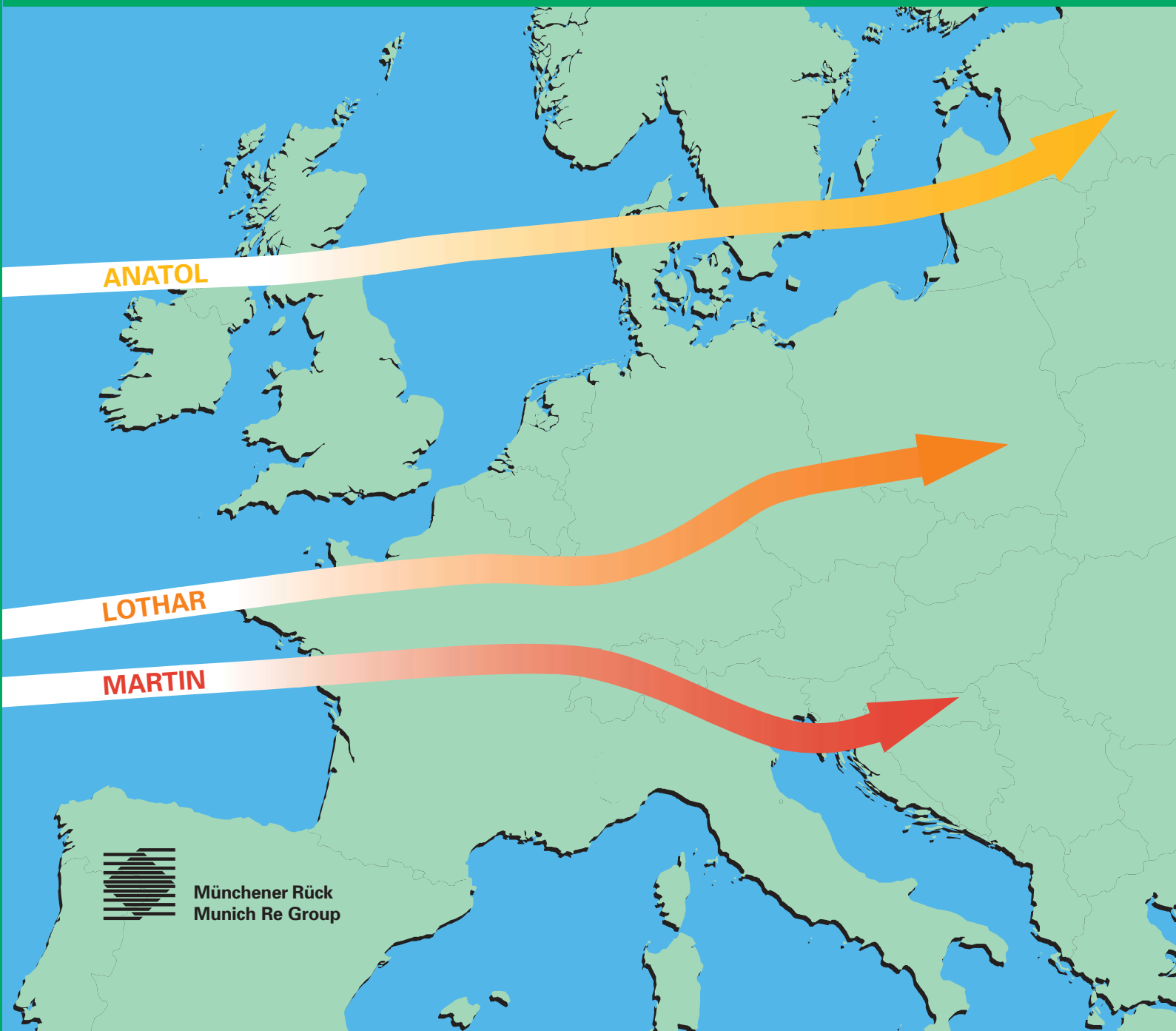
Winter storms in Europe (II)

ANALYSIS OF 1999 LOSSES AND LOSS POTENTIALS

The 1999 winter storms I Data used as the basis for the loss analysis of the 1999 windstorm losses I Analysis of portfolio and loss data on the 1999 winter storms I New findings on the correlation between various loss parameters and wind speed I Windstorm loss potentials in Europe – accumulation aspects I Special topic 1: The frequency of windstorms in Europe I Special topic 2: Climate change – Is the windstorm risk changing too?



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Contents

Summary

The losses from the gales Anatol, Lothar, and Martin in December 1999 supply valuable new findings on the windstorm risk in Europe. A comparison with the loss experience from the winter storm series in 1990 has led to a new assessment of important loss parameters in France and Germany. For the first time ever, detailed windstorm data for Denmark was available in a form that could be used in a scientific study.

The crucial findings on vulnerability to windstorm losses in the countries most severely affected are as follows:

- Denmark
  The loss ratios for residential and commercial risks are in some cases much higher than in the other European countries we analysed in 1990 and 1999. The increase in the loss ratios is roughly equivalent to the 4th to 5th power of wind speed. The loss parameters of loss frequency and average loss per affected policy are comparable with the corresponding data on other countries in this study.

- Germany
  At high wind speeds, the increase in losses (loss ratios) is steeper than that extrapolated on the basis of the 1990 data. The 1999 loss frequencies for residential buildings are comparable with the 1990 loss experience but are below those for household and commercial risks in 1990. The average losses in all the classes examined are mostly much higher than in 1990 but still within the expected range (i.e. in line with the development of the average sums insured of the affected risks).

- France
  Since there are no data on sums insured in the primary insurance market, it is only marginally possible to compare the loss ratios from Lothar and Martin with the 1990 data. Nevertheless, we can say that the 1999 events tend to confirm the loss experience of the earlier event, although the losses at higher wind speeds were in some cases larger in 1999. At moderate wind speeds the loss frequency in 1999 is comparable with 1990 but the increase in the loss frequency at higher windstorm intensities is in part steeper. The average losses are much higher than in 1990; they follow the (assumed) development of the insured values.

In conjunction with an analysis of the windstorm hazard in Europe and on the basis of exposure distributions, these new findings may be used to derive updated occurrence probabilities of extreme market losses. For the market losses from Lothar, for instance, (€5.9bn) a return period of around 15 years may be estimated (for Europe as a whole). Detailed results from our examination of loss occurrence probabilities may be found in the final section of this publication.

Preface

"Windstorms in Europe – (still) an underestimated risk?"
This was one of the central questions posed by numerous insurers and reinsurers once it was established that the total insured loss from the gales Anatol, Lothar, and Martin in December 1999 would exceed €10bn. And yet in 1990, not even ten years earlier, a series of gales in western Europe – Daria, Vivian, Wiebke, and five others – had presented insurers with a bill approaching €9bn (1990 values).

Munich Re responded to the losses from the catastrophic events in 1999 – as it had after the 1990 series of gales – by carrying out an in-depth examination of the windstorm risk in Europe. To this extent, then, the current publication represents an update of our exposé "Winter Storms in Europe: Analysis of 1990 Losses and Future Loss Potentials" supplemented with the loss experience from Anatol, Lothar, and Martin.

The main objective of the study was to estimate the loss potentials from future windstorm events in Europe. For this purpose, we analysed comprehensive meteorological and underwriting data relating to the 1999 windstorms and recalculated the correlation between wind speed and loss intensity. In Germany and France, which were severely affected in 1990 and in 1999, the loss experience from the 1990 gales was compared with the 1999 data. This, in conjunction with various hypothetical windstorm scenarios and on the basis of individual exposure distributions, makes it possible to estimate potential future accumulation losses for individual portfolios and even entire markets.

In our publication on the 1990 windstorms, the question of global climate change and its impact on the insurance industry was considered in the outlook at the end of the study. In this new publication, this aspect assumes a central position, and we have endeavoured to consider and quantify this risk of change in our estimate of occurrence probabilities.

We would like to thank our clients for supplying us with their exposure and loss data on the December 1999 windstorms and thus making this new publication possible.

1 The 1999 winter storms

In December 1999 Europe was hit by three severe windstorms which in the most severely affected countries reached a wind force of 12 on the Beaufort Wind Scale ("hurricane", i.e. over 118 km/h) and attained peak wind speeds locally of over 180 km/h.

This windstorm series was opened on 3rd December 1999 by Anatol, which produced a record loss in Denmark of almost €2bn (total insured loss) – thus reaching a scale that many insurers had previously thought impossible. Together with other losses in Great Britain, Germany, and Sweden, the overall burden to be carried by the insurance industry from this event was €2.2bn.

A good three weeks later, on 26th December 1999, a further gale, Lothar, developed over the Atlantic off the northwest coast of France. Categorized as a meteorological "bomb" because of its almost explosive generation, this gale likewise caused new and unexpected record losses. The French insurance industry had to pay claims totalling approx. €4.4bn. The loss generated in France by Lothar was therefore about seven times as high as the previous record set in 1990 by the winter storm Herta with a loss of €600m (1990 values). The overall loss in Europe as a whole came to €6bn, making Lothar the largest loss ever to be carried by the insurance industry following a European windstorm event. For the sake of comparison, the previous record for Europe as a whole had been set by Daria in 1990, with insured losses equivalent to almost €4.4bn, with Great Britain bearing the largest share: €2.6bn.

One day later, on 27th December 1999, Martin, a second low-pressure vortex on the edge of a low-pressure system over the northern Atlantic, developed in a way very similar to Lothar. Martin followed a track somewhat further south and mainly hit southern France but also affected northern Spain and western parts of Switzerland. The French insurance industry again had to bear the brunt of the loss, €2.4bn of the €2.5bn recorded in Europe as a whole.

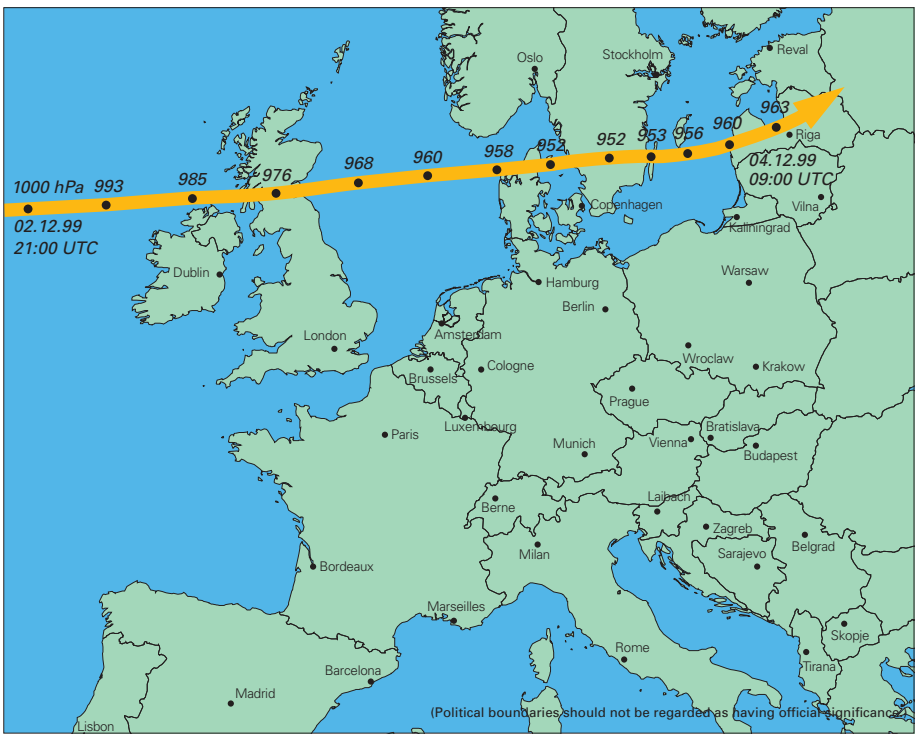
Like the 1990 series, the two gale events that hit western Europe in rapid succession in December 1999, inflicting damage on some areas twice in less than 48 hours, constituted what is called a "cluster" of intensive low-pressure vortices, a phenomenon not untypical of extratropical storms. In 1990 Vivian (25th–27th February 1990) and Wiebke (28th February–1st March 1990) were mainly responsible for two windstorm catastrophes in short succession and marked the conclusion of an exceptionally "gale-ridden" large-scale meteorological situation subsequent to 25th January 1990 (Daria). The formation of clusters is not to be ignored in any consideration of accumulation aspects on the basis of annual aggregate losses or in the design of reinsurance and retrocession agreements for windstorm cover in Europe.

