and then tracked along the length of the peninsula. This came just weeks after Hurricane Norbert had caused flooding in parts of Baja California, while its remnants brought floods to California, Arizona, New Mexico and Nevada. Odile caused damage from wind and heavy rainfall, with flooding in both Mexico and in the southwest of the USA. Overall losses came to over US$ 2.5bn, of which some US$ 1.2bn was insured. In the central North Pacific, Hurricane Iselle hit Big Island on 7 August as a tropical storm – the first landfall on Hawaii since Hurricane Iniki in 1992. Only moderate damage to infrastructure and agriculture resulted, while at roughly the same time, Hurricane Julio tracked north past the Hawaiian Islands.

With 21 named storms, the season in the western North Pacific was milder than the long-term average for the period 1965–2013 (26), a fact that was also reflected in the relatively low number of typhoons (11 versus 16). The season roughly matched the long-term average for severe typhoons (7 versus 8). Up until July, the accumulated number of tropical cyclones was below average, but after the low-activity month of August it moved into the above-average range. One factor behind the exceptionally low level of activity in August, with just two active storms, was widespread abnormal dryness in the middle troposphere. Added to this was descending air resulting in a stable air stratification in many parts of the basin, which is not conducive for convection. The relatively high number of landfalls in Japan (4) from typhoons Neoguri, Halong, Phanfone and Vongfong between July and October corresponds to the typical El Niño pattern, where the northern routes can occur somewhat more frequently. Damage remained slight in Japan thanks to good building and infrastructure standards.

In the Indian Ocean, there was a severe loss totalling US$ 7bn from Cyclone Hudhud, an SSHWS category 3–4 storm when it made landfall on the east coast of India. Roughly US$ 0.5bn of this was insured.

Even though individual regions were badly affected, for example India, the Philippines and Mexico, the 2014 cyclone season was a mild one in terms of global aggregate losses. Some ocean basins showed signs of the controlling influence of the incipient El Niño event.

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OUR EXPERTS

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Global databases changing

Big data and growing specifications for informational content and level of detail in natural catastrophe analysis mean that global databases have to be continually refined and developed.

Petra Löw

Despite the fact that no new record costs have been recorded for natural catastrophes in the last three years, there is no reason to relax our guard. In recent decades, natural catastrophe losses have developed to different extents, depending on the particular region and hazard. The challenge for risk management at a reinsurer with global operations is to identify, assess and integrate into the business model any long-term changes. This includes considering the use of new technologies and more detailed information for all processes. Big data is a very good example in this context, a field in which the ways of recording and analysing large quantities of data are constantly evolving. This also has implications for working with global databases on natural catastrophes.

Munich Re's NatCatSERVICE – the most comprehensive database on natural catastrophes worldwide – forms the basis for a wide spectrum of analysis and statistics in the areas of risk management and risk research. We have been investigating these subjects since the 1970s and are continually expanding our database. Some of the issues we examine include data collection, loss evaluation and loss estimates, as well as ways to improve methods of adjusting for inflation and normalising losses. The objective is to allow us to create more precise risk analyses for the relevant markets and regions. We introduced the latest improvement at the start of 2014. Since then, we have based all our evaluations of overall and insured losses on the respective changes in values in a country. This allows historical losses to be compared more accurately with losses today. In this way, the NatCatSERVICE is meeting the growing demand for more detailed market information.

In 2014, there were more than 400 floods worldwide, like here in the Philippines.

The year in pictures

5–8 January
Winter damage: USA, Canada
Overall losses: US$ 2,500m
Insured losses: US$ 1,700m

December 2013 to February 2014
Storm surges, floods: UK, Ireland
Overall losses: US$ 1,500m
Insured losses: US$ 1,100m

7–16 February
Winter damage: Japan
Overall losses: US$ 5,900m
Insured losses: US$ 3,100m
Fatalities: 37

Whole year
Drought: Brazil
Overall losses: US$ 5,000m
Insured losses: minor

22 March
Landslide: USA (Washington)
Overall losses: US$ 20m
Insured losses: minor
Fatalities: 43

5–18 April
Tropical Cyclone Ita: Australia,
New Zealand, Papua New Guinea
Overall losses: US$ 190m
Insured losses: US$ 50m

2 May
Landslide: Afghanistan
Overall losses: US$ 3m
Insured losses: very minor
Fatalities: 100

13–30 May
Floods: Eastern and southern Europe
Overall losses: US$ 3,600m
Insured losses: US$ 70m
Fatalities: 86

7–10 June
Severe weather, hailstorm: France,
Belgium, Germany
Overall losses: US$ 3,500m
Insured losses: US$ 2,800m
Fatalities: 6

14–19 June
Severe weather, tornadoes: USA
Overall losses: US$ 700m
Insured losses: US$ 540m
Fatalities: 2

11–22 July
Typhoon Rammasun: China, Philippines, Vietnam
Overall losses: US$ 4,600m
Insured losses: US$ 250m
Fatalities: 195

31 July–28 August
Wildfires: Sweden
Overall losses: US$ 150m
Insured losses: US$ 40m
Fatalities: 1

3 August
Earthquake: China
Overall losses: US$ 5,000m
Insured losses: minor
Fatalities: 617

11–17 September
Hurricane Odile: Mexico
Overall losses: US$ 2,500m
Insured losses: US$ 1,200m
Fatalities: 6

29–30 September
Volcanic eruption: Japan (Ontake)
Overall losses: minor
Insured losses: very minor
Fatalities: 63

12–13 October
Cyclone Hudhud: India
Overall losses: US$ 7,000m
Insured losses: US$ 530m
Fatalities: 84

21 November–1 December
Severe weather: Morocco
Overall losses: US$ 300m
Insured losses: very minor
Fatalities: 47

5–8 December
Typhoon Hagupit: Philippines
Overall losses: US$ 170m
Insured losses: minor
Fatalities: 18

Source: Munich Re NatCatSERVICE

The year in figures – Global

As was the case in 2012 and 2013, economies and insurers were spared devastating natural catastrophes in 2014, and the year can once again be described as relatively moderate. Despite this, the NatCatSERVICE – Munich Re's natural catastrophe loss database – registered a record number of almost 1,000 catastrophe events. All events were registered that either resulted in direct property damage and/or at least one fatality.

Direct overall losses from natural catastrophes in 2014 amounted to US$ 110bn, well below the average for the last ten years of US$ 190bn. This figure also fell well below the long-term average for the last 30 years of US$ 130bn. Similarly, at US$ 31bn, insured losses were well below mean levels. At US$ 58bn, the average over the last ten years has been nearly twice this figure. The long-term average is US$ 33bn a year.

Likewise, in line with the trend in losses, the number of fatalities from natural catastrophes (7,700) was thankfully at a very low level. The figure was much lower than the averages for both the last ten years and the last 30 years. Only 1984, with a figure of around 7,000, had fewer fatalities.

Number of events

The following picture emerges for the percentage distribution of the main risks into geophysical, meteorological, hydrological and climatological events: of the total of 980 natural catastrophes, 92% took the form of weather events such as windstorms, floods and droughts. Just 8% fell into the category of geophysical events such as earthquakes, tsunamis and volcanic activity. This was 4 percentage points below the long-term average of 12% for the period between 1980 and 2013. There was also a shift in hydrological events: at 42%, they were at a relatively higher frequency than the long-term average (36%). On the other hand, at 41%, windstorm events matched the long-term average. At 9%, the group of climatological events in 2014 was slightly below the long-term average.

