

Trends in perils¹

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Purpose of the investigation

At the international scientific workshop on climate change and disaster losses in Hohenkammer 2006, organized by the University of Colorado and Munich Re, the 32 participants arrived at a catalogue of consensus statements.² Two of these statements read:

- Climate change and [natural climate] variability are factors which influence trends in disasters.
- There is evidence that changing patterns of extreme events are drivers for recent increases in global losses.

What signs are there to show that a changing climate contributes towards the trend in losses due to natural hazards? Can we see changing patterns of extreme weather occurrences reflected in elevated loss levels? The latter were investigated in the subsection on multidecadal regimes in US hurricane losses, which revealed a clear correlation between the climate signal and a running distribution of US hurricane losses. In other words, changing climate conditions have led to a change in the distribution of losses.

The following section summarizes the time series of losses since 1980, especially in two large regions: North and Central America (including the Caribbean) and Europe. Here too, we want to know whether climate has played a contributory part.

Underlying data

The evaluation is based on data for the period 1980–2007 from Munich Re's NatCatSERVICE® loss database. Natural catastrophes occurring worldwide since 1970 have been completely recorded in this database³ as well as all the major natural catastrophes since 1950. The frequently cited insurance industry data are a particularly important source of information on losses for the NatCatSERVICE® database, as are other regularly consulted sources such as scientific reports, governments and NGOs, weather services, and news agencies. Further information on classifications according to quality of data and other systematizations within the databank can be found in the literature.⁴ Due to the nature of a loss database based

¹ The CMF II talk presented in New York on 11 June 2008 combined two topics, namely an investigation of the development of loss time series for natural hazards worldwide and in regions, as well as an analysis of multidecadal regimes of US hurricane losses. The latter are closely associated with the loss time series, as the development of losses on a worldwide scale is to a very large extent determined by hurricanes. For pragmatic reasons, however, I have separated these two topics into two papers here. The present paper covers trends in perils.

² available at http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/workshop_report.html

³ However, only catastrophes which are covered by the information sources can be recorded.

⁴ See Faust, E., Höppe, P., Wirtz, A., Schmidt, S. (2006), Trends in natural catastrophes – potential role of climate change, in: Höppe, P. and Pielke, R., Jr. (editors) (2006), Understanding and attributing trends and projections, Workshop on climate change and disaster losses, 25 – 26 May 2006, Hohenkammer, Germany, p.89-102 (available at http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/)

on the requirements of the insurance industry, losses attributable to weather phenomena are more likely to be classified in categories of significance for insurance policies than in purely meteorological categories.

A rough geographical survey of major natural catastrophes worldwide since 1980 causing insured losses exceeding one billion US dollars (2007 US\$)⁵ reveals three hot-spot regions in particular: North and Central America (including the Caribbean), Europe (excluding Eastern Europe) and East Asia (Japan, South Korea, Taiwan). Indeed, insured losses exceeding US\$ 10 billion⁶ are to be found exclusively in East Asia and North/Central America with a distinct focus on hurricane hits in the Gulf of Mexico and Caribbean (Fig. 1).