1.1 Meteorological sequence of events

1999 was on the whole a very warm year throughout the world. Together with 1990, it was the third warmest year of the century in central Europe (after 1994 and 1934). In Germany the average temperature for the year was 1.3°C above the average for the so-called climatic normal period of 1961–1990. In December the temperatures on the European mainland were also much higher than the long-term average – with the exception of the week before Christmas. The large-scale meteorological situation which led to the development of Anatol, Lothar, and Martin was therefore quite similar to the one at the beginning of the series in 1990.

Track of Anatol
2nd–4th December 1999
The bullets mark the centre of the low-pressure system at three-hour intervals (the figures: central pressure in hPa).

Source: Deutscher Wetterdienst, 2000.



The development of Anatol began over the North Atlantic northwest of Ireland in the early morning of 3rd December. On its way over Scotland and the North Sea the central pressure of the low-pressure vortex dropped by more than 40 hPa in the space of only twelve hours, reaching its minimum of 952 hPa directly over Denmark. This made Anatol the strongest gale to hit Denmark in the whole of the 20th century. The highest wind speeds were recorded south of the low-pressure system over German Bight in the central North Sea and in southern Denmark. With gusts of 180–185 km/h record levels were registered in the long-term wind time series at some meteorological stations. On the island of Sylt (Germany) the maximum wind speed of 184 km/h was 10% above the previous record set in 1976. As no recordings could be taken for several hours after that because of problems with the electricity supply, the occurrence of even stronger gusts during that time cannot be ruled out. The situation was rather similar in terms of peak wind speeds in Denmark, where a record speed

of 185 km/h was recorded on the North Sea island of Rømø. In the early hours of 4th December Anatol was still blowing gusts of 130 km/h in Gdansk (Poland) and 126 km/h in Kaliningrad (Russia).

Selected maximum wind speeds of Anatol

Denmark	Rømø	185 km/h
	Copenhagen	155 km/h
Germany	Sylt	184 km/h
	Cape Arcona (Rügen)	166 km/h

Source: Deutscher Wetterdienst, 2000.

The gale initially came from the west-southwest, then changed to west and in the early evening on 3rd December to west-northwest, generating heavy storm surges on the North Sea coasts of Denmark and Schleswig-Holstein in Germany. In Hamburg the water rose to 5.86 m above NN, the fourth highest storm-surge level in recent decades. Fortunately, the dykes stood up to the deluge, and there was no major damage.

Track of Lothar
26th December 1999
The bullets mark the centre of the low-pressure system at three-hour intervals (the figures: central pressure in hPa).

Source: Deutscher Wetterdienst, 2000.

On 25th December 1999 a disturbance built up over the northeastern Atlantic on a sharp air mass boundary (frontal zone) between cold air in the north and warm air in the south belonging to a mighty central low (given the name Kurt) and developed into a series of intense low-pressure systems. Around noon, one of these systems, the secondary low named Lothar, had a central pressure of 995 hPa, which meant that it was still a rather inconspicuous bad weather front. As in the case of Anatol, the development of the low-pressure system was almost explosive, involving a large pressure drop within the space of a few hours. The most noticeable change in pressure was observed at the Caen station on the French coast, where a pressure drop of 28 hPa was recorded between 3 and 6 o'clock CET followed by a similarly extreme increase of 29 hPa between 6 and 9 o'clock CET after the passage of a low-pressure core. Such dimensions had not been observed in Europe for at least thirty years.

The atmospheric pressure reached its minimum of 961 hPa over Normandy. Anatol had a minimum central pressure of 952 hPa, making Lothar a much less extreme event in meteorological terms. Although many weather stations registered record wind speeds, Lothar's maximum remained distinctly below the levels reached by Anatol in Denmark and northern Germany.

Selected maximum wind speeds of Lothar

France	Rennes	126 km/h
	Alençon	166 km/h
	Rouen	140 km/h
	Orly	173 km/h
	Metz	155 km/h
	Colmar	165 km/h
	Strasbourg	144 km/h
Germany	Saarbrücken	130 km/h
	Karlsruhe	151 km/h
	Stuttgart	144 km/h
	Augsburg	130 km/h
	Munich (airport)	122 km/h
Switzerland	Neuchâtel	115 km/h
	Berne (Liebefeld)	134 km/h
	Zurich (SMA)	158 km/h
	St. Gall	131 km/h

Sources: Deutscher Wetterdienst, 2000; Météo France, 2000; MeteoSwiss, 2000.

The above table only considers wind speeds recorded at weather stations with a normal exposure. Much higher values were recorded in extreme places in the Alps and the Black Forest:

– Säntis (Switzerland): 230 km/h
– Jungfraujoch (Switzerland): 249 km/h
– Feldberg (Germany): 212 km/h
– Wendelstein (Germany): 259 km/h

Lothar's wind field over France was very similar to Herta's in February 1990. And Lothar struck a severe blow to Greater Paris on 26th December 1999, just as Herta had done on 3rd February 1990. There were also strong similarities in terms of the geographical extent of the two wind fields. The main difference between these two windstorm systems was the wind speed. With peak gusts of around 170 km/h in Paris, Lothar was in fact 30–40% more intense than Herta, which reached about 120–130 km/h.

Track of Martin
27th–28th December 1999
The bullets mark the centre of the low-pressure system at three-hour intervals (the figures: central pressure in hPa).

Source: Deutscher Wetterdienst, 2000.

By the evening of 26th December 1999 Lothar's centre had shifted eastwards to Poland. But then another secondary low, Martin, detached itself on the frontal zone over the North Atlantic in almost the same way as Lothar. Its track was a little further to the south so that the regions particularly affected in France were around Bordeaux, Biarritz, and Toulouse. On 27th December 1999 Martin brought gale-force winds to northern Spain, western parts of Switzerland, and Upper Italy too.

Selected maximum wind speeds of Martin

France	Île d'Yeu	162 km/h
	La Rochelle	151 km/h
	Cap Ferret	173 km/h
	Bordeaux	144 km/h
	Limoges	148 km/h
	Clermont-Ferrand	159 km/h

Source: Météo France, 2000.

The insurance industry, particularly in France, was thus confronted with catastrophic windstorm losses from two events in less than 48 hours. As already demonstrated by the series of gales in January/February 1990, the development of a windstorm series over the North Atlantic with a close succession of intense low-pressure systems is not unusual given an appropriate large-scale meteorological situation.

1.2 1999 loss figures – comparison with the 1990 winter storm series

Insured losses

The table below shows the geographical distribution of the insured losses generated by the four most devastating gales in 1990 (original values converted into € and rounded) and the gales Anatol, Lothar, and Martin in 1999.

Comparison of insured losses from the windstorm series in 1990 and 1999 (€m)

Country/Region	Daria 25/26.1.1990	Herta 3/4.2.1990	Vivian 25–27.2.1990	Wiebke 28.2/1.3.1990	Anatol 3/4.12.1999	Lothar 26.12.1999	Martin 27/28.12.1999
Austria			70	70			
Belgium	220	100	170	50			
Denmark	50		30		2,000		
France	260	600	90	100		4,450	2,450
Germany	520	260	520	520	100	650	
Great Britain	2,600		700	280			
Luxembourg	50	50	50	50			
Netherlands	700	100	90	30			
Spain							50
Switzerland			50	50		800	
Loss total*	4,400	1,110	1,820	1,180	2,250	5,900	2,500

*For Europe as a whole, including countries not shown individually. All loss figures in original values and converted into €.
Source: Munich Re NatCat*SERVICE*.

In order to compare the 1990 and 1999 series of gales on a uniform exposure basis, the 1990 losses must be adjusted to 1999 values. Taking the development of insurance density and the average sum insured per policy/risk as a basis, the total sum insured of all exposed (property) values in western Europe increased by a factor of 1.8 to 2.0 between 1990 and 1999.

This results in the following observations:
– On the basis of the 1999 windstorm exposure, the "as if" overall insured loss from the 1990 windstorm series comes to around €16bn, i.e. 50% more than the loss carried by the insurance industry as a result of Anatol, Lothar, and Martin. This means that the loss total in Europe as a whole from the 1999 gales was not a record for the insurance industry.

– In Denmark and France, however, accumulation losses from individual windstorm events reached new highs:
  - Denmark: At €2bn the loss generated by Anatol was about 20 times greater than that generated by Daria in 1990 ("as if" 1999: €100m). The largest insured windstorm loss in Denmark prior to 1999 occurred in 1981 and amounted to about €120m (1981 values). Assuming a fourfold increase in exposure in Denmark between 1981 and 1999, we estimate that, after adjusting for inflation, Anatol exceeded the hitherto largest windstorm loss by a factor of more than 4.
  - France: The loss caused by Lothar was also about four times as large as the loss caused by Herta ("as if" 1999: €1.1bn).

– Germany: Lothar generated almost two-thirds of the loss caused by Daria or Vivian (both "as if" 1999: €1.0bn). It constituted no more than a medium-size loss for the German insurance market. Nevertheless, the losses were focussed to an unusually large degree in the southwest region of Germany so that insurers whose exposure was concentrated in this region were very badly hit.

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1.3 Details of the 1999 loss figures

Bodily injury and property damage

Anatol
– Countries/regions most severely affected: Denmark, Germany, Great Britain, Sweden, Lithuania, Latvia, Russia, Poland
– > 20 fatalities
– Economic losses: €2.9bn
– 600,000 individual insured losses
– Average insured loss: €3,700 (all lines of business)
– Main damage: roofs, façades, vehicles, boats, scaffolding; also: flooding due to heavy rain
– Infrastructure: 165,000 households without electricity due to major damage to the overhead line network (Denmark, Sweden)

Lothar
– Countries most severely affected: France, Germany, Switzerland, Belgium, Austria
– 110 fatalities
– Economic losses: €11.5bn
– 2.4 million individual insured losses
– Average insured loss: €2,500 (all lines of business)
– Main damage: roofs, façades, scaffolding, cranes, forests, overhead line network
– Infrastructure: over four million households without electricity for several weeks in many cases (France); Électricité de France suffered (uninsured) losses amounting to several billion francs because of damage to the overhead line network and power stations; public transport disrupted with stoppages lasting for days (especially France and Greater Paris); airports in Paris temporarily closed; telecommunications networks (fixed and mobile networks) disrupted for days in some cases (interrupted power supplies, damage to transmission facilities)

Martin
– Countries most severely affected: France, Spain, Switzerland
– 30 fatalities
– Economic losses: €4bn
– One million individual insured losses
– Average insured loss: €2,500 (all lines of business)
– Main damage (like Lothar): roofs, façades, scaffolding, cranes, forests, overhead transmission lines, agriculture
– Numerous historical buildings damaged (castles, monasteries, etc.)
– Infrastructure: over one million households (in France) without electricity

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Forest damage

On account of their intensity and the regions they affected, all three of the severe gales in December 1999 generated extreme losses in the forestry sector in Denmark, France, Germany, and Switzerland.