The distribution by continent shows that Asia was again worst affected in 2014, with 37%, followed by North America with 20% and Europe with 16%. Africa, South America and Australia accounted for 10%, 9% and 8% respectively of the registered events. In terms of the long-term average, relative frequency therefore declined in North America and Europe, but was 4 and 3 percentage points higher in Asia and South America respectively.
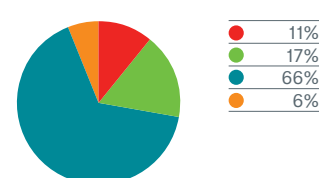
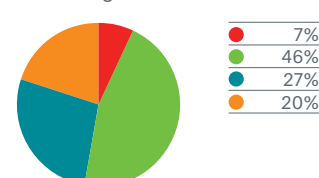**Events: 980**
Percentage distribution worldwide

●	8%
●	41%
●	42%
●	9%
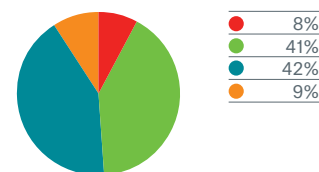
Fatalities: 7,700
Percentage distribution worldwide

●	11%
●	17%
●	66%
●	6%

Overall losses: US$ 110bn
Percentage distribution worldwide

●	7%
●	46%
●	27%
●	20%

Insured losses: US$ 31bn
Percentage distribution worldwide

●	2%
●	69%
●	11%
●	18%
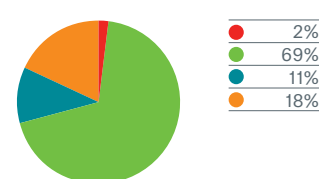
Source: Munich Re NatCatSERVICE

Number of loss events 1980–2014
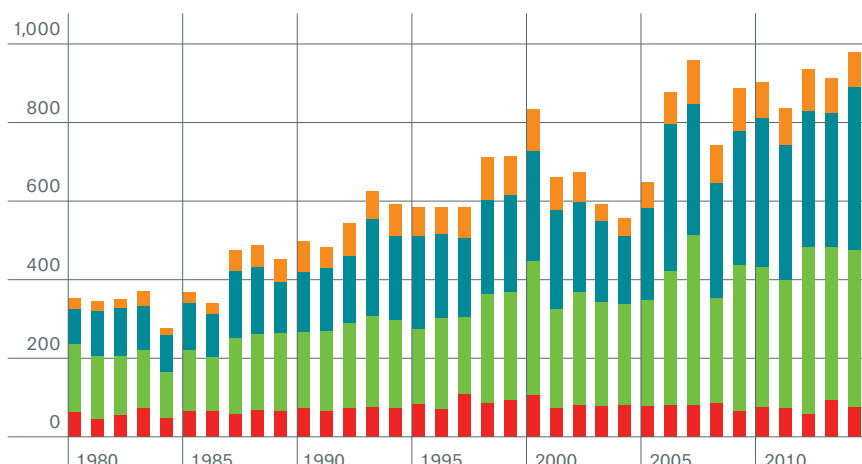
■ Geophysical events (earthquake, tsunami, volcanic activity)

■ Meteorological events (tropical storm, extratropical storm, convective storm, local storm)

■ Hydrological events (flood, mass movement)

■ Climatological events (extreme temperatures, drought, wildfire)

Source: Munich Re NatCatSERVICE

Various reasons can be given for the high total number of events in 2014. Firstly, the reporting rate for small and very small events is steadily rising in emerging economies. China and India are notable examples of this. Another striking feature is the connection between the absence of mediagenic major events that often attract worldwide attention for weeks at a time, and the higher number of reported loss events. If one looks at the period between 1980 and the present, there have repeatedly been years in which a large number of catastrophes were documented, despite the low claims burden for the insurance industry and the economy as a whole. Such high-frequency low-impact events then dominate the statistics. This was the case in 2000, 2006 and 2007, when there were no major catastrophes. In 2014, the number of smaller events also increased in comparison with previous years.

Fatalities

A total of 7,700 people lost their lives in approximately 460 natural catastrophes. With 75% of total fatalities, Asia was the worst-affected continent, and above the long-term average of 69%. Ov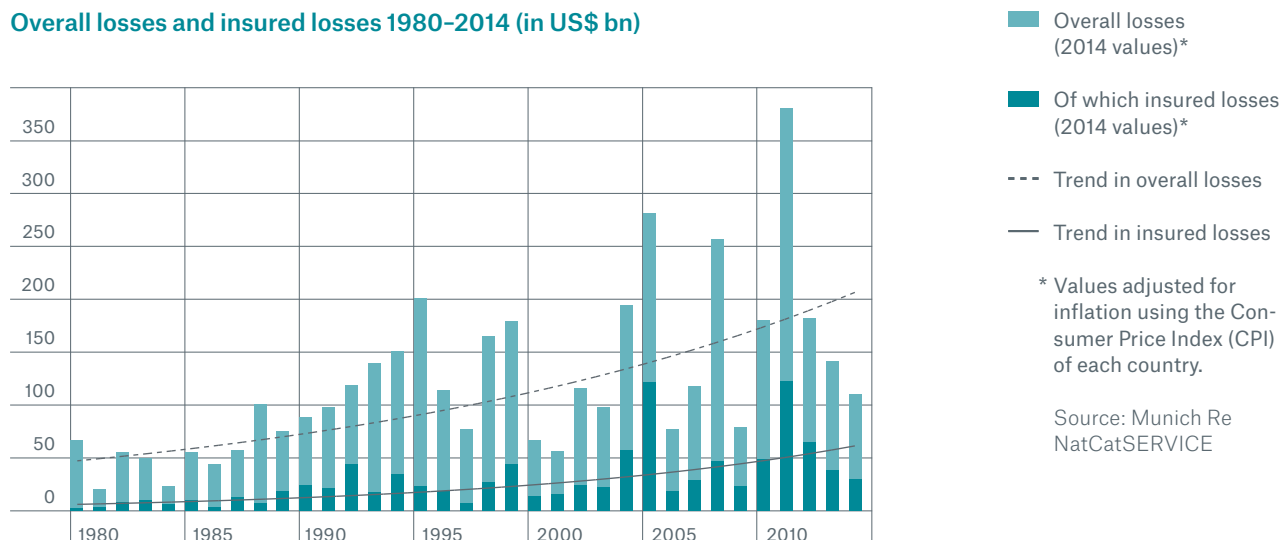er 1,000 people died in natural catastrophes in both China and India, while Afghanistan and Nepal each accounted for several hundred fatalities. An especially large number of victims (66%) lost their lives in hydrological events. This represents a substantial increase on the 49% figure for 2013 and also on the long-term average of 13%. Geophysical events were responsible for 11%, meteorological events for 17% and climatological events for 6% of fatalities.

Losses

With US$ 110bn in overall losses and an insured share of US$ 31bn, 2014 was the third successive year with low losses. After adjustment for inflation, it was slightly above the levels of 2002 and 2003. Windstorm events, at 46%, represented the largest portion of overall losses, followed by floods with 27% and climatological events with 20%. In this area, winter weather extremes in Japan and the USA, and drought events in China, the USA and Brazil, caused billion-dollar losses. With US$ 20bn, the tropical storm season, featuring some very intense systems, also accounted for a substantial portion of the loss burden.

The distribution by continent reveals a similar picture to that for the period between 1980 and 2013. Asia and North America bore the brunt of losses, with 46% and 29% respectively. The insured portion of overall losses reached 28%, slightly under the 30% average for the last ten years. Here again, the most costly events for the global insurance industry were the winter losses in Japan and the USA, followed by severe weather events in Europe and the USA, and floods in the United Kingdom.

Overall losses and insured losses 1980–2014 (in US$ bn)

- Overall losses (2014 values)*
- Of which insured losses (2014 values)*
- --- Trend in overall losses
- — Trend in insured losses
- * Values adjusted for inflation using the Consumer Price Index (CPI) of each country.

Source: Munich Re NatCatSERVICE

The year in figures – Regional

North America

When the natural catastrophes of 2014 are divided by region, North America (including Central America and the Caribbean) accounts for 20% of all events, claiming the lives of nearly 400 people. Of the US$ 31bn in direct overall losses, US$ 18bn were insured losses. Six separate events were responsible for insured losses in excess of US$ 1bn. These included severe thunderstorms with hail and tornado outbreaks, and also extensive winter damage in the USA and Canada. In the USA alone, the financial burden from natural catastrophes came to US$ 25bn, of which US$ 15bn was insured. Overall losses in Canada (US$ 1.9bn) exceeded the billion dollar mark for the fourth successive year; US$ 1.3bn of this was insured. In September, Hurricane Odile in Mexico caused overall losses of US$ 2.5 billion, of which US$ 1.2bn was insured. In the Caribbean, hurricanes Bertha and Gonzalo all made landfall, mainly causing damage to buildings and infrastructure. The total loss amount was approximately US$ 100m.