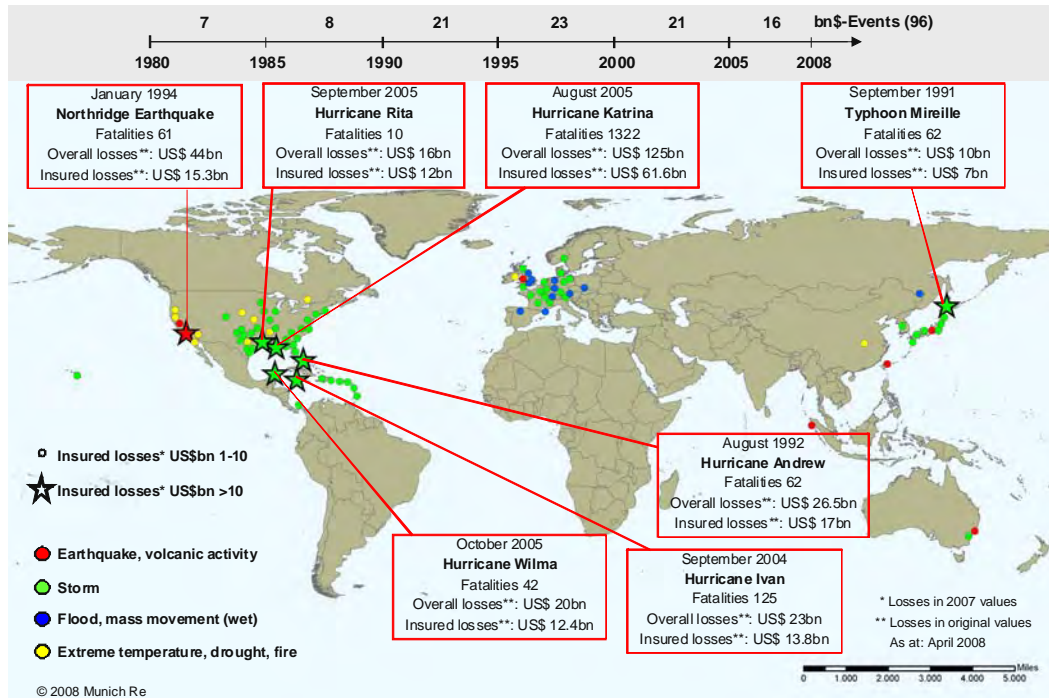


Fig. 1 Billion and 10 billion US\$ losses from 1980 to April 2008. Source: Munich Re, 2008.

On the one hand, these hot spots can be attributed to the fact that they are the scene of particularly intense natural catastrophes, such as the hurricanes along the coasts of North and Central America, as well as the Caribbean, the typhoons along the coasts of East Asia and the winter storms in Europe. Another equally important factor in the genesis of such high losses is that considerable insured values are concentrated in these regions. To give a general impression of the situation, Fig. 2 shows a rough classification of countries according to average insurance premiums per person.

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⁵ To determine the insured losses exceeding US\$ 1 billion, the time series of losses due to natural catastrophes since 1980 has been adjusted to allow for inflation.

⁶ Refer to the preceding footnote with regard to the procedure for determining insured losses exceeding US\$ 10 billion.

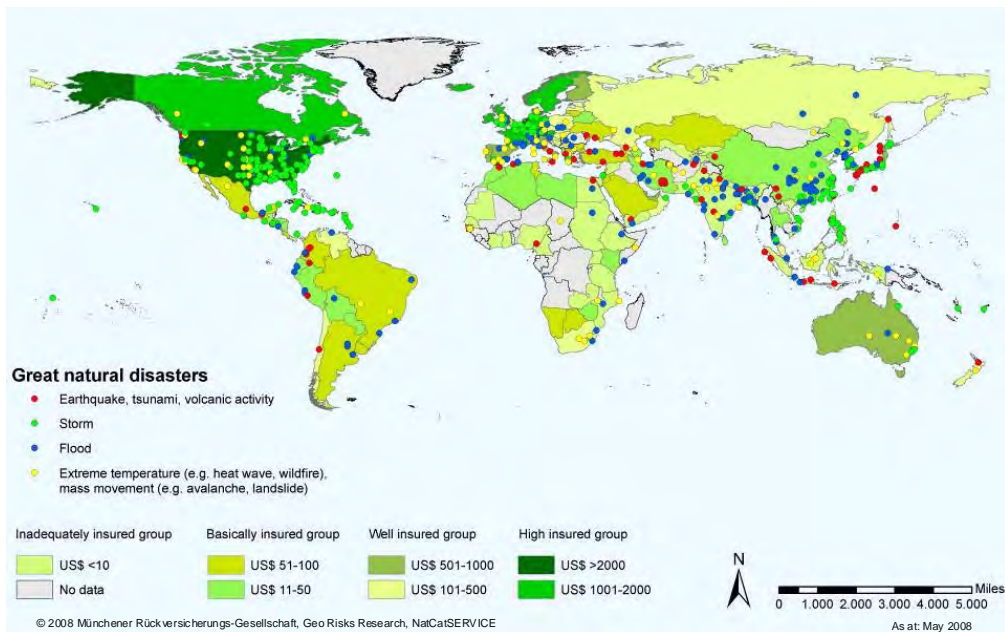


Fig. 2 Average insurance premiums per person and country (colour of the countries). The locations of so-called great natural catastrophes since 1980 have been plotted additionally. Source: Munich Re, 2008.