The two tables below present a long-term comparison of timber losses in Europe and are a vivid illustration of just how exceptional 1999 was:

Forest damage caused by Lothar

Country/Region	**Timber loss** (million m³)	**Relationship to average annual usage** (%)
France	140.0	300
Germany/Baden-Württemberg	25.0	250
Germany/Bayern	4.3	40
Switzerland	12.7	280

Source: WSL, 2001.

Forest damage caused by Anatol

Country/Region	**Timber loss** (million m³)	**Relationship to average annual usage** (%)
Denmark	3.4	100–150
Sweden	5.0	<10

Sources: Danish Forestry Association, 1999; Swedish Forest Industries Federation, 2001.


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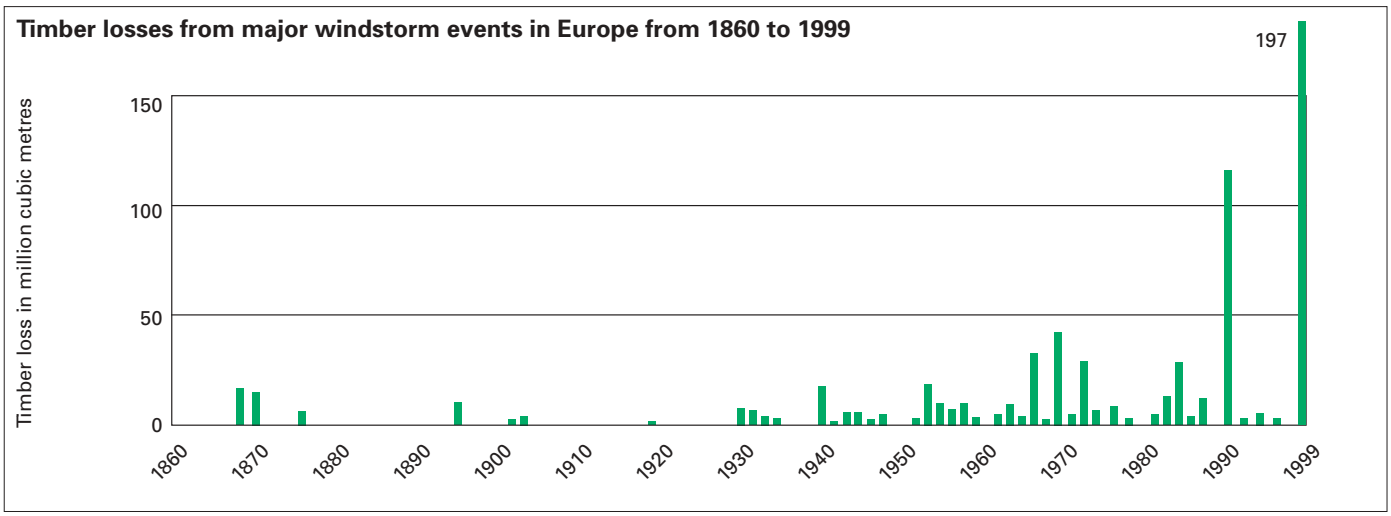


The 1999 windstorm series caused a record timber loss of almost 200m m³, exceeding by more than 50% the previous record forest damage of 120m m³ caused by the 1990 gales.
Source: WSL, 2001.

As there are a number of factors which have an impact on the extent of loss in terms of both forest damage and property damage, the following supplementary information will be useful for evaluating the losses:

Change in forest area since the 19th century:
– Switzerland: +35%
– Baden-Württemberg (Germany): +27%
– France: +70%

Change in wood volume per unit area in the 20th century (data for earlier periods not available):
– Switzerland: +1% per annum
– Baden-Württemberg (Germany): +1% per annum
– France: +1% per annum

If we combine the increase in area and the change in wood volume per unit area, we find that the standing wood volume in the three countries examined has increased by a factor of between two and three in the last 100 years.

This explains at least in part the increase in forest damage in Europe since 1860 (see graph above). Comparisons of tree numbers in European forests in recent decades have also shown that the proportion of tall – and hence more windstorm-prone – trees has increased too. Whether any other factors such as stress caused by air pollution and climate change have led to a change in the vulnerability to windstorm has not yet been fully determined.

2 Data used as the basis for the analysis of the 1999 windstorm losses

2.1 Meteorological data: wind fields

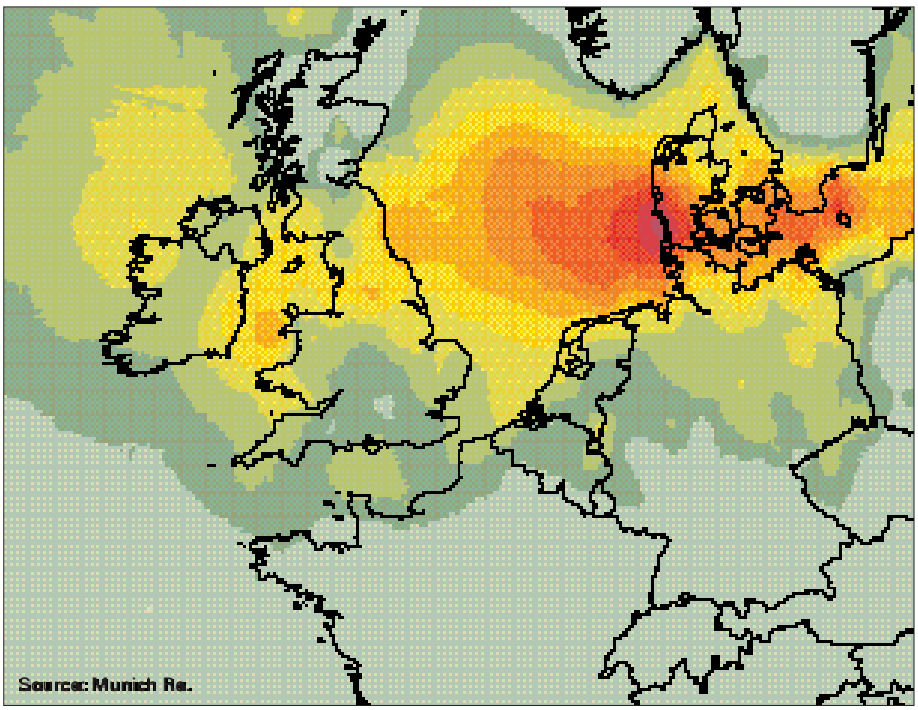
In this study we used wind speed data received from the following meteorological services: Météo France, MeteoSwiss, and Deutscher Wetterdienst (for locations in Germany and other countries).

With the aid of a spatial interpolation method (kriging, see box) the wind fields of Anatol, Lothar, and Martin were estimated from the recorded data with a geographical resolution of 0.1 x 0.1 degrees.

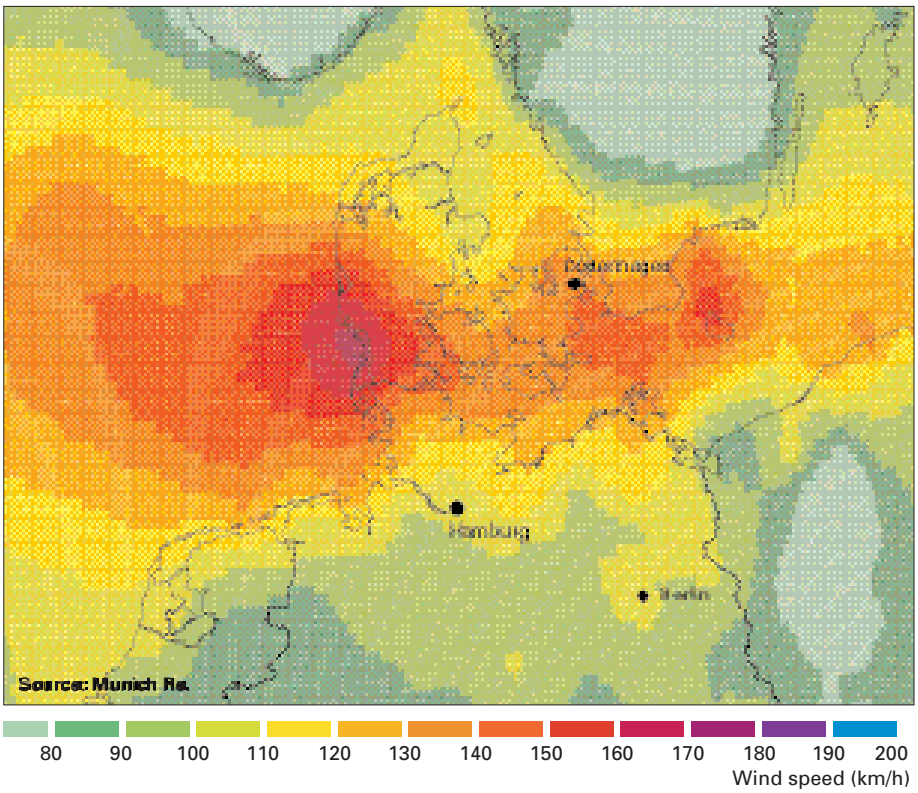
"Kriging interpolation method"

Originally developed to optimize mining processes, the interpolation method named after the South African engineer D. G. Krige is being used increasingly by geoscientists in such procedures as groundwater modelling and soil mapping. The advantage of this method is that it takes spatially stochastic processes into account. It also allows the effects of persistence to be considered as a function of distance and direction. Applied to the generation of wind fields this advantage may be described as follows: Determining the wind field of a windstorm event in a specific area does not involve taking a snapshot at a particular point in time but making observations over a longer period of hours to days. Within this space of time the dynamic low-pressure system determining the wind field moves across the area, generally from west to east. The occurrence of peak gusts in time and space will therefore be more or less consistent with the shifting of the low-pressure system. If the maximum wind speed is to be determined at a particular place, the probability of similarly high wind speeds is greater parallel to the track than perpendicular to it. This may be taken into account in the kriging process by means of an anisotropic (i.e. direction-dependent) interpolation.

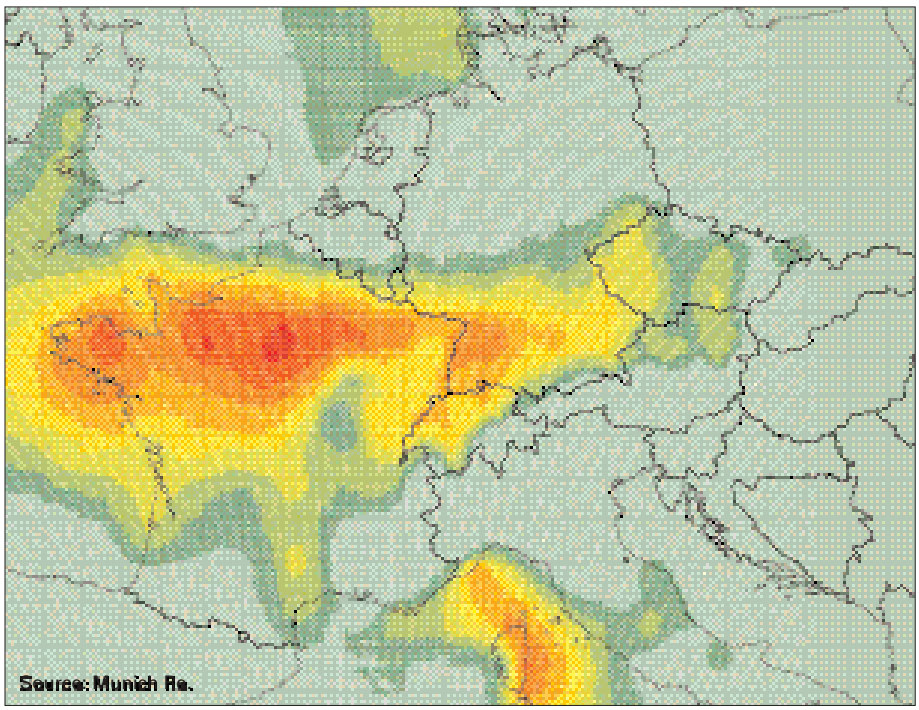
Wind field (peak gusts) of Anatol over Europe (2nd–4th December 1999).