South America

The South American continent was affected by 9% of the loss events, claiming the lives of some 370 people. Overall losses came to US$ 7bn, of which some US$ 400m was insured. The absence of rain since December 2013 in southeast Brazil had a severe effect on the agricultural sector. Coffee and sugar cane plantations were particularly hard hit. The overall loss from this drought so far has been estimated at US$ 5bn. An earthquake with a magnitude of 8.2 in Chile triggered a tsunami with two-metre high waves and caused severe damage in the region around the city of Iquique. More than 10,000 houses were damaged, or in some cases destroyed. Overall losses came to US$ 800m, of which just under 50% were insured.

Europe

Around 160 loss events in Europe left overall losses of US$ 18bn, some US$ 6.3bn of which were insured losses. In five events, the overall loss exceeded US$ 1bn. The most costly was the low pressure system Yvette, at US$ 3.6bn. In May, this storm produced intense rain, leaving large areas of Serbia, Croatia and Bosnia and Herzegovina under water. The second most costly overall loss was US$ 3.5bn from the low pressure system Ela, which swept through France, Belgium and Germany in June, accompanied by high winds and hailstones up to 8 cm in diameter. With an insured loss of US$ 2.8bn, this storm turned out to be the third most costly event of the year for the global insurance industry. A series of winter storms accompanied by heavy rain, which began at the end of December 2013 and lasted until mid-February, triggered floods in the British Isles. Many rivers burst their banks, and severe storm surges damaged quaysides and seawalls in coastal areas. Overall losses amounted to US$ 1.5bn, including insured losses of around US$ 1.1bn. A total of 350 people lost their lives in natural catastrophes in Europe in 2014.

Loss events worldwide 2014
Ten costliest events for the insurance industry

Date	Event	Affected area	Overall losses in US$ m original values	Insured losses in US$ m original values	Fatalities
7–16.2.2014	Winter damage, snowstorms	Japan	5,900	3,100	37
18–23.5.2014	Severe storms, hailstorms	United States	3,900	2,900*	
7–10.6.2014	Severe storms, hailstorm	France, Belgium, Germany	3,500	2,800	6
5–8.1.2014	Winter damage	United States, Canada	2,500	1,700*	
3–5.6.2014	Severe storms, tornadoes	United States	1,600	1,300*	
27.4.–1.5.2014	Severe storms, tornadoes	United States	2,000	1,200*	40
11–17.9.2014	Hurricane Odile	Mexico	2,500	1,200	6
Dec 2013–Feb 2014	Storm surges, floods	United Kingdom, Ireland	1,500	1,100	
2–4.4.2014	Severe storms, tornadoes	United States	1,500	1,100*	2
27.11.2014	Hailstorm	Australia	1,200	890	

Source: Munich Re NatCatSERVICE, *PCS

Africa

The African continent registered 100 loss events, claiming the lives of 750 people. Overall losses from natural catastrophes came to US$ 730m, of which approximately one-tenth was insured. The main occurrences were thunderstorms, flash floods, landslides and floods, triggered in most cases by convective events. Three tropical cyclones passed over islands off the African mainland. Cyclones Hellen and Bejisa, in particular, caused damage on Madagascar, Mayotte, Réunion and the Comoro Islands.

Asia

In 2014, Asia was again affected by the largest number of loss events. Its 360 natural catastrophes resulted in overall losses of US$ 50bn, with eleven separate events each accounting for a loss of at least US$ 1bn. Three-quarters of all fatalities in natural catastrophes in 2014 were in Asia, principally in India and China. Cyclone Hudhud, which hit the east coast of India in October, was globally the most costly event of the year, with overall losses of US$ 7bn. The second most costly natural catastrophe was also in Asia. Extreme

weather conditions in the winter with ice and snow caused damage of US$ 5.9bn in Japan. With insured losses of US$ 3.1bn, this was the costliest event of the year for the insurance industry. In August, an earthquake in China caused an overall loss of US$ 5bn, making it one of the costliest events worldwide. Widespread seasonal floods in India and Pakistan resulted in overall losses of US$ 5.1bn.

Australia/Oceania

The region of Australia, New Zealand and the Pacific island states experienced 80 loss events, accounting for overall losses of US$ 1.6bn. The burden for insurers was US$ 1bn. A total of 70 people lost their lives. Cyclone Ita caused major losses in Australia, New Zealand and on Papua New Guinea. Local storms and storm events also occurred in Australia. At the end of November, severe damage was caused in Brisbane by a storm cell accompanied by intense rain, squalls and hail. At US$ 890m, it was

the costliest event for the local insurance market. As well as Cyclones Ita and Lusi, New Zealand mainly experienced local thunderstorms with floods and landslides. On the country's North Island, an earthquake with a magnitude of 6.2 only caused minor property damage to apartment blocks and infrastructure.

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OUR EXPERT

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Loss events in Asia 2014
Ten costliest events for the economy overall

Date	Event	Affected area	Overall losses in US$ m original values	Insured losses in US$ m original values	Fatalities
12–13.10.2014	Cyclone Hudhud	India	7,000	530	84
7–16.2.2014	Winter damage, snowstorms	Japan	5,900	3,100	37
3–15.9.2014	Floods	India, Pakistan	5,100	370	665
3.8.2014	Earthquake	China	5,000		617
11–22.7.2014	Typhoon Rammasun, floods	China, Philippines, Vietnam	4,600	250	195
April–September 2014	Drought	China	2,500		
12–20.9.2014	Typhoon Kalmaegi (Luis), floods	China, Philippines, Vietnam	2,500		33
9–18.9.2014	Floods, landslides	China	1,300		39
20–28.5.2014	Floods	China	1,000		37
11–20.7.2014	Floods, severe storms	China	1,000		68

Source: Munich Re NatCatSERVICE

Natural catastrophes 1980 to 2014

Breakdown by continents and main perils

Between 1980 and 2014, Munich Re's NatCatSERVICE registered a total of 21,700 loss events. The graphs provide a breakdown of these events by continent and subcontinent and shows the percentages attributable to the following four main perils:
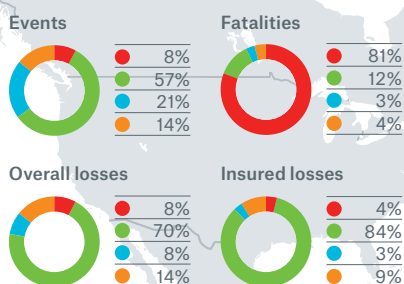
- **Geophysical events:**
  Earthquake, tsunami, volcanic activity
- **Meteorological events:**
  Tropical storm, extratropical storm, convective storm, local storm
- **Hydrological events:**
  Flood, mass movement
- **Climatological events:**
  Extreme temperatures, drought, wildfire

* North America includes Central America and the Caribbean

Overall losses and insured losses in 2014 values.
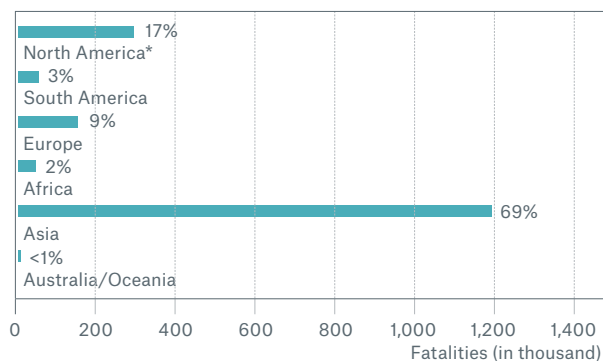
Source: Munich Re NatCatSERVICE

North America*

Events
- 8%
- 57%
- 21%
- 14%

Fatalities
- 81%
- 12%
- 3%
- 4%

Overall losses
- 8%
- 70%
- 8%
- 14%

Insured losses
- 4%
- 84%
- 3%
- 9%

South America

Events
- 17%
- 21%
- 51%
- 11%

Fatalities
- 59%
- 3%
- 36%
- 2%

Overall losses
- 36%
- 5%
- 35%
- 24%

Insured losses
- 74%
- 3%
- 18%
- 5%

Number of loss events: 21,700

- North America* — 24%
- South America — 6%
- Europe — 20%
- Africa — 9%
- Asia — 33%
- Australia/Oceania — 8%