On a worldwide scale, the inflation-adjusted time series of *annual losses* due to great natural catastrophes⁷ since 1950 displays a progressively increasing development both in terms of overall loss⁸ and with regard to the share of insured losses (Fig. 3, top). The main drivers of the trend are the progressive increase in values and – as far as insured losses are concerned – the rise in insurance penetration. There are other factors, too, such as the fact that built-up areas and value concentrations very often develop in regions of particularly high risk, that the susceptibility of insured properties to damage from extreme weather might have changed, or that the frequency and intensity of (weather-related) natural catastrophes are increasing. This last aspect corresponds to the influence of climate.

In the time series of annual counts of great natural catastrophes– differentiated according to types of peril – it is notable that geophysical catastrophes unrelated to the weather, such as earthquakes and tsunamis, do not display the same major increase as weather-related catastrophes (Fig. 3, below). Both types of catastrophe, whether weather-related or unrelated to weather, are subject to worldwide socioeconomic changes. This can be interpreted as an indication that the weather-related part in particular was exposed to a unique dynamism in recent decades which cannot be explained purely through socioeconomic developments.

⁷ Great natural catastrophes match the criteria that an affected region's ability to help itself is distinctly overtaxed and hence interregional or international assistance is necessary. Substantial overall losses defined as exceeding $106 \times 5\%$ of per capita GDP (developed countries) or at least U.S.\$ 300 million (developing countries) and/or more than a thousand fatalities, and/or more than a hundred thousand people made homeless serve as subsidiary criteria. This data set is generated to be homogenous since the 1970s, as it does not include smaller weather events that would be underreported earlier in the record.

⁸ Overall loss is defined as the direct losses associated with a catastrophic event's impact as determined in the weeks and sometimes months after the event. Indirect losses and longer-term macroeconomic effects are not included.

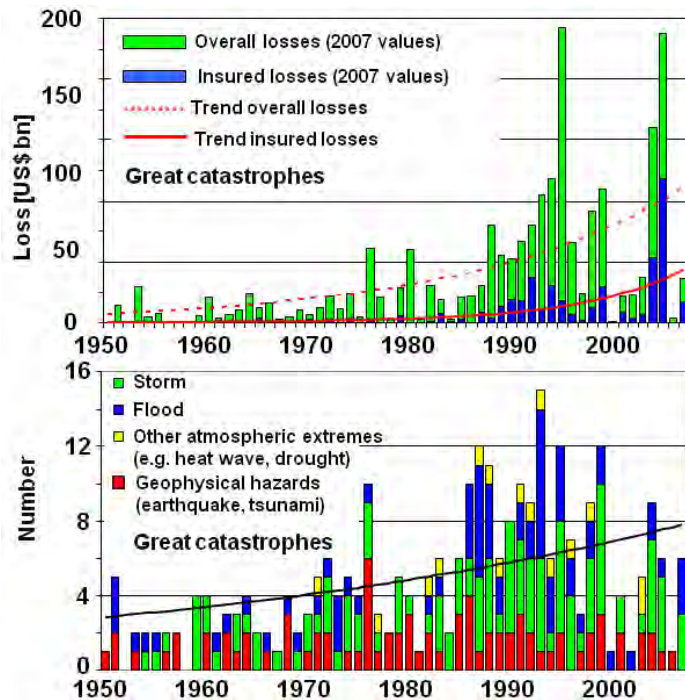


Fig. 3 Time series of overall and insured annual losses due to great natural catastrophes worldwide (top) and the annual numbers per type of peril (below).
Source: NatCatSERVICE®, Munich Re, 2008.

When considering the annual counts of weather-related catastrophes on a continental scale, increases are evident in the time series for North and Central America (including the Caribbean) and Europe (Fig. 4).