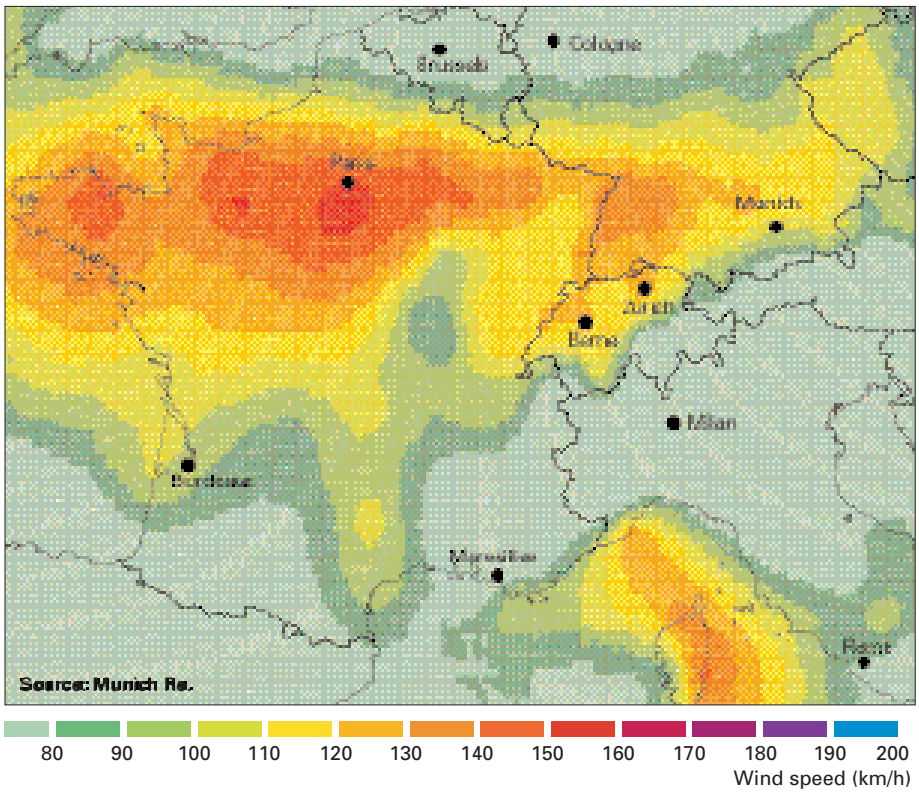
Detailed view of the wind field of Anatol.



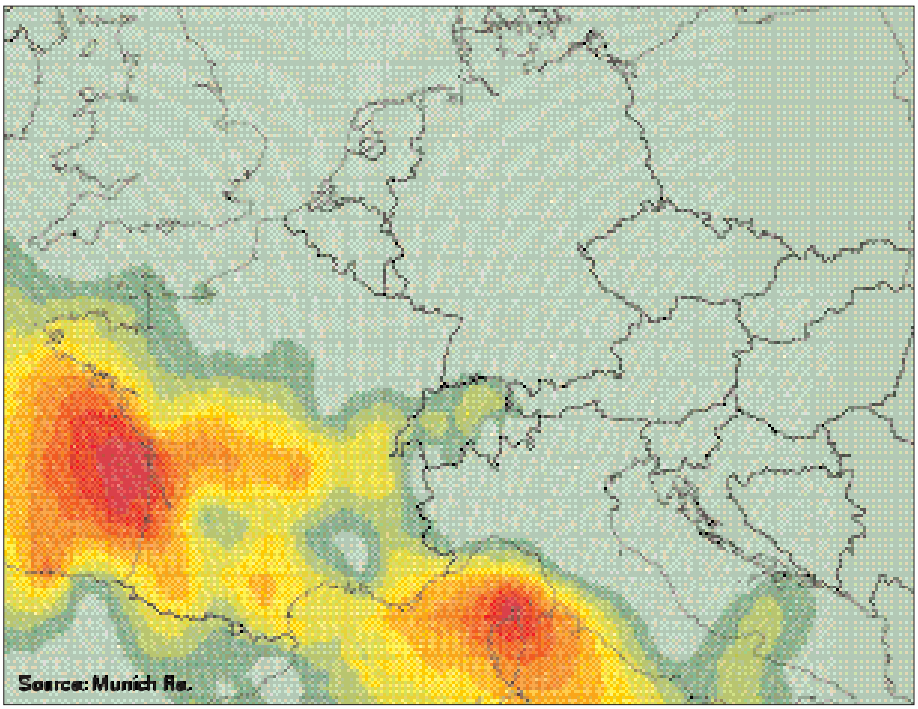
Wind field (peak gusts) of Lothar over Europe (26th December 1999).



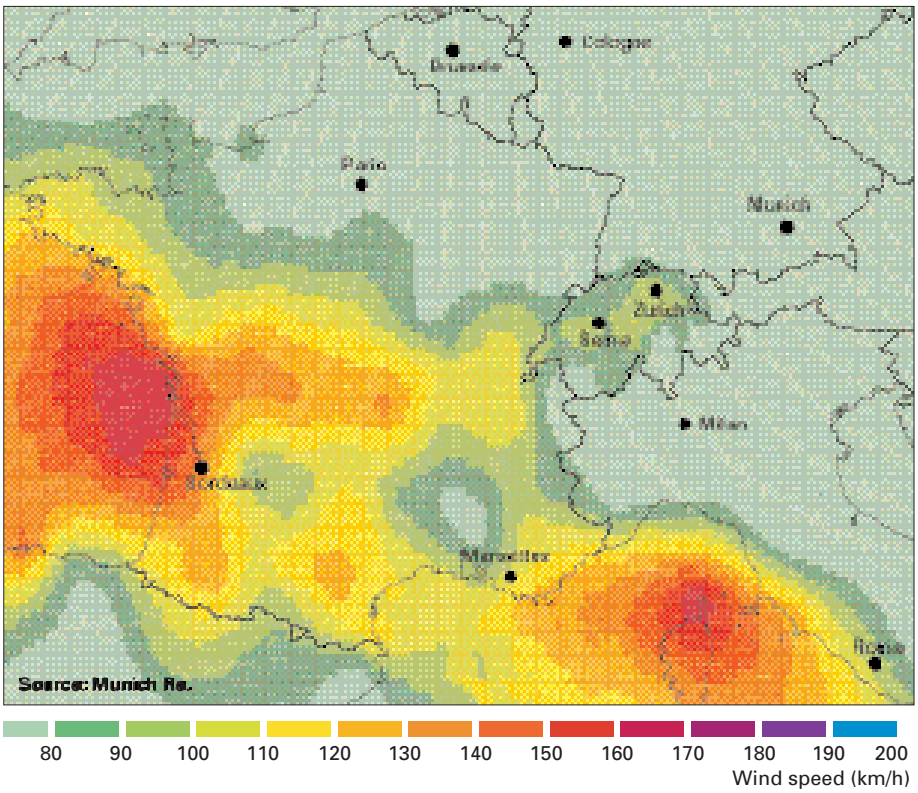
Detailed view of the wind field of Lothar.



Wind field (peak gusts) of Martin over Europe (27th–28th December 1999).



Detailed view of the wind field of Martin.

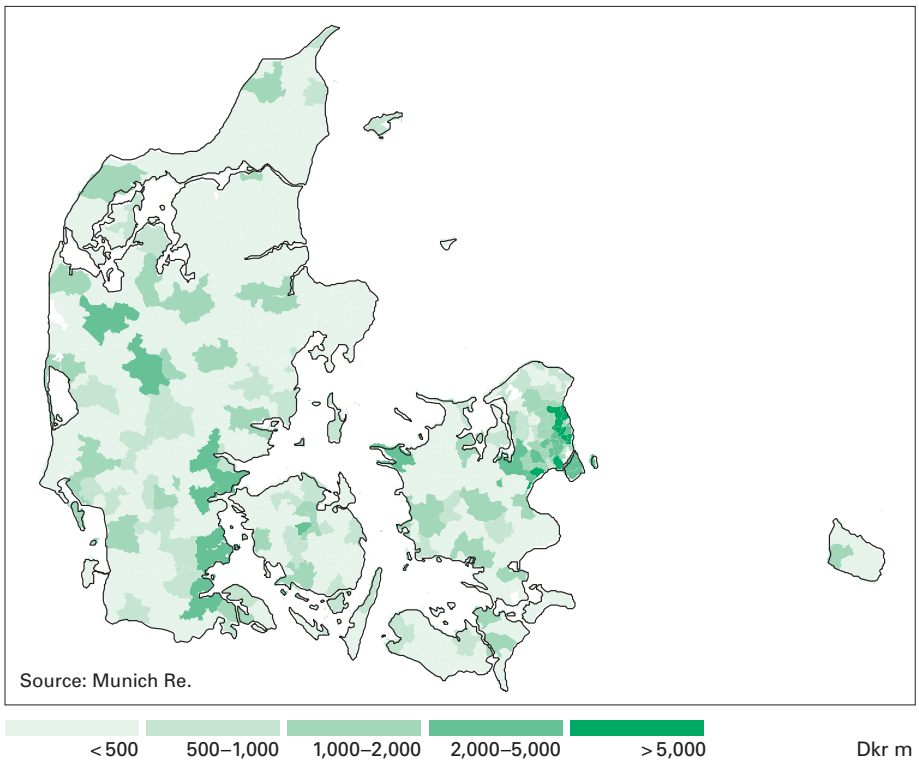


2.2 Underwriting data

The data we received from clients that participated in this study were mainly in the form of the following portfolio and loss information:
– number of policies/risks
– sums insured (in France: premiums and/or number of risks)
– number of losses
– loss amounts
This information was broken down into the various classes of insurance, CRESTA zones (postal codes, in France: départements), size categories (loss and/or exposure data), and windstorm events.