Fatalities**: 1.74 million

- North America* — 17%
- South America — 3%
- Europe — 9%
- Africa — 2%
- Asia — 69%
- Australia/Oceania — <1%
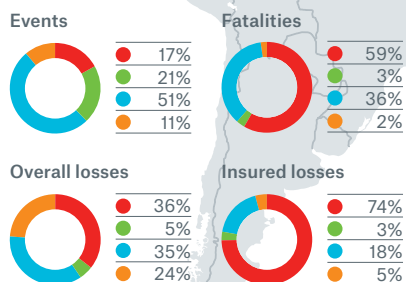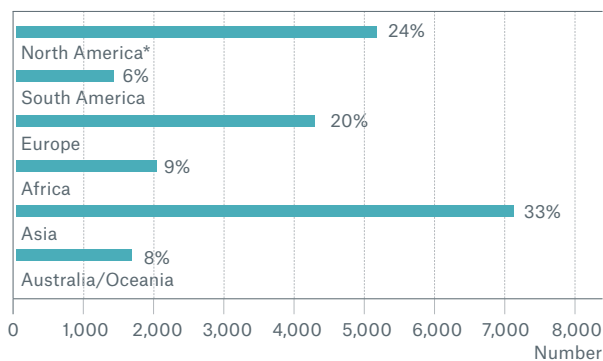
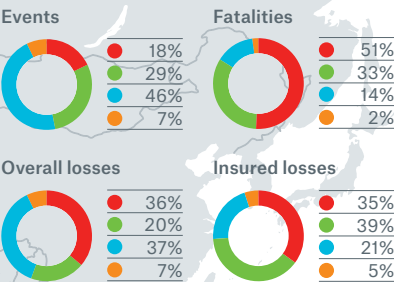**Does not include famine victims

Europe

Events

🔴	8%
🟢	46%
🔵	32%
🟠	14%

Fatalities

🔴	2%
🟢	3%
🔵	3%
🟠	92%

Overall losses

🔴	14%
🟢	32%
🔵	33%
🟠	21%

Insured losses

🔴	2%
🟢	63%
🔵	27%
🟠	8%

Asia

Events

🔴	18%
🟢	29%
🔵	46%
🟠	7%

Fatalities

🔴	51%
🟢	33%
🔵	14%
🟠	2%

Overall losses

🔴	36%
🟢	20%
🔵	37%
🟠	7%

Insured losses

🔴	35%
🟢	39%
🔵	21%
🟠	5%

Africa

Events

🔴	7%
🟢	31%
🔵	49%
🟠	13%

Fatalities

🔴	21%
🟢	11%
🔵	67%
🟠	1%

Overall losses

🔴	23%
🟢	12%
🔵	20%
🟠	45%

Insured losses

🔴	3%
🟢	49%
🔵	40%
🟠	8%

Australia/Oceania

Events

🔴	9%
🟢	54%
🔵	25%
🟠	12%

Fatalities

🔴	51%
🟢	19%
🔵	15%
🟠	15%

Overall losses

🔴	28%
🟢	28%
🔵	18%
🟠	26%

Insured losses

🔴	49%
🟢	31%
🔵	15%
🟠	5%

Overall losses: US$: 4,200bn

Region	%
North America*	37%
South America	3%
Europe	15%
Africa	1%
Asia	40%
Australia/Oceania	4%

Insured losses: US$ 1,100bn

Region	%
North America*	64%
South America	1%
Europe	17%
Africa	<1%
Asia	12%
Australia/Oceania	6%

Tornadoes in the USA: Increasing frequency of major outbreaks

Trail of devastation: Aerial view of Tuscaloosa, Alabama, after a tornado.

Eberhard Faust

Over the last few years, outbreaks of multiple tornadoes in the USA have caused very serious damage, without any apparent fundamental change in the annual tornado total. New research results show that, while tornadoes occur on fewer days, there are now more frequent major outbreaks featuring large numbers of twisters at the same time.

The most destructive tornado outbreaks up to now were observed in the spring of 2011 (see table). The extent of damage was equivalent to the scale of hurricane damage because cities like Tuscaloosa, Birmingham (Alabama) and Joplin (Missouri) were badly hit.

Back in 2013, we already described how there has been an increase in variability and range since the 1970s for normalised losses from the aggregated severe thunderstorm risks of hail, tornado, squall and heavy rain in the USA east of the Rocky Mountains (see TOPICS Geo Natural catastrophes 2013). This means that ever greater annual losses occurred over the period, whereas lower loss amounts had occurred in other years. A crucial factor here was evidence that the reason for the increasing loss range was an analogous change in the meteorologically measurable forcing for severe outbreaks of thunderstorms, in other words a change in climatic conditions. At that time, it could only be illustrated in aggregated form for all thunderstorm risks, but not for individual risks like tornadoes.

Now, however, research results are available that systematically describe and classify the striking accumulation of major tornado outbreaks over the last two decades in the context of the entire time series since the 1950s. This shows that the increase in major tornado outbreaks supports the analysed increase in range for severe thunderstorms: the annual number of days with more than 30 tornadoes of intensity 1 on

the (Enhanced) Fujita Scale or more intensive ones (EF1+) occurring has therefore increased ever more sharply. In contrast, the number of days on which only a few tornadoes occur is declining (see graph on page 56). Additionally, the increasing frequency of major outbreak days enhances the potential loss per event because most of such days occur within severe thunderstorm periods lasting for several days (Trapp, 2014). Thus, the aggregate losses for the days covered by the hours clause of a thunderstorm event lasting several days can be even higher than the losses caused for the major tornado outbreak days alone. If one additionally takes the comparatively small and linear footprint of tornadoes and the associated randomness of hits to highly valuable urban areas, this effect can increase the variability of losses.

The investigation of tornadoes of intensity EF1+ is due to the fact that tornadoes that occurred before the 1970s were only assigned intensities retrospectively. However, in all probability, the procedure used for this produced higher nominal intensities than those actually achieved. This means that the higher intensity categories EF2 to EF5 cannot be represented with the same degree of reliability over time. Since, in terms of the total number of tornadoes, the increase in major outbreak days and the decline in days with just a few tornadoes more or less compensate for one another, there is no discernible long-term trend in the annual aggregate from EF1+ tornadoes.

Over 30 tornadoes of EF1 intensity or greater were registered just once a year on average in the decade between 1994 and 2003. However, in the period 2004–2013 (including the exceptionally destructive year of 2011), the figure tripled (Brooks et al., 2014). In other words: generally speaking, tornadoes are occurring on fewer days, but when they do, then in much greater numbers.

Costly tornadoes

Period	Regions	Overall losses in US$ bn	Insured losses in US$ bn
April 2011	Alabama (among others Tuscaloosa, Birmingham) and 11 other states	15.0	7.3
May 2011	Missouri (among others Joplin) and 21 other states	14.0	6.9
May 2003	Oklahoma (among others Oklahoma City) and 18 other states	4.3	3.3
May 2013	Oklahoma (among others Moore) and 7 other states	2.8	1.8
April/May 2002	17 states	2.2	1.7
May 1999	Oklahoma (among others Oklahoma City) and 17 other states	2.8	1.5
April 2006	8 states	1.6	1.3
February 2008	Alabama (among others Tuscaloosa) and 10 other states	1.3	1.0
April 1994	12 states	1.5	0.8
May 2010	Kansas (among others Arkansas City), Oklahoma (among others Oklahoma City)	0.8	0.6

The top ten loss events of the last two decades (original losses)

Source: Munich Re NatCatSERVICE

As well as this observation, there are further aspects to the increasing range: the start of the tornado season today fluctuates more strongly than it did in the past. The season start is defined as the day in a particular year on which the 50th tornado of EF1 intensity or stronger is registered (Brooks et al., 2014). We can find the two earliest and also the four latest start dates ever for the season in the period between the end of the 1990s and the present.

And one additional development stands out: tornadoes are not only occurring in greater frequency on fewer days – the spatial tornado density is also increasing. Based on a linear trend, the density has more than doubled between the 1960s and today (Elsner et al., 2014). Days were considered on which at least 32 tornadoes occurred. There are therefore two aspects to the growing clustering of tornadoes: the frequency of major outbreak events and the spatial density of the tornadoes have both increased.