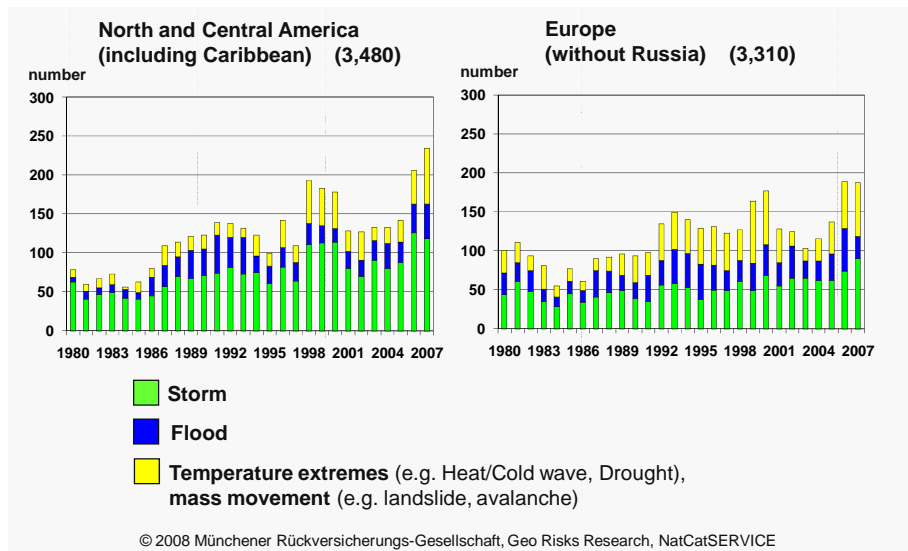


Fig. 4 Annual number of weather-related losses per phenomenon and per region 1980-2007. The time series for South America, Africa and Oceania have not been included here. Source: Munich Re, 2008.

These two large regions will be considered in more detail below by way of example in order to investigate the time series of annual numbers of different types of weather losses, as well as the development of loss intensity classes over time.

North and Central America, Caribbean

When considering the storm phenomena (see Fig. 5, top left), it is found that the number of windstorm losses per year, which are not related to tropical cyclones or winter storms and are therefore classified as convective windstorms, has increased almost three-fold according to the linear trend for the period 1980 – 2007. The number of tornado losses per year more than tripled. The number of annual winter storm losses has increased even more strongly, while the number of hurricane losses per year has risen to more than twice the original level (linear trend).

A distinct increase yielding a three-fold rise in the linear trend can be seen when considering the flood losses (see Fig. 5, top right). The number of flash floods in the period under review displays considerable variability on a multidecadal scale but no linear trend, while there is no trend at all to be seen in the number of storm surges. The number of wildfires (see Fig. 5, bottom) is seen to have increased 7-fold over the period since 1980 in the exponential fit applied here. However, these numbers must be viewed with caution, as the databank's sources alternate between collective reports of several fires treated as one occurrence and individual reports. Drought reports must also be treated with caution, as they sometimes refer to occurrences embracing several years and appropriate results cannot be obtained when considering annual numbers.