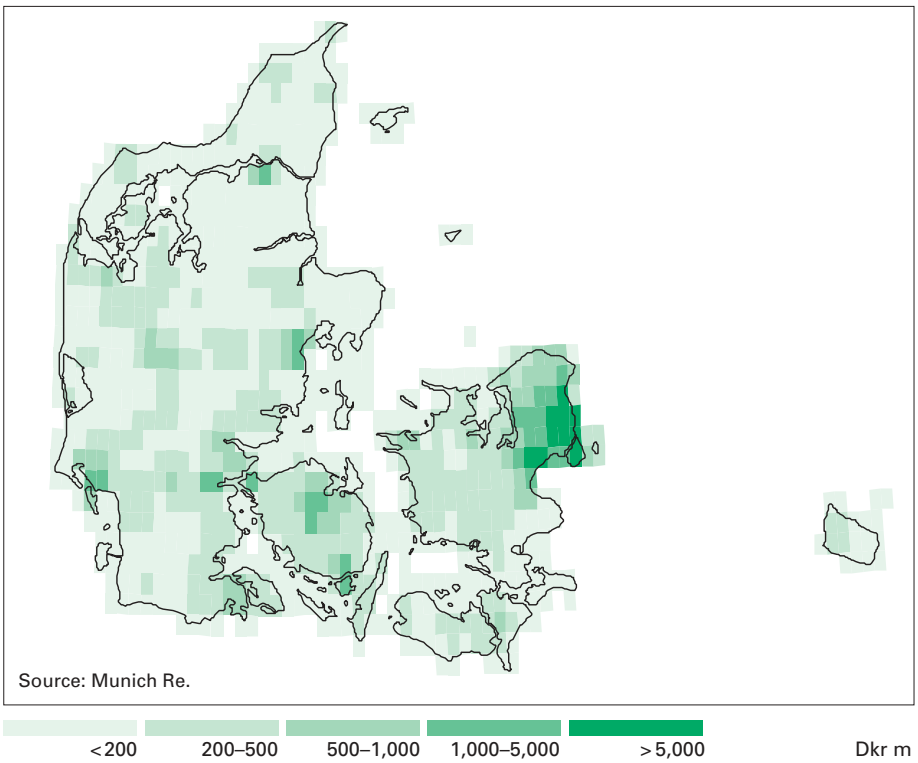
The first step involved allocating the primary insurance data, transmitted originally on the basis of CRESTA, to a 0.1 x 0.1 degree grid identical to the wind field.

Example of an exposure distribution for residential risks in Denmark (CRESTA data on the basis of postal codes).



Using the example of Denmark, the two figures on pages 22 and 23 show the geographical distribution of the sums insured for a portfolio of single-family and multiple-family houses. Similar maps were produced for all relevant exposure data (number of policies and/or risks; in France, premiums and/or number of rooms instead of sums insured).

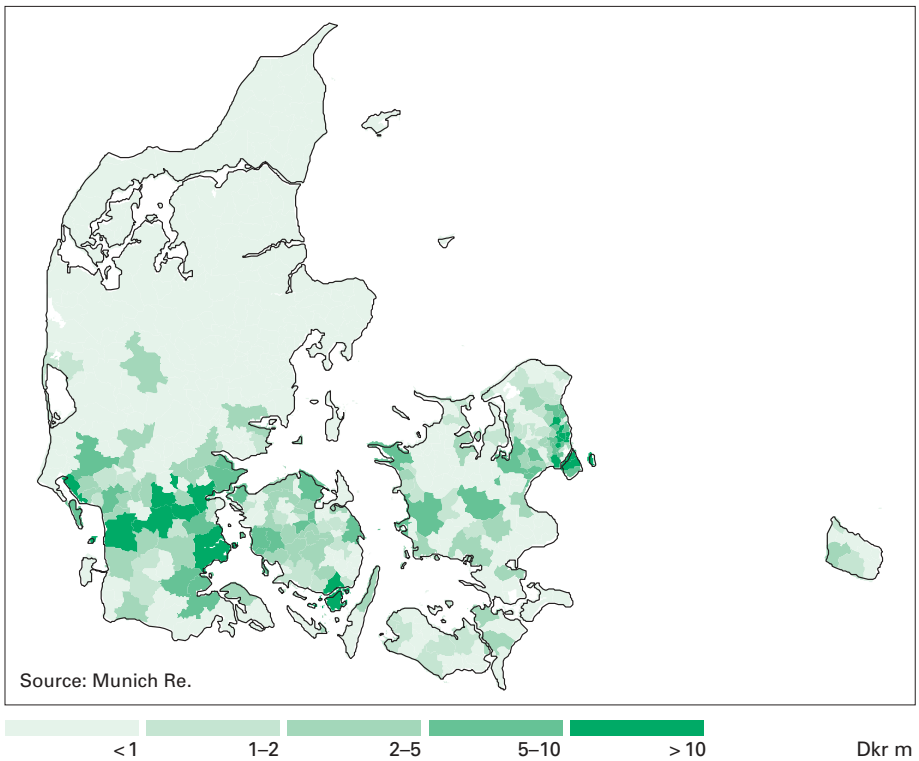
The same exposure distribution as in the figure on page 22, but using a 0.1 x 0.1-degree grid.



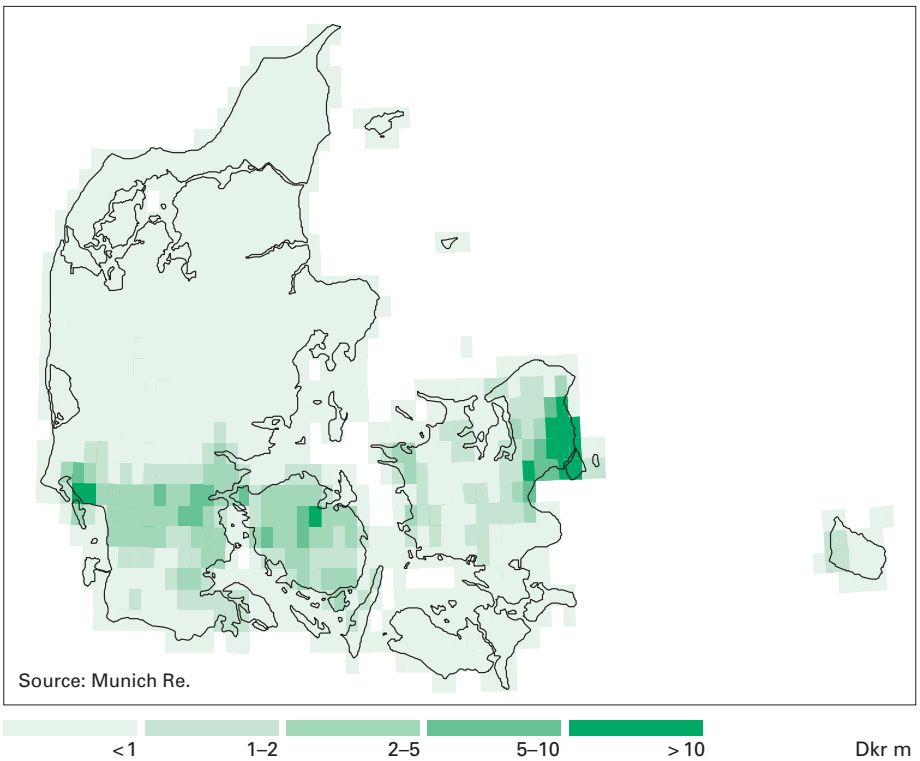
In the same way as the exposure data, the loss data (loss amount, number of losses) in the corresponding portfolios were processed and distributed on an identical 0.1-degree grid.

Three layers of information on a standardized grid with a size of about 7 x 11 km thus formed the basis for analysing the windstorm vulnerability of individual portfolios:
– insured values (broken down by class of insurance)
– insured losses (broken down by class of insurance and by event: Anatol, Lothar, and Martin)
– interpolated wind fields for the 1999 windstorms

An example of a distribution of windstorm losses for residential risks from Anatol in Denmark (on the basis of postal codes).



The same exposure distribution as in the figure on page 24, but using a 0.1 x 0.1-degree grid.



3 Analysis of portfolio and loss data relating to the 1999 winter storms

The main objective of this study was to estimate loss potentials from future windstorm events in Europe on the basis of the experience from the 1999 windstorm series. As France and Germany were also severely affected during the 1990 winter storms, the 1999 loss data for these two countries were compared with the corresponding data from 1990.

The following loss parameters were analysed in depth in this study:

– loss ratio (ratio between loss and sum insured, expressed in ‰)
– loss frequency (ratio between the number of loss-affected policies/risks and the total number of policies/risks, expressed in %)
– average loss (ratio between the overall loss and the number of loss-affected policies, expressed in €)

The calculations were carried out separately for each class of insurance with windstorm cover.

The next step in the study involved analysing the distributions of loss amounts ("loss profiles"), which provided us with an idea of the effect that deductibles in windstorm insurance might have on the overall insured loss and the number of individual claims that have to be settled.

Sums insured in France and Denmark

France
In France, unlike the majority of insurance markets, the sums insured are omitted in the insurance policies for simple risks business (risques simples) and frequently for commercial business (risques commerciaux) too. Furthermore, the premium is not calculated on the basis of quantified values but on the basis of auxiliary parameters like the number of rooms, the area of the building/apartment, or an (estimated) average sum insured per policy/risk.
The problem is that modelling the windstorm risk (simulating historical and/or hypothetical windstorms to calculate the accumulation PML and the technical risk price) is performed in nearly all commercially available windstorm models and in the simulation programmes of major reinsurers on the same basis: the vulnerability parameter "loss ratio" (loss/sum insured) as a function of the wind speed of windstorms. In non-proportional (excess of loss) reinsurance treaties too, priorities and liability limits are defined in monetary units.

Estimating the sums insured on the basis of information in the original policies assumes corresponding conversion parameters. Owing to the lack of a standardized procedure in the market for calculating exposure, the range of estimates is very large and heavily dependent on personal assessments. Consequently, the exposure estimates from various sources (commercial modellers, reinsurers) for one and the same portfolio often deviate from each other by a factor of two to three.

The loss ratios calculated in this study for France (graphs in Chapter 4) are based on the following conversions:

Conversion parameters for estimating sums insured (on a replacement value basis) in France*

Type of risk	Premium rate	Average SI/policy (€)
simples	0.8 ‰	240,000
professionnels/commerciaux	0.8‰	460,000
entreprises	0.6‰	4,600,000
agricoles	1.5‰	400,000

*buildings and contents
Source: Munich Re, Geo Risks Research Department.

Denmark
The sums insured are not always shown in insurance policies in Denmark either. As a rule, however, insurance companies convert their own exposure definitions into monetary units before reporting the CRESTA (accumulation) data to their reinsurers.

In our analysis of the loss ratios for Denmark (graphs in Chapter 4) we have taken over these conversion factors unchanged:

Conversion parameters for estimating sums insured (on a replacement value basis) in Denmark*

Type of risk	Average SI/policy (€)
residential	240,000
commercial/industrial	3,000,000
agricultural	620,000

*buildings and contents
Source: Danish primary insurance companies.

3.1 Evaluation method

The large-scale peak wind speeds reached by Anatol, Lothar, and Martin in some regions were as high as 160 km/h, whereas the local peak values in exposed locations – which say very little about the damaging effects and were therefore not used in our study – were in some cases considerably higher (up to almost 260 km/h).

Peak wind speeds observed over large areas during the 1999 windstorm series

Land	Denmark	France	Germany	Switzerland
Maximum wind speed (kmph)	160	160	140	140

In the light of the meteorological observations in all the countries affected, we must assume even higher wind speeds than those recorded in 1999 when estimating future probable maximum losses. For this reason the loss parameters analysed here (loss ratio, loss frequency, average loss) were extrapolated on the basis of the available data to give the maximum expected wind speeds.

This extrapolation was based in essence on the assumption that if the wind speed increases by a factor of x, the losses will rise by the same power of x as was calculated from the increase in the loss curves using the actual data from 1999.

Wind speed and loss ratio for a sample homeowners insurance portfolio in Germany

Wind speed (km/h)	80	100	120	140	160
Loss ratio (‰)	0.08	0.20	0.40	0.75	1.20

The average increase in the loss ratio is approx. the fourth to fifth power of the increase in wind speed (cf. "New findings on the correlation between various loss parameters and wind speed" beginning on page 33).