Tornado clusters are responsible for major accumulation losses

What are the consequences from this on losses that are adjusted (normalised) for the increase in value? Since there is no trend in the number of tornadoes of EF1+ intensity, one could also assume that there is no trend for normalised losses in the period. Because from an economic perspective, it seems immaterial whether a specific number of tornadoes cause dam-

age on many, generally "small" outbreak days, or on just a few days as a temporal cluster. However, this view reveals nothing of the specific effects for the insurance industry. Insurers are confronted with ever greater accumulation losses as a result of virtually simultaneous tornado hits, against the background of more and more frequent major outbreak days. And the range of the accumulation losses is increasing. The challenge for risk management in the insurer–reinsurer chain is therefore growing, if one considers that the market losses from individual outbreak events have approached the scale of hurricane hits.

Up to now, the connection between climate change and increasingly large tornado outbreak events has not been clarified in detail. Current climate models assume that progressive climate change will more often produce environmental conditions favouring the development of severe thunderstorms, including tornadoes and hail. This is because, with higher temperatures, the moisture content of the atmosphere increases and likewise the available convective thunderstorm energy. And finally, a sufficiently high shear force remains in the lower regions of the atmosphere (Diffenbaugh, 2013). The increased spatial and tem-

Not more frequent, but clustered
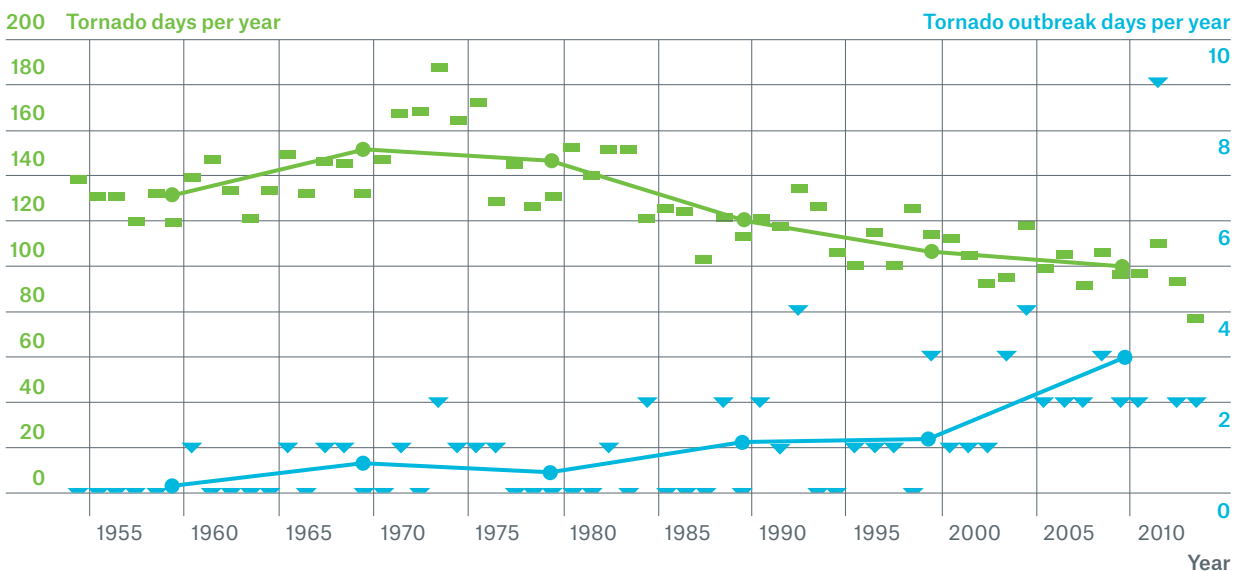
Whereas outbreak days with more than 30 tornadoes of EF1 intensity or greater have progressively increased (blue curve, right-hand scale), the by far larger number of days with at least one tornado is declining (green curve, left-hand scale).

Source: Munich Re, based on Brooks et al., 2014

poral concentration of tornadoes already observed does not contradict these model results, even though it has not been possible to analyse such detailed aspects of individual hazards.

What is key for the insurance industry is that it takes into account the greater concentration of tornadoes into individual outbreak events as an external loss driver. This has already led to a higher number of accumulation events. In any case, when assessing the current risk, the industry would be ill-advised to apply the frequencies of the last two decades as a standard. For example, the annual number of major outbreak days has already tripled on average within the space of just two decades. So the statistics are trend-prone and therefore non-stationary. This fact should be factored in when estimating the future level of hazard and risk.

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El Niño behind schedule

Contrary to original forecasts, the recurring climate oscillation El Niño (the Christ child) arrived later and in a weaker form in 2014. Models are not yet able to forecast the dynamics or intensity of this climate phenomenon with any degree of reliability.

Eberhard Faust

El Niño occurs in the Pacific every three to six years on average. Central and eastern portions of the tropical Pacific warm up more than usual, leading to heavy precipitation in some regions, while triggering droughts in others. El Niño also has an impact on marine ecology and can have a dire effect on the fish catch close to the coast. Peruvian fishermen called the phenomenon El Niño because its peak intensity was frequently around Christmas time.

Striking weather patterns in the summer months

In the autumn of 2013, a substantial El Niño event was predicted for the following year, based on a new method of forecasting (Ludescher et al., 2014). In the first half of 2014, several models then indicated that persistent El Niño conditions could set in as early as the summer. In fact, conditions only developed from October/November 2014.

However, prior to this, there were continuous phases of temperature fluctuation in the tropical Pacific that came close to the El Niño temperature threshold defined by the Climate Prediction Center (at NOAA, the US weather agency) for what is termed the Nino3.4 region; this threshold was even exceeded for short periods. Phases like this occurred between mid-April and early July, and from the second half of August. The possibility cannot therefore be ruled out that warming in the central and eastern equatorial Pacific was partly responsible for some anomalies in the summer months of 2014. The changes in atmospheric circulation patterns as a result of the warming may have contributed to the remarkably quiet Atlantic hurricane season. For example, an increase in average vertical wind shear was observed in the Caribbean Sea, along with increased atmospheric stability due

What happens during a neutral phase
Normal conditions are referred to as a neutral phase. Strong trade winds from easterly directions push the warm surface water west as far as the coast of Indonesia, thereby reducing the depth of the warm equatorial top layer in the east. Cold, nutrient-rich water is then able to well up into the top layer off the coast of South America. The warm surface water evaporates close to Indonesia. The resulting rising moisture-laden air leads to increased precipitation over Indonesia and the adjacent land areas. Conversely, dry air accompanied by cloud dispersion sinks over the eastern tropical Pacific and the west coast of South America, resulting in dry weather conditions.
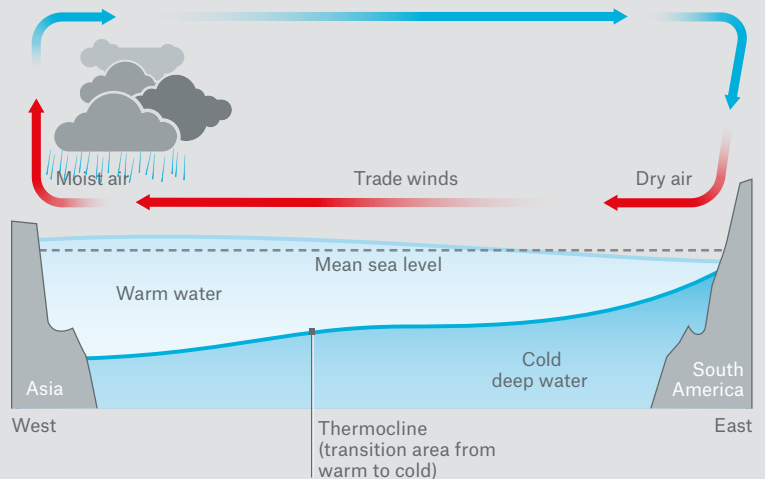
What happens during an El Niño phase
The trade winds lose much of their strength during an El Niño phase, or blow in an easterly direction. Warm surface water moves from Indonesia along an equatorial corridor to the coast of South America and intensifies the thickness of the warm top layer there. The cold deep water is then no longer able to upwell into the surface layer of water. In the eastern tropical Pacific and off the west coast of South America warm surface water is evaporating, which results in heavy rain there. In Indonesia and neighbouring regions, however, the weather tends to be dry.
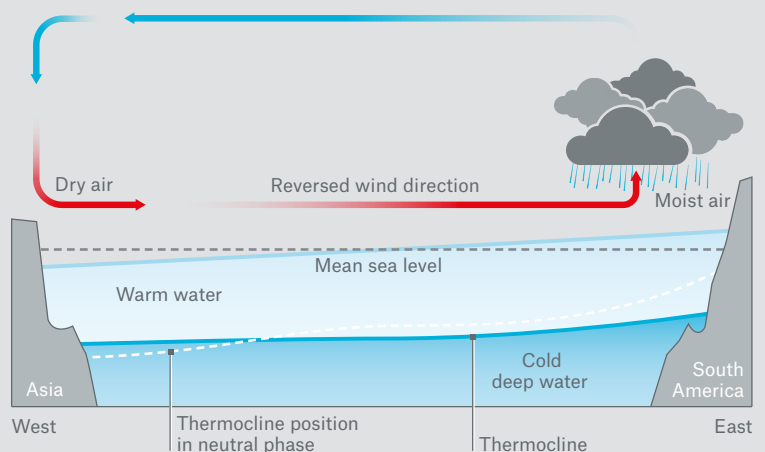
to descending air movement – both of which are tele-connection effects that occur in El Niño years and typically inhibit the development of hurricanes.