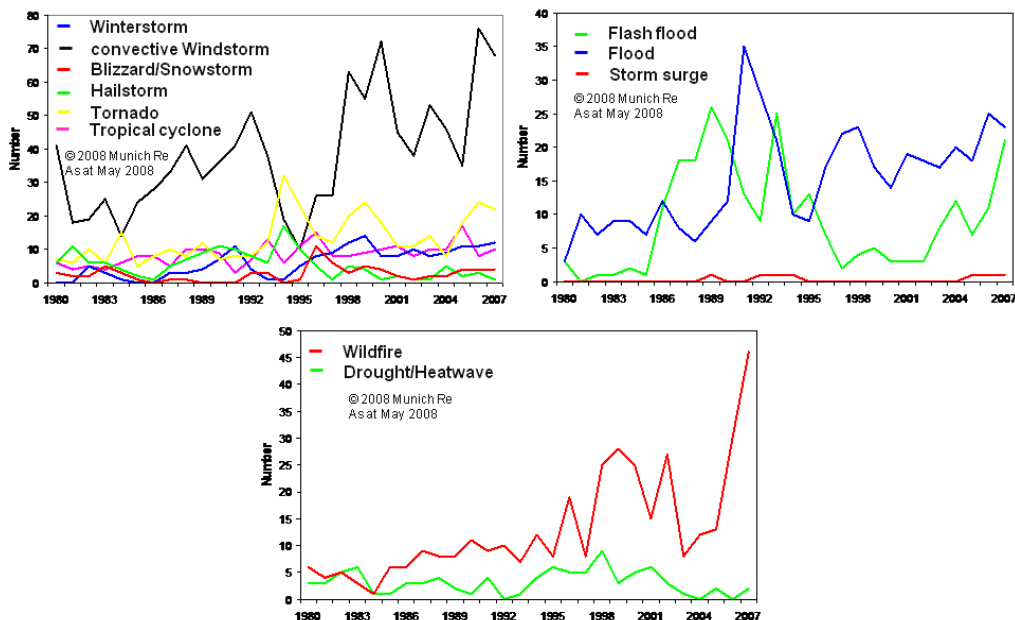
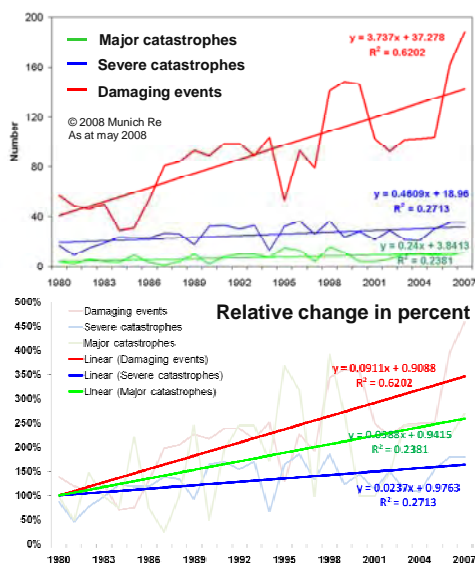


Fig. 5 Annual number of weather-related losses according to types of occurrence in North and Central America (including the Caribbean). Top left: windstorm phenomena, top right: flood phenomena, bottom: temperature extremes. Source: Munich Re, 2008.

Logically the recorded number of annual losses shows an increase when the area of settlements with asset value increases (e.g. due to urban sprawl), when the damage susceptibility of existing structures increases or when the frequency/intensity of extreme weather increases. The latter corresponds to the climate effect. Although we cannot present an exhaustive analysis of the first two aspects for North and Central America here, it nevertheless appears improbable that the structures should have become substantially more susceptible to losses in the period between 1980 and 2007. The effect of sprawling settlement areas with their concentration of values during this period is more difficult to assess and can be considerable in individual

regions. This factor has very probably contributed to the higher number of weather-related losses.

On the other hand, it is similarly known that weather events of high amplitude have also increased from the climate angle. This is particularly evident in the case of hurricanes, for a phase of great activity has been in progress since roughly the mid-1990s and has also resulted in a changed loss distribution (see below). Where convective events are concerned, it is known that an increase in 6-hour periods with significant severe thunderstorm environments of 8% per decade has been observed over the USA east of the Rocky Mountains since the 1970s.⁹ A significant fact with regard to flood losses is that the share of heavy precipitation (95th percentile) in total annual precipitation has increased by up to 3% per decade over almost the whole of North and Central America since 1950.¹⁰ One of the prerequisites for the growing number of wildfires lies in the persistent dryness of the southern and southwestern USA, as well as Mexico and other parts of Central America, which has also increased as the climate has changed.¹¹ In other words, there are also changes in climate which could be viewed as drivers leading to the higher number of weather-related losses.



Classification:

- Damaging events:**
< 20 deaths, up to considerable property damage
- Severe catastrophes:**
20 – 500 deaths,
US\$ 50 – 500m total losses
- Major catastrophes:**
> 500 deaths,
> US\$ 500m total losses

Fig. 6 Annual counts of natural catastrophes in North and Central America (including the Caribbean) according to loss intensity classes. Upper figure: absolute numbers per year. Lower figure: relative change (setting linear trend in 1980 to 100%). Source: Munich Re, 2008.

⁹ Brooks, H.E. and Dotzek, N. (2008), The spatial distribution of severe convective storms and an analysis of their secular changes, in: Diaz, H.F. and Murnane, R. (eds.) (2008), Climate extremes and society, Cambridge University Press, Cambridge, 35-53. See also Brooks, H.E. (2006), AMS Severe local storms special symposium.