This means, for example, that given an increase in wind speed from 160 km/h to 190 km/h, the loss ratio is

$$LR(190) = LR(160) * \left(\frac{190}{160}\right)^4 = 1.2\,‰ * 1.99 = 2.4\,‰ \text{ (rounded)},$$

i.e. more than twice as high,
with
LR(190) being the wanted loss ratio based on a wind speed of 190 km/h and
LR(160) being the average loss ratio in homeowners insurance based on a wind speed of 160 km/h as derived from the analysis of Lothar in Germany.

This extrapolation method is applied to the three examined parameters: loss ratio, loss frequency, and average loss. It assumes that the observed insurance portfolios do not reveal any "discontinuities" in loss behaviour even at higher wind speeds. In particular, it is assumed that up to the extrapolation limits, i.e. the maximum wind speeds expected in the light of meteorological considerations, there is no saturation of the loss parameters. This would be conceivable, for instance, in the case of the loss frequency if, given the wind speeds observed in 1999, nearly all the policies with windstorm cover had already been subject to losses, i.e. the loss frequency had been close on 100%. The above extrapolation would also be questionable if, given the high intensities of Anatol, Lothar, and Martin, there had been any fundamental changes in the "loss pattern" of European winter storms such as, for example, a significant increase in structural damage to buildings, which would have led to the loss ratios and average losses soaring. However, no such changes were observed.

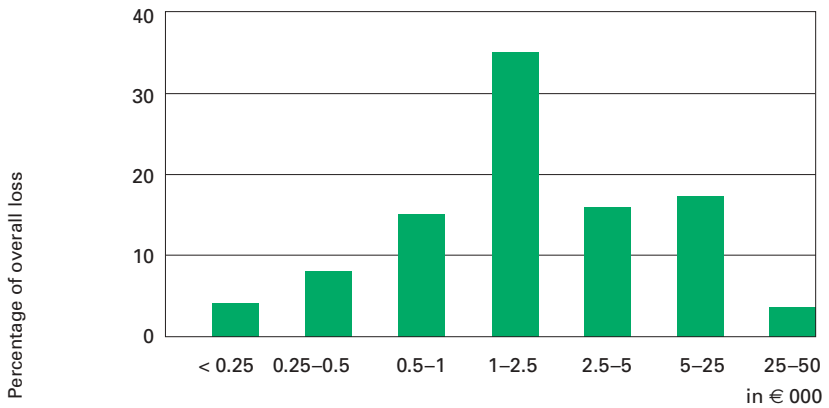
The influence of other windstorm characteristics like duration, gustiness, or precipitation volume on the vulnerability of insurance portfolios was not examined in this study, because it is not possible to draw sufficiently qualified conclusions on this aspect using the meteorological data available.

3.2 Loss profiles

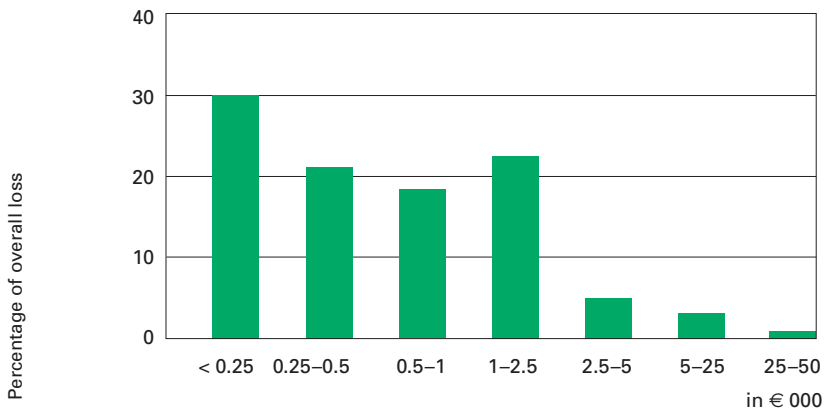
The analysis of loss profiles (distributions of loss amounts) makes it possible, among other things, to estimate the effects of deductibles on the number of individual losses that need to be adjusted and the overall insured loss. The following graphs show, by way of example, loss profiles for homeowners risks resulting from Lothar in Germany as the average derived from a number of portfolios. Any deductibles that may have been applied in isolated cases are considered in the diagrams. For France and Denmark we mainly had aggregated loss reports, whose representation as a loss profile is not worthwhile.

Typical loss profile of homeowners insurance in Germany from Lothar.

Distribution of loss amounts by size ranges



Distribution of loss numbers by size ranges



The decrease in the number of losses that insurers need to indemnify after a windstorm catastrophe with deductibles of €500, €1,000, etc. may be clearly seen in the graphs of loss profiles on the previous page.

To estimate the influence on the overall loss it is necessary to consider the loss elimination effect of deductibles as well, which is also observed in the higher loss amount brackets.

The formula for this is:

$$MED(DA) = P(DA) + (1 - B(DA)) * \frac{DA}{A}$$

with

MED	=	minimizing effect of deductibles (as a percentage of the overall loss not considering deductibles)
DA	=	deductible amount
A	=	average loss amount
P(DA)	=	proportion of losses ≤ DA of the total amount of all losses
B(DA)	=	proportion of losses ≤ DA of the total number of all losses

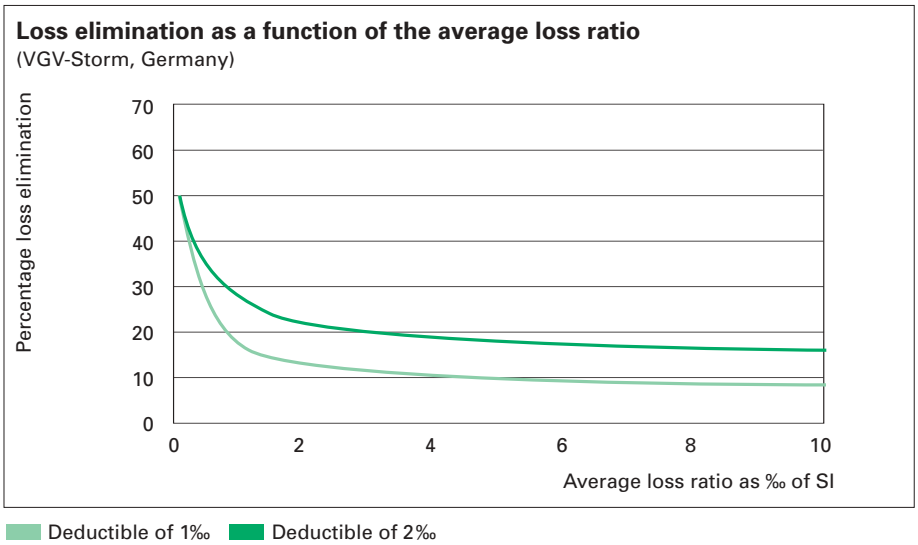
For the example of homeowners insurance in Germany (cf. the graphs on page 30), the following loss elimination effect on the overall loss is derived assuming an average loss amount from Lothar of A = €1,300 for a deductible of €500:

DA	=	500 (€)
A	=	1,300 (€)
P(DA)	=	0.12
B(DA)	=	0.51

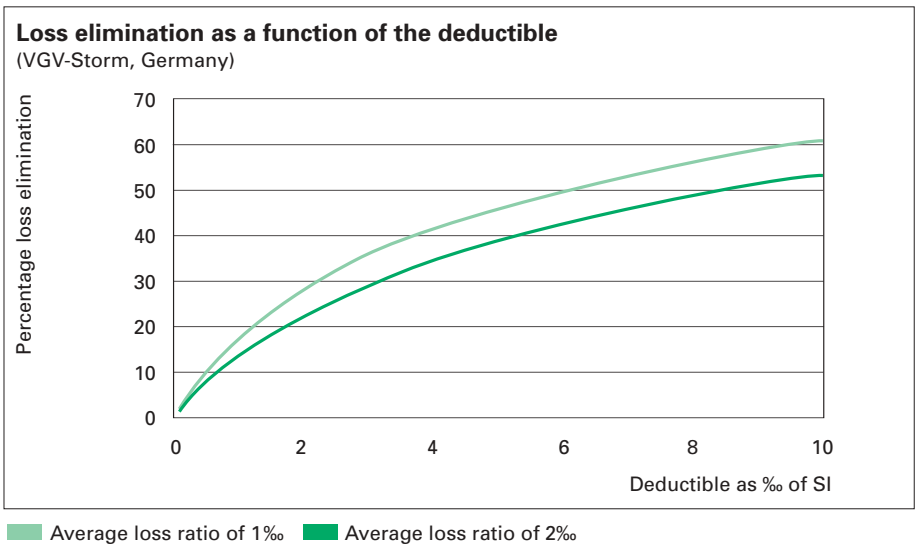
$$MED(DA) = 0.12 + (1 - 0.51) * \frac{500}{1{,}300} = 31\%$$

On the basis of fixed deductibles of 1‰ and 2‰ of the SI, Graph a shows – again for homeowners insurance in Germany – the calculated loss reduction as a function of the average loss ratio, i.e. the intensity of the windstorm. By analogy, it is also possible to show the effect that deductibles of differing amounts have on a certain loss ratio (Graph b).

Graph a:
Loss elimination by means of deductibles.
The (theoretical/calculated) loss elimination effect may be seen on the y axis for windstorm events with average loss ratios of up to 10‰ of the SI on the basis of deductibles of 1‰ and 2‰ of the SI.



Graph b:
Loss elimination by means of deductibles.
In contrast to Graph a, the (theoretical/calculated) loss elimination effect may be seen directly on the y axis for windstorm events with average loss ratios of 1‰ and 2‰ of the SI on the basis of deductibles of up to 10‰ of the SI.



4 New findings on the correlation between various loss parameters and wind speed

In the following section we present the results of our analysis of three loss parameters (loss ratio, loss frequency, and average loss) from the December 1999 gales and – wherever possible – compare them with our examination of the losses from the 1990 winter storm series.

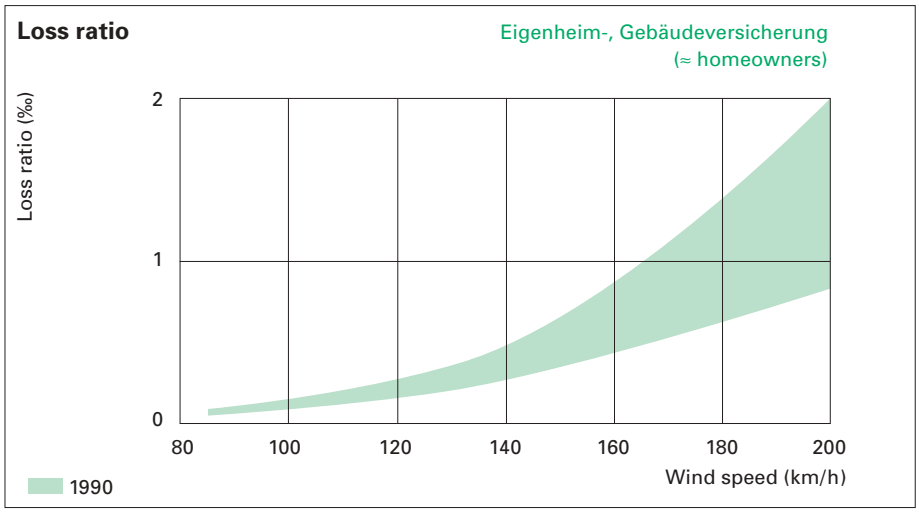
The method described in Chapter 3 (analysis of portfolio and loss data on the 1999 winter storms) was used to determine the correlation between loss parameters and wind speed by country and class of insurance.