Another striking feature was much higher levels of hurricane activity in the eastern Pacific in comparison with the long-term average. The reasons for this included below-average vertical wind shear and above-average sea surface temperatures – both of which are also familiar features in El Niño years. Research has still to clarify whether such phenomena can actually be attributed to the beginning phase of the El Niño event.

El Niño noticeable worldwide

In many instances, the developments leading to an El Niño event begin in the northern hemisphere spring or summer of the year in question (onset year), peak around the end of the year, and subside again in the following year (decay year). The central and east-ern parts of the equatorial Pacific warm up much more than the long-term average, with the result that the trade winds, which normally blow from east to west, can reverse their direction. As a result, warm water is pushed eastwards from the western part of the equatorial Pacific. Along with the warmer water, atmospheric convection and rainfall move towards the central and eastern equatorial Pacific. The conse-quences include drought in the north and east of Aus-tralia, in Indonesia and parts of Southeast Asia, and heavy convective precipitation close to the Pacific coasts of Ecuador and northern Peru. Weather in North America is also affected through diverse tele-connection effects: in winter, the northwest and north are generally warmer than the long-term mean, whereas temperatures in the southeast and south are exceptionally cool. On the West Coast, in California and Oregon, the probability of (heavy) rainfall increases, as was witnessed in December 2014. This harbours the risk of substantial losses being triggered by landslides and floods.

Because of changes in circulation, the probability of rainfall also increases in other parts of the world, for example in the region around the Horn of Africa. In the northeast of Argentina and in the south of Brazil, Paraguay and Uruguay, increased rainfall and severe thunderstorms are also likely. In contrast, the north-east of Brazil is typically drier. Heatwaves can exacer-bate drought conditions in southern Africa, especially in South Africa, and on the Indian subcontinent. In extreme cases, an El Niño phase that persists into the summer can lead to a weakening of the summer mon-soon in India. Whether this actually happens depends on a further climate oscillation, the Indian Ocean Dipole. The index used for it indirectly describes the position of a large pool of warm water in the Indian Ocean. If the index is in a positive phase, it roughly balances El Niño's negative effect on the monsoon.

However, any weakening of the monsoon, or even drought conditions, can have a serious impact on Indian agricultural yields, especially soybeans, but also corn and wheat. And this can have dire conse-quences for the Indian economy. In years like these, GDP falls between 2% and 5%. In contrast, positive effects are felt in North America and Brazil, where better harvests can be expected. Globally, soybean yields in El Niño years are around 3.5% higher than average. Corn and wheat yields on the other hand are reduced by 2.3% and 1.4% respectively.

The natural oscillation that characterises El Niño and La Niña is one of the most important in the earth's cli-mate system. It has far-reaching effects for certain regions of the world. However, it is difficult to deduce any obvious effects on a global level. But in years with pronounced El Niño events, the risks from natural hazards in individual regions can alter substantially. So far, models from scientific institutes are able to predict up to six months in advance whether we are headed for an El Niño or its counterpart La Niña. There are still shortcomings with predicting the tem-poral dynamics of the event and its intensity. If El Niño and La Niña events could be predicted with a degree of reliability, it would be extremely helpful, not just for the regions affected, but also for insurers' and reinsurers' risk management.

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NATHAN Mobile: Portable risk assessment of natural hazards

Jürgen Schimetschek

With the new NATHAN Mobile module in the NATHAN Risk Suite, risk managers can now carry out natural hazard analyses at any time anywhere in the world and compare assessments – a truly pioneering innovation. The local risk situation first needs to be known before a professional assessment of natural hazards can be carried out. For example, if a risk inspector or underwriter wishes to discuss risk-related issues with an industry client, wherever possible they need to have direct access to all the latest relevant information if they are execute a qualified risk assessment. The challenge for Munich Re in this context was to provide the information stored in the NATHAN database for mobile devices in such a way that risk inspectors anywhere in the world could reliably retrieve natural hazard situations at city and address level – and in real time as well.

Risk assessments become simpler and quicker

With NATHAN, Munich Re has been offering a successful platform to assist with risk assessments for many years. An innovative application has now been developed for the NATHAN Risk Suite that meets all the requirements described above. To ensure risk inspectors always have access to current data, the developer team decided to connect NATHAN Mobile directly to the NATHAN database, which is protected on Munich Re's servers. To guarantee that it is up to date, NATHAN Mobile can only be called up via the existing browser on the mobile device. This saves the client any costly or resource-consuming IT implementation.

Because smartphones and tablets have different screen sizes and resolutions, particular emphasis was placed from the start on having a straightforward intuitive touch operation and an ergonomic design. The application is programmed in HTML5 and guarantees optimal dynamic adjustment to the different screen sizes (responsive design).

The new NATHAN Mobile adds a further innovative module to the NATHAN Risk Suite.

In NATHAN Mobile, the user either enters the address of the insured property or calculates their current position using the device's GPS signal. The different hazard zones for the location are marked in colour on the superimposed map. You can zoom in and out of the map using the simple finger movement that is standard with smartphones and tablets.

Overall risk score for a better overview

The overall risk score in NATHAN Mobile has been visually highlighted to give a quick overview of the severity level of the local hazards. The overall risk score represents an absolute measurement of the degree of natural hazard risk in property insurance. It includes the hazards earthquake, tropical storm, winter storm, tornado, hail, flash flood, storm surge and flood, and consists of the relevant natural hazard categories and a generalised loss experience value for standard commercial and industrial business. If required, the overall risk score can be scaled to the client's individual risk situation.

In NATHAN Mobile, real-time events (feeds) that are updated daily, and past natural catastrophe events, are also visually linked to the relevant map section. The feeds come from qualified scientific sources, and from the Munich Re NatCatSERVICE database.

Accelerating and optimising the workflow was a further aspect that development focused on. For example, a NATHAN Risk Report can now be e-mailed directly to the insurance underwriter from the application. The PDF contains the risk parameters calculated by NATHAN Mobile for further assessment. Since no follow-up risk report is required, this reduces the effort required by the risk manager on site. In addition, the underwriter can draw up an offer for the policyholder much faster.

Focus on the essentials

In order to ensure that the application is smooth and simple to operate, the developers consciously dispensed with more complex elements, such as comparing and assessing entire portfolios. These functions are still possible in the NATHAN Portfolio Risk module of the NATHAN Risk suite.

As with all other modules in the NATHAN Risk Suite, access to NATHAN Mobile can be individually negotiated with the Client Manager at Munich Re. What's more, with NATHAN Light, Munich Re also offers a free version with restrictions on functionalities (less detailed maps, restricted data material).

A storage medium, many different output options: Desktops, laptops, tablets and smartphones all access the same data, and the output is always optimised for the device's technical requirements.