¹⁰ Alexander, L.F. et al. (2006), Global observed changes in daily climate extremes of temperature and precipitation, JGR 111, doi:10.1029/2005JD006290. Heavy rains are naturally only one of the factors leading to floods. Increases of 14% and 20% in heavy and very heavy precipitation (95th and 99th percentile) are demonstrated for the USA by Groisman, P.Y. et al. (2004), Contemporary changes of the hydrological cycle over the contiguous United States: Trends derived from in situ observations, Journal of Hydrometeorology 5, 64-85. See also Trenberth, K.E. (2008), Climate Change and extreme weather events, CMF II.

¹¹ See Seager, R. et al (2008), Mexican drought: An observational, modeling and tree ring study of variability and climate change, Atmosfera (in press), available at www.ldeo.columbia.edu/res/div/ocp/drought/mexican.shtml, Seager, R. et al. (2007), Model projections of an imminent transition to a more arid climate in southwestern North America, Science 316, 1181-1184,

Figure 6 brings us to the annual number of natural catastrophes considered according to loss intensity classes.¹² According to the linear trend over the time series since 1980, the annual number of damaging events - the lowest intensity class – has increased more than three-fold. The number of severe catastrophes – the middle intensity class – has increased by roughly 50 percent since 1980 according to the linear trend, while the highest intensity class – the major catastrophes – has more than doubled. These are all very substantial increases. The sequence of the linear trends per loss intensity class in terms of relative increases compared to 1980 (= 100%) might give a clue to the mechanisms involved (Fig. 6, bottom left). Under the hypothetical assumptions of (1) a stable climate over time, i.e. no changes in frequencies/intensities of extreme weather events, and of (2) no substantial changes in damage susceptibility of structures since 1980¹³, we would expect the expansion of settlement areas and – with respect to small events – an increase in reporting as the main drivers of increasing annual loss counts. But, theoretically, these drivers should project most on the number of events associated with the smallest spatial footprints (such as the damaging events) or on the number of medium-scale footprint events (such as severe catastrophes). The most intense class, the major catastrophes, are associated with the largest spatial footprints (e.g. hurricane hits) and cannot increase in number at the same pace as the smaller events through expanding settlement areas (and reporting).¹⁴ So from a hypothetical viewpoint which switches off any changes in climate and starts from the expansion in settlement area (urban sprawl) and reporting as the main drivers of change, we should expect the strongest increase in the smallest intensity category (damaging events), followed by the medium category (severe catastrophes) and finally by the highest intensity category (major catastrophes). What has been observed deviates from this sequence substantially, insofar as the strongest intensity class associated with the largest spatial footprint has increased much stronger than the middle intensity class. Thus it seems that urban sprawl and reporting alone fail to explain this pattern of increase. So changing climate conditions are a plausible candidate for a driving factor at this stage. This initial hint needs to be analyzed and proved in more depth in the future.¹⁵

Europe

In Europe, a distinct increase in the annual number of windstorm phenomena over the entire time series (see Fig. 7, top left) is only evident in the case of windstorms which are not attributable to winter storms, i.e. convective windstorm. According to a second order polynomial trend curve, which is the most appropriate here, the number

¹² Figure 6 shows three intensity classes which have in turn been aggregated from seven of the intensity classes existing in the NatCatSERVICE® loss database. The monetary thresholds for the categories have been adjusted for inflation (CPI) each year. For a description, see A. Wirtz, Natural disasters and the insurance industry, submitted and accepted as a chapter for the ISDR book publication “Economic impacts of natural disasters”, to be published by Earthscan, 2009.

¹³ The latter seems to be a plausible assumption because the majority of structures today already existed in 1980 and most of these structures have been maintained without adjustments in order to improve the resilience.

¹⁴ Two examples might illustrate this: As the built-up area on the edge of settlements is expanding, more and more hits associated with small-scale events such as local severe storms, lightning strokes, hail strikes, convective gusts, tornadoes, flash floods, etc. should become “detected” by the increasing built-up area. In contrast, large-scale events such as today’s hurricane hits would also have been classified as major catastrophes in 1980 when the expansions on the edge of settlements which have been observed since then were still missing. In 1980, these hurricanes would already have affected many (at that time smaller) built-up areas.