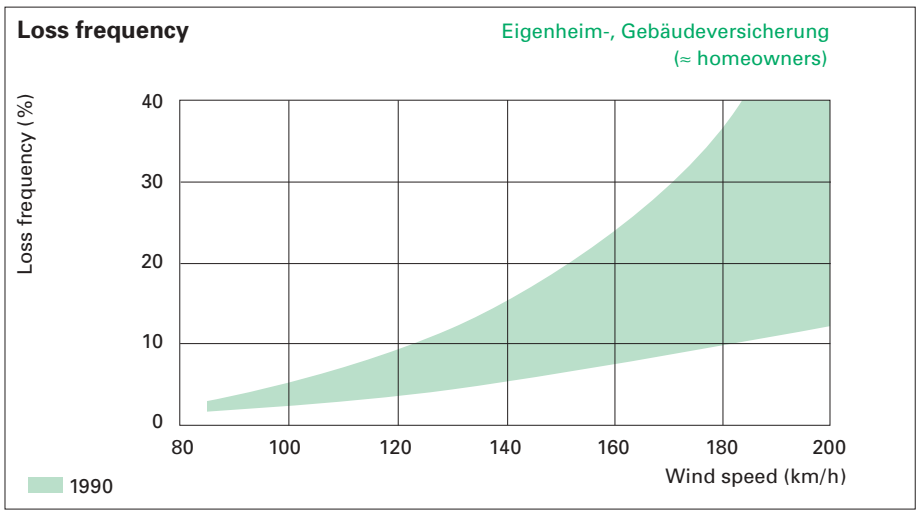
The cross-hatched area of the curves shows the range in the results of the analysed companies. In some cases, there are considerable differences in the vulnerability of the portfolios (in identical classes); these are mainly due to the following factors:

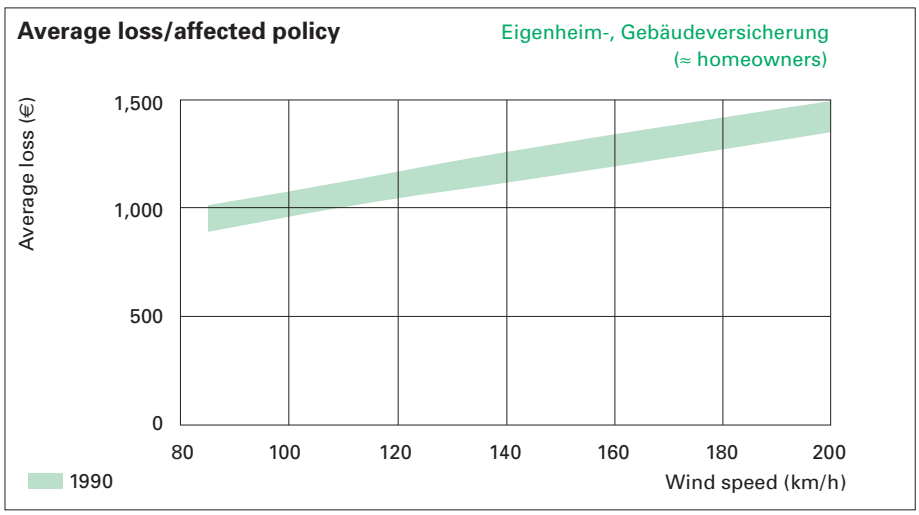
– Deductibles: The typical range of deductibles in European windstorm covers goes from 0 (no deductible) to about 1‰ of the sum insured (and rarely higher). Note: The deductible is often stated in monetary units, e.g. €300; it may be converted into a permillage of the sum insured.
– Underwriting guidelines: Depending on the company's own underwriting criteria, the overall composition of a portfolio in terms of the windstorm risk may be altogether more positive or negative than the market average.
– Adjustment practices: Lothar and Martin alone generated over three million individual losses. In order to cope with the flood of claims, some insurers decided they would only make random checks of repair invoices below a certain amount. Conversely, other companies rigorously called for detailed evidence as to the correctness of the losses reported.

To conclude this examination of the windstorm vulnerability of risks in Europe, the loss parameters are shown even for the countries that were not or only slightly affected by Anatol, Lothar, and Martin in 1999. These data are based on Munich Re's analyses of the 1990 winter storm series (cf. our exposé “Winter Storms in Europe: Analysis of 1990 Losses and Future Loss Potentials”).

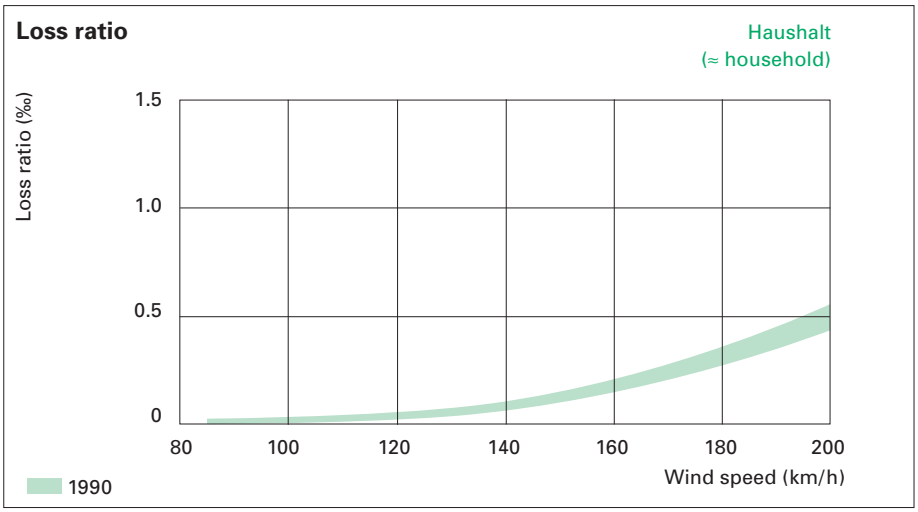
Austria
Loss parameters as a function of wind speed.

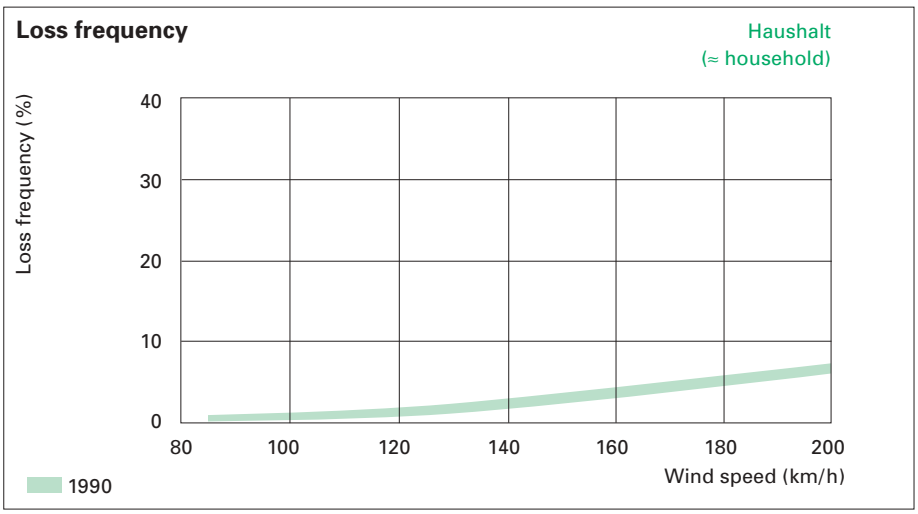


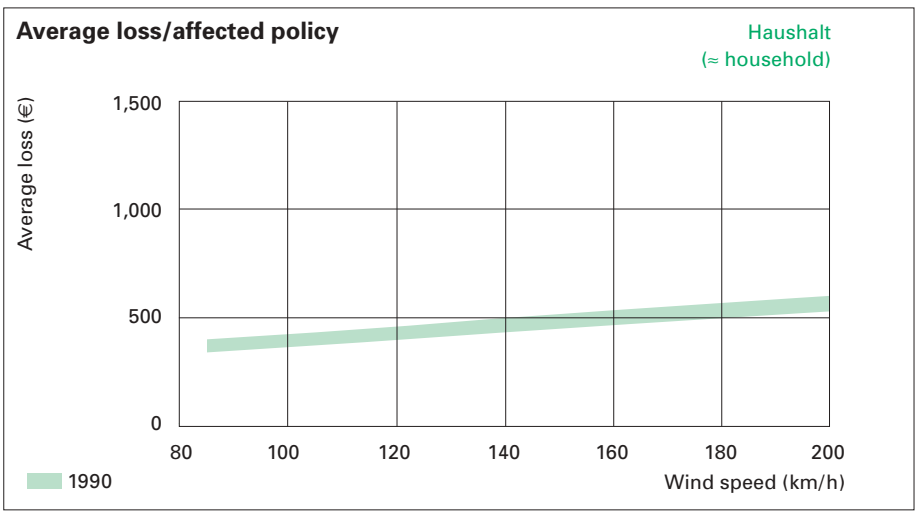




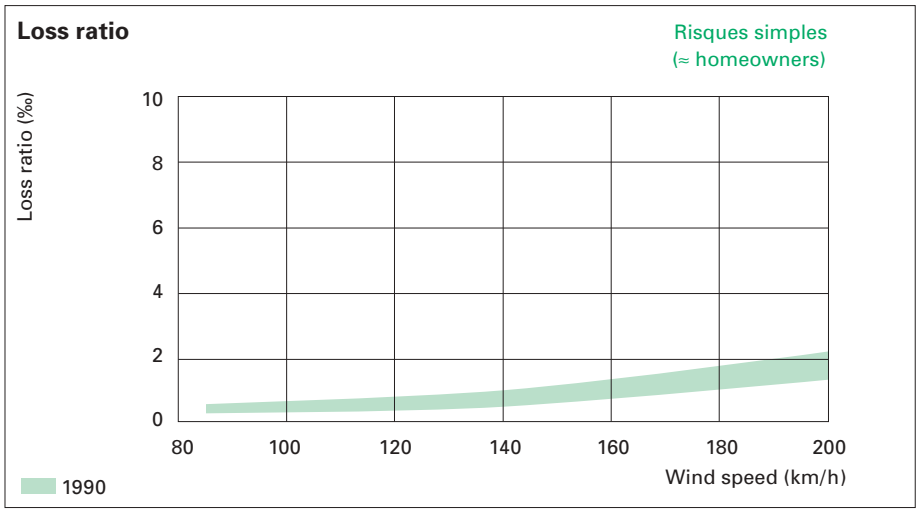
Austria
Loss parameters as a function of wind speed.

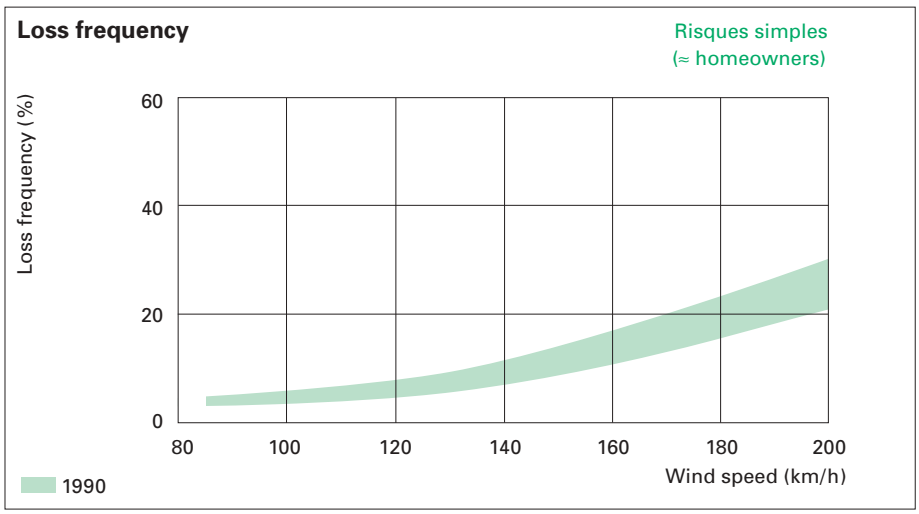


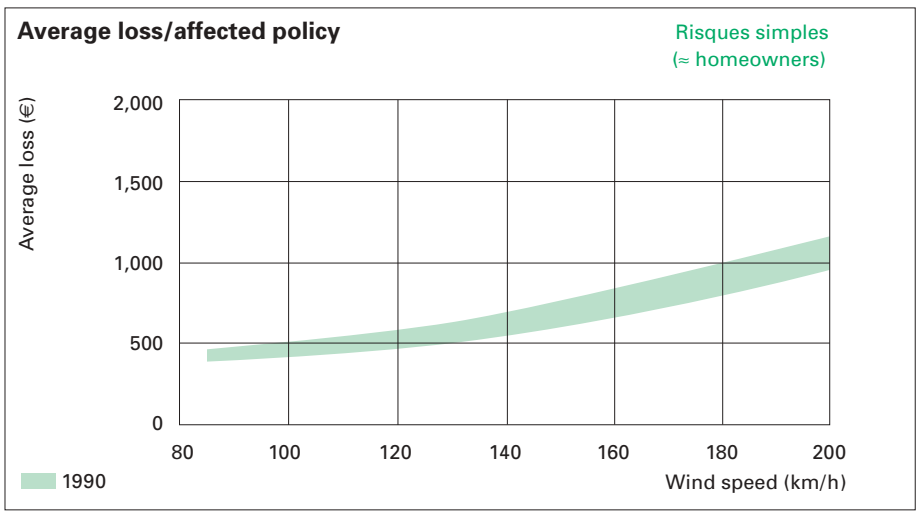




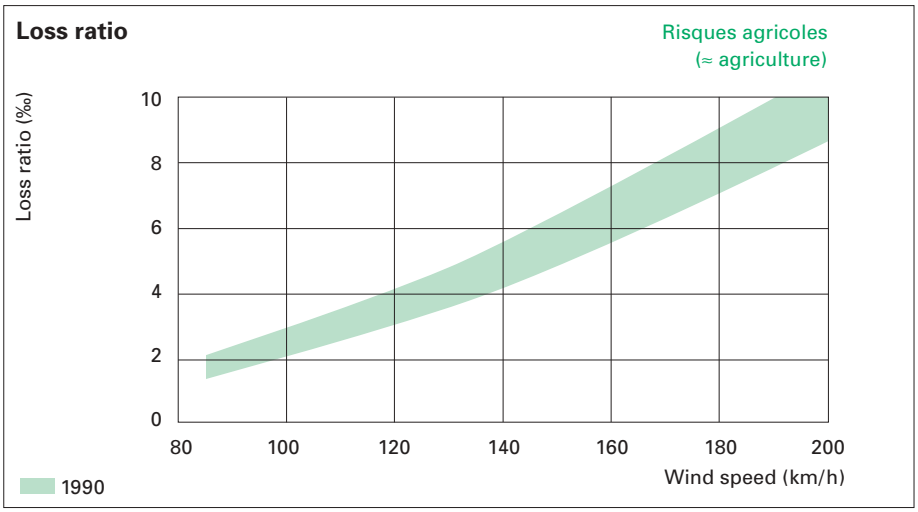
Belgium
Loss parameters as a function of wind speed.

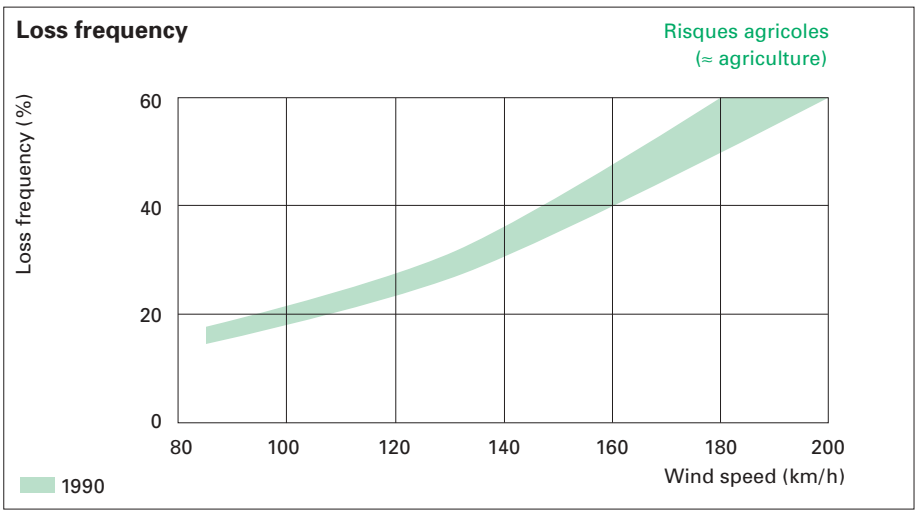


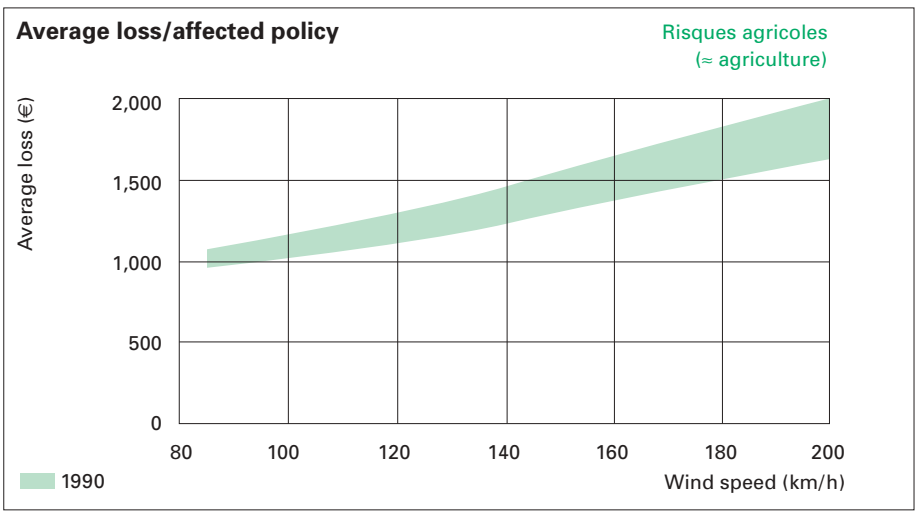




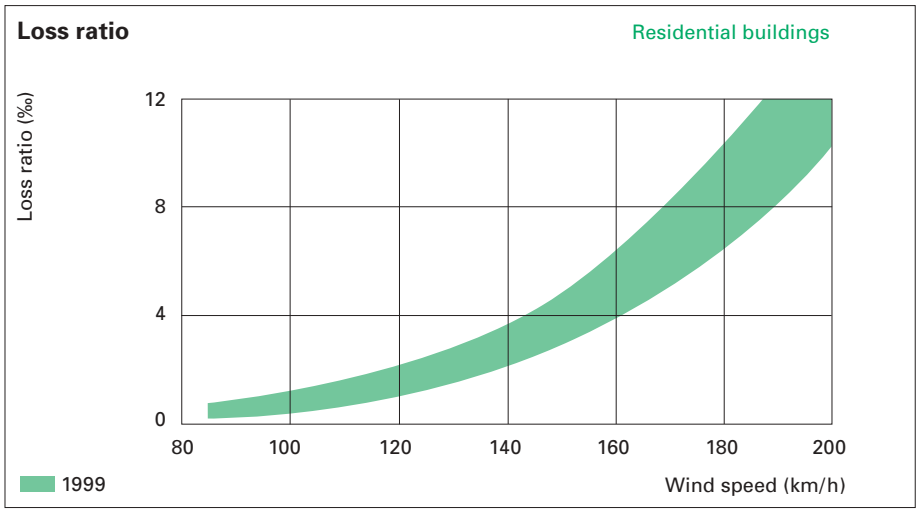
Belgium
Loss parameters as a function of wind speed.

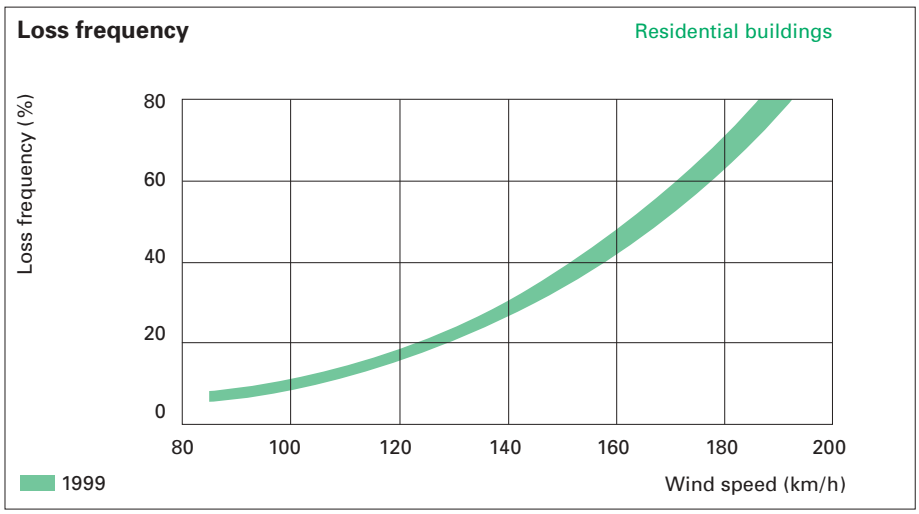


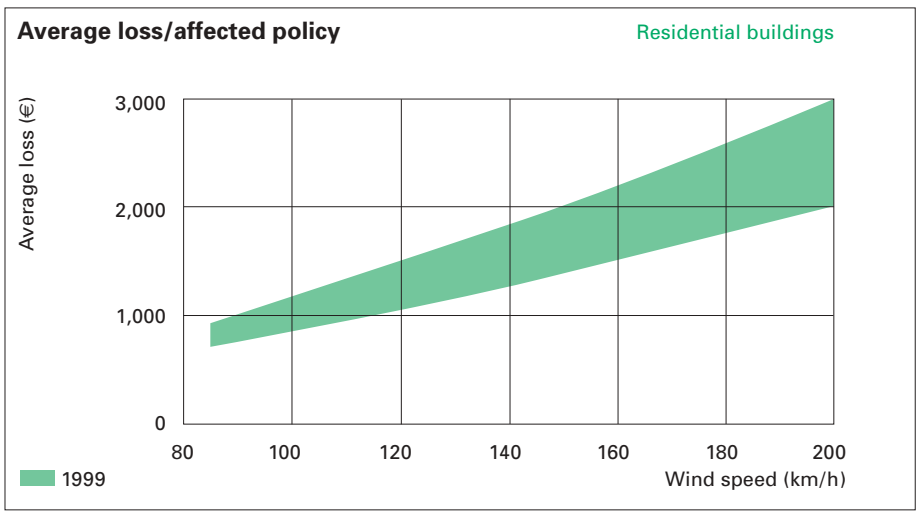