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Topics Geo – 50 major loss events 2014

No.	Date	Loss event	Country/Region	Deaths	Overall losses US$ m	Insured losses US$ m	Explanations, descriptions
1	Dec 2013–Feb 2014	Floods , storm surges	UK, Ireland		1,500	1,100	Ground saturated, landslides, floods. Villages cut off for four weeks. >6,500 properties, businesses, vehicles flooded. Power outages. Evacuations.
2	2014	Drought	Brazil		5,000		Lack of rain, high temperatures. Reservoirs, rivers dry up. Severe losses to agriculture (sugar cane, coffee). Electricity generation by water power plants reduced. Affected: >27,000,000.
3	5–8.1.	Winter damage, cold wave	USA, Canada		2,500	1,700	Cold Arctic air mass. Extreme low temperatures (down to -50°C). Roads damaged, hundreds of accidents. Air and rail traffic disrupted. Business interruption. Great Lakes partly frozen.
4	18–20.1.	Flash floods, landslides	France, Italy	3	450	270	Torrential rain, mudslides. Rivers burst their banks. >2,000 houses, schools, shops, hotels damaged. Vehicles destroyed. 30 boats sank. >4,000 homes without power. Camp site flooded. Trees downed. Crops damaged, livestock affected. Evacuated: 2,500.
5	7–16.2.	Winter damage, snowstorms	Japan	37	5,900	3,100	Heavy snowfall, high wind speeds, snowdrifts. Villages cut off. Numerous houses damaged. Air, road and rail traffic disrupted. Traffic accidents. Power outages. Injured: >2,800.
6	11–14.2.	Winter damage, winter storm	USA	25	750	280	Icy rain and snowfall, sleet, freezing rain, black ice. Buildings, houses damaged. Thousands of flights cancelled, thousands of traffic accidents. Schools closed. Severe timber loss to state's woodlands.
7	12–14.2.	Winter Storm Tini, floods	Northern and western Europe	1	650	400	Thunderstorms, small tornadoes, gusts up to 180 km/h. Rivers burst their banks. Numerous houses damaged, flooded. Road, rail, bus, ferry traffic disrupted. >2,000 trees downed.
8	22.3.	Landslide	USA	43	20		15 million cubic metres of slip mass, heavy rain, 49 buildings destroyed. Road blocked. River backed up.
9	27–29.3.	Hailstorm	USA		800	590	Thunderstorms, gusts up to 130 km/h, hail (10 cm), flash floods. Numerous houses damaged.
10	27.3. –1.4.	Cyclone Hellen	Madagascar, Comoros, Mayotte	4	25		Cat 4 cyclone. Wind speeds up to 230 km/h, heavy rain, flash floods, landslides, high waves, coastal flooding. >460 houses destroyed. Hospital, schools damaged/destroyed.
11	April-May	Floods, flash floods	Afghanistan	175			Several flood waves, heavy rain, landslides. >6,000 houses, 250 shops, schools destroyed, >9,100 houses, >50 mills damaged. >730 km of roads. >20,500 head of livestock killed.
12	1–4.4.	Earthquake (series), tsunami	Chile, Peru	7	800	400	M_w 8.2. >700 aftershocks up to M_w 7.6. Tsunami up to 2 m, fires, landslides. >2,000 houses destroyed, >10,000 damaged, several businesses burnt. Gas lines burst, explosions. Affected: >510,000.
13	2–4.4.	Severe storms, tornadoes	USA	2	1,500	1,100	Severe thunderstorms. >10 tornadoes up to EF2, large hailstones (10 cm), flash floods. Rivers burst their banks. >22,000 houses damaged. >36,000 vehicles damaged (by hail).
14	5–18.4.	Cyclone Ita, floods	Australia, New Zealand		190	50	Cat 4 cyclone. Wind speeds up to 215 km/h, gusts up to 295 km/h, heavy rain (185 mm/24 h), flash floods. Houses destroyed. >700 km² of crops damaged (esp. sugar cane). Affected: 54,000.
15	27.4.–1.5.	Severe storms, tornadoes	USA	40	2,000	1,200	>60 tornadoes up to EF4, mudslides. >1,200 buildings, houses destroyed/damaged, hospital damaged. Farm buildings damaged. Injured: 115.
16	10–14.5.	Severe storm, tornadoes	USA		850	640	Thunderstorms, tornadoes, gusts up to 190 km/h, hail (7 cm), heavy rain, flash floods. >20 buildings destroyed, >600 buildings, 3 churches damaged.
17	13–30.5.	Floods, landslides	Serbia, Croatia, Bosnia and Herzegovina, Romania	86	3,600	70	Low pressure system "Yvette", torrential rain, flash floods, landslides. >100,000 houses, 230 public buildings, dozens of factories damaged/destroyed. Entire villages destroyed. Power outages. Water supply disrupted. Extensive losses to agriculture, livestock killed. Affected: >3.1 million.
18	18–23.5.	Severe storms, hailstorms	USA		3,900	2,900	Severe thunderstorms (super cell), tornadoes. Numerous buildings, houses, farm buildings, businesses (roofs) damaged. Thousands of vehicles damaged. Roads flooded, weather-related accidents.
19	20–28.5.	Floods	China	37	1,000		Heavy rain (635 mm/72 h). >95,000 houses damaged/destroyed. >2,600 km² of crops damaged/destroyed. Missing: 39, displaced: 447,000, affected: >5.5 million.
20	1.6.–6.7.	Floods	Ivory Coast	39			Seasonal rains, flash floods, mudslides. Hundreds of houses flooded. Injured: 24.
21	3–5.6.	Severe storms, tornadoes	USA		1,600	1,300	Thunderstorms, hail (11 cm), heavy rain, flash floods. Hundreds of buildings, houses, hotels damaged. Hail damage to 4,500 vehicles. Extensive losses to agriculture. Injured: 36.
22	5.6.–20.7.	Floods, flash floods	Argentina, Brazil	26	560		Persistent heavy rain (375 mm/24 h). Rivers burst their banks. >53,000 properties damaged/destroyed. Roads, >150 bridges damaged/destroyed. Crops destroyed. Schools closed. Injured: 117.
23	7–10.6.	Severe storms, hailstorms	France, Belgium, Germany	6	3,500	2,800	Low pressure system "Ela". Numerous houses damaged/basements flooded. >340,000 vehicles damaged. >80,000 trees downed. Losses to agriculture, livestock killed. Injured: 70.
24	14–19.6.	Severe storm, tornadoes	USA	2	700	540	Thunderstorms, tornadoes, gusts up to 145 km/h, large hailstones, flash floods, lightning. Missouri river burst its banks. Town (Pilger, Nebraska) damaged/destroyed (75%) due to tornadoes. Crops damaged.
25	28.6.–1.7.	Floods, severe storms	Canada		850	500	Thunderstorms, gusts up to 130 km/h, heavy rain (230 mm/48 h), hail. Many houses, shops, businesses, vehicles flooded/damaged. Bridges damaged/destroyed, roads, highways damaged.
26	8.7.	Hailstorm	Bulgaria	1	700	120	High wind speeds, hail (3.5 cm), heavy rain. Many houses, hospital, >50,000 vehicles damaged.
27	11–20.7.	Floods	China	68	1,000		Wave of monsoon rains. >150,000 homes, structures damaged/destroyed. Power outages.
28	11–22.7.	Typhoon Rammasun (Glenda)	China, Philippines, Vietnam	195	4,600	250	Cat 4 typhoon. Gusts up to 300 km/h, high storm surge. >69,000 houses, dwellings destroyed. Air, road, ferry traffic disrupted. Power outages. Affected: >9.6 million. Injured: 99.
29	19–26.7.	Typhoon Matmo (Henry), floods	China, Philippines, Taiwan	64	530		Cat 1 typhoon. >2,600 houses destroyed. Plane crash (48 deaths). Air traffic disrupted, ferry services suspended. Business interruption. Schools closed. Losses to agriculture.
30	28–29.7.	Severe storms, flash floods	Germany	2	400	190	Thunderstorms, high wind speeds, heavy rain (292 mm/7 h), flash floods. Basements, vehicles, roads flooded, weather-related accidents. Air traffic disrupted. Trees, power lines downed.
31	30.7.	Landslide	India	151			Heavy rain, massive landslide. >40 houses destroyed. Roads damaged or blocked.
32	31.7.–28.8.	Wildfire	Sweden	1	150	40	Dry conditions, strong gusts. 25 buildings/structures destroyed. >150 km² forest destroyed.
33	3.8.	Earthquake	China	617	5,000		M_w 6.1. >400 aftershocks. >52,500 houses collapsed, >156,000 damaged. Roads, bridges destroyed. Power outages. Water supply disrupted. Injured: >3,100, displaced: 230,000, affected: >1 million.
34	7–8.8.	Severe storms	Canada		650	500	Thunderstorms, heavy rain. Extensive damage to vehicles.
35	11–13.8.	Floods	USA	2	1,600	540	Thunderstorms, heavy rain, strong gusts. >34,000 houses flooded. Hundreds of roads closed.
36	24.8.	Earthquake	USA	1	700	150	M_w 6.0. Major fires. 175 buildings, houses, hospital, courthouse, library severely damaged, >1,000 houses damaged. Severe damage to vineyards and wineries. Injured: >250.
37	3–15.9.	Floods	India, Pakistan	665	5,100	370	Heavy seasonal rains (southwest monsoon), landslides. Hundreds of towns, villages flooded. >100,000 homes destroyed. Vehicles damaged. Air, rail traffic affected. Injured: >600.
38	11–17.9.	Hurricane Odile, floods	Mexico	6	2,500	1,200	Cat 4 hurricane. >25,000 homes, dwellings damaged/destroyed. Vehicles, boats damaged. Airports, ports closed. Severe damage to power infrastructure. Water supply affected.
39	12–20.9.	Typhoon Kalmaegi (Luis)	China, Philippines, Vietnam	33	2,500		Cat 1 typhoon. >2,000 houses destroyed. Boats damaged. Ferry sank. Rail, air traffic affected. Stock market closed. Trees downed. Losses to agriculture: >8,000 km² of farmland affected.
40	29–30.9.	Mt. Ontake volcano	Japan	63			Ejection of rocks, ash, emission of gas. Steam eruption. Huts damaged. Injured: 70.
41	October	Floods	Democratic Republic of Congo	154	15		Heavy rain, landslides. Rivers burst their banks. >1,000 houses damaged/destroyed, health centres, church destroyed. 2 bridges destroyed, roads damaged. Gold mine flooded. Injured: >100.
42	11–13.10.	Cyclone Hudhud, storm surge	India	84	7,000	530	Cat 4 cyclone. >80,000 houses, commercial buildings damaged. Food stocks, rice crops damaged. Severe damage to power grid: >40,000 electrical poles destroyed. Affected: 920,000.
43	October–December	Volcanic activity Mount Sinabung	Indonesia	50			Ejection of ash, pyroclastic flows. >140 tremors. Several houses destroyed. Air traffic affected. Losses to agriculture, >100 km² of farmland damaged/destroyed. Evacuated: >12,000.
44	12–19.10.	Hurricane Gonzalo	Antigua and Barbuda, Anguilla, Sint Maarten, Bermuda	1	100	55	Cat 4 hurricane. Wind speeds up to 220 km/h, heavy rain, flash floods, storm surge. Numerous hotels, houses damaged. >30 boats destroyed. Zoo severely damaged. Air, road traffic affected, ferry service suspended. Trees, power lines downed. Water pipes damaged.
45	30.10.–23.11.	Floods	Colombia	44	8		Heavy seasonal rains, hail, landslides, lightning. Rivers burst their banks. >250 houses/businesses, numerous vehicles, damaged. Roads blocked. Coal mine flooded. Displaced: >18,000.
46	3–19.11.	Severe storms	France, Italy, Switzerland	20	260		High wind speeds, tornadoes, heavy rain, snow. Numerous houses flooded. Vehicles flooded. Roads, tunnels, metro stations flooded/closed. Airport terminal flooded. Railway line blocked.
47	21.11.–1.12.	Floods, flash floods	Morocco	47	300		High wind speeds, heavy rain, huge waves, coastal flooding. Thousands of houses damaged/destroyed. >18,000 roads, >500 bridges damaged. Power outages.
48	27.11.	Hailstorm	Australia		1,200	890	Supercell thunderstorm, large hailstones (11 cm), heavy rain. Numerous apartments, houses, businesses, vehicles damaged. Hangar, 7 small planes, several helicopters damaged.
49	5–8.12.	Typhoon Hagupit (Ruby)	Philippines	18	170		Cat 5 cyclone. Gusts up to 210 km/h, heavy rain. >39,000 houses destroyed, >253,000 damaged. Losses to agriculture, >45,000 tons of rice, >7,000 tons of corn lost. Affected: >3.9 million.
50	12.12.2014–2.1.2015	Floods	Malaysia, Thailand	36	300		Heavy seasonal rains, high wind speeds, landslides. Thousands of houses damaged/destroyed. Schools, roads, bridges, railway lines damaged. Evacuated: >150,000, displaced: >250,000.

Topics Geo – World map of natural catastrophes 2014

Munich RE
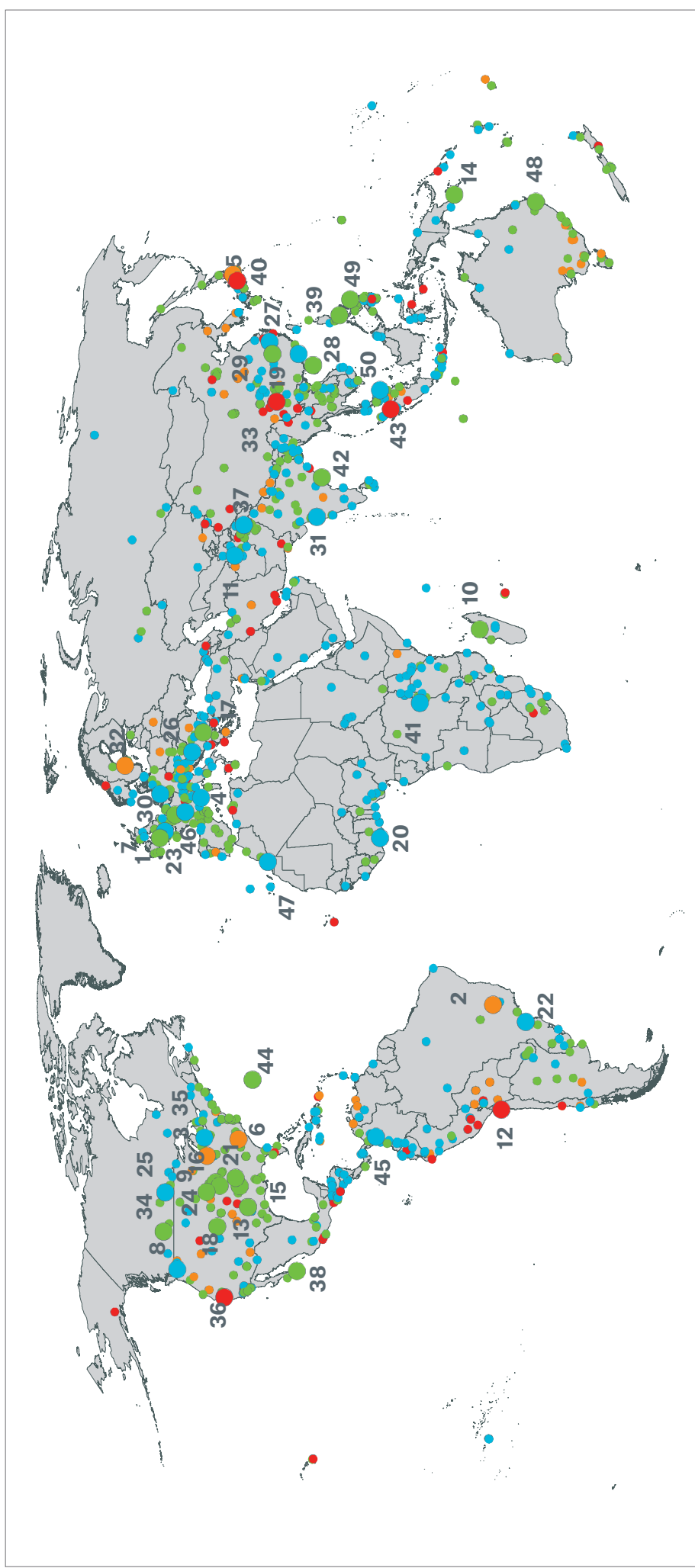
980 natural hazard events, thereof

○ 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

NOT IF, BUT HOW