¹⁵ This argument certainly has some limitations (e.g. urban sprawl is occurring at a different pace in different regions of the continent with different types of peril prevailing). It is more a starting point than an end point of thinking.

of events increased roughly two-fold. An increase is also to be observed in the number of flood losses (see Fig. 7, top right): a second order polynomial trend curve shows an increase of roughly 50% over the time series. There is no clear trend in the number of flash floods, which display considerable variability between decades, nor in the number of storm surges.

An upward trend can be observed in the number of wildfires (see Fig. 7, bottom). However, these numbers must be treated with caution, for the database sources have also combined several fires into a single occurrence. Reservations also apply with regard to the drought reports, as explained above.

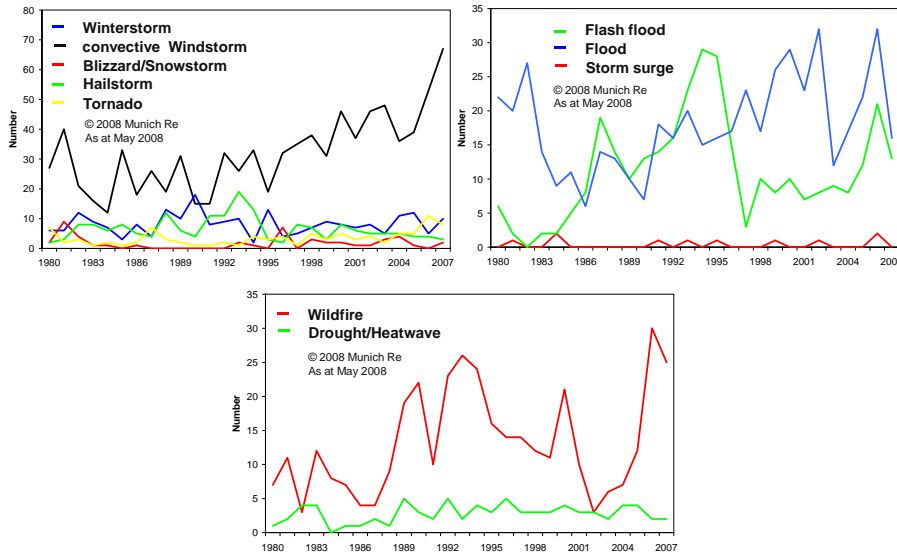
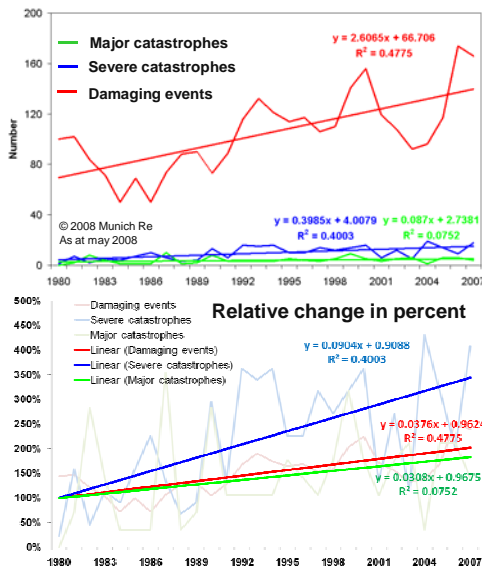


Fig. 7 Annual number of weather losses according to type of occurrence in Europe (without Russia). Top left: windstorm phenomena, top right: flood phenomena, bottom: temperature extremes. Source: Munich Re, 2008.

Here too, we are looking for the possible effects of a changing climate without at the same time disputing other drivers, such as the change in settlement areas. High-amplitude weather occurrences have also increased in Europe in the past few decades. One major prerequisite for more floods is that, in large parts of Europe, the share of heavy precipitation (95th percentile) in total annual precipitation has increased by up to 2% per decade since 1950 according to the linear trend.¹⁶ Researchers at Karlsruhe University have observed a distinct increase in the number of days with high thunderstorm potential in Germany's southwest during the summer months since 1970.¹⁷ At least in some parts of Europe, there are consequently also changes in climate which can be considered as drivers in the growing number of weather-related losses.

¹⁶ Alexander, L.F. et al. (2006), Global observed changes in daily climate extremes of temperature and precipitation, *JGR* 111, doi:10.1029/2005JD006290. Specifically for Germany see Grieser, J., Beck, C. (2003), Extreme precipitation in Germany – chance or omen?, *DWD Climate Status Report 2002*, 141- 150, Offenbach. For Scandinavia and European Russia see Groisman, P.Y. et al. (2005), Trends in intense precipitation in the climate record, *Journal of Climate* 18, 1326-1350.

¹⁷ Potsdam Institute for Climate Research (2005), *KLARA: Climate change - impacts, risks, adjustment, PIK-Report 99*. For increases in convective activity in adjacent Switzerland see Schiesser, H. H. (2003), Ch. 2.6, in: *Organe consultatif sur les changement climatiques (2003) : Extremereignisse und Klimaenderung*, p.65-68.



Classification:

Damaging events:

< 20 deaths, up to considerable property damage

Severe catastrophes:

20 – 500 deaths,
US\$ 50 – 500m total losses

Major catastrophes:

> 500 deaths,
> US\$ 500m total losses

Fig. 8 Annual counts of natural catastrophes in Europe (without Russia) according to loss intensity classes. Upper figure: absolute numbers per year. Lower figure: relative change (setting linear trend in 1980 to 100%). Source: Munich Re, 2008.

Figure 8 illustrates the annual number of natural catastrophes according to loss intensity classes.¹⁸ According to the linear trend, the annual number of damaging events – the lowest intensity class – has roughly doubled over the time series since 1980. The annual number of severe catastrophes – the middle loss intensity class – has more than tripled since 1980, while the number of major catastrophes – the highest intensity class – has increased by roughly 80%. Here too, under the hypothetical assumptions of (1) no climate change effect and (2) no substantial change in damage susceptibility of structures since 1980¹⁹, the only drivers would be the expansion of built-up areas on the edge of settlements and reporting. These would have to result in a sequence of linear trends where the strongest increase is associated with the smallest event footprint, i.e. damaging events, and the least increase associated with the largest event footprint, i.e. major catastrophes.²⁰ The observation deviates from this idealized sequence because the middle intensity class, i.e. severe catastrophes, is increasing in annual numbers much stronger than the lowest intensity class. Again this finding tends to contradict the hypothesis that expanding built-up areas and ever-increasing reporting can completely explain the pattern of relative increase. Hence climate change has to be considered as a plausible candidate for one of the drivers.

Conclusions

In North and Central America, annual numbers of weather-related losses per type of peril since 1980 display an upward trend for the majority of windstorm phenomena, as well as for floods and wildfires. The number of convective windstorm losses, flood losses and wildfires in Europe is also increasing. In both regions, convective windstorm losses account for the numerically largest share. This correlates with the fact that convective phenomena are associated with small spatial footprints but occur

¹⁸ See above Fig. 6 and the discussion there.

¹⁹ See above footnote 13.

²⁰ See above and footnote 14.

much more frequently than large-area windstorm phenomena, such as winter storms or hurricanes. It is indeed notable that, as a rule, the relative increase in numbers per type of peril in North and Central America is distinctly higher than the relative increase in Europe. This could be due to the larger relative sprawl of settlements, but this has still to be analyzed quantitatively. At the same time, relevant meteorological extremes have also increased in both of these large regions over the last few decades. The contributory part played by climate change must therefore also be considered. This cannot be quantitatively assessed in a methodologically assured manner at present.

Annual counts of natural disasters *according to loss intensity class* since 1980 reveal that both in North and Central America and in Europe all damage intensity classes have increased, but at a different pace. While, theoretically, settlement expansion and improved reporting efficiency should project much more on an enhanced detection frequency of small event footprints (low loss intensity) compared to larger event footprints (higher loss intensity), observations in both major regions are different. We have been observing higher loss intensity classes (larger footprints) increasing relatively faster than smaller loss intensity classes (smaller footprints). Thus it seems that expanding settlement areas and changes in reporting cannot explain all of the increases. At this stage, changing patterns of extreme weather events, i.e. changing climate conditions, have to be considered as a potential contributory driver. Further quantitative analyses on this are on our agenda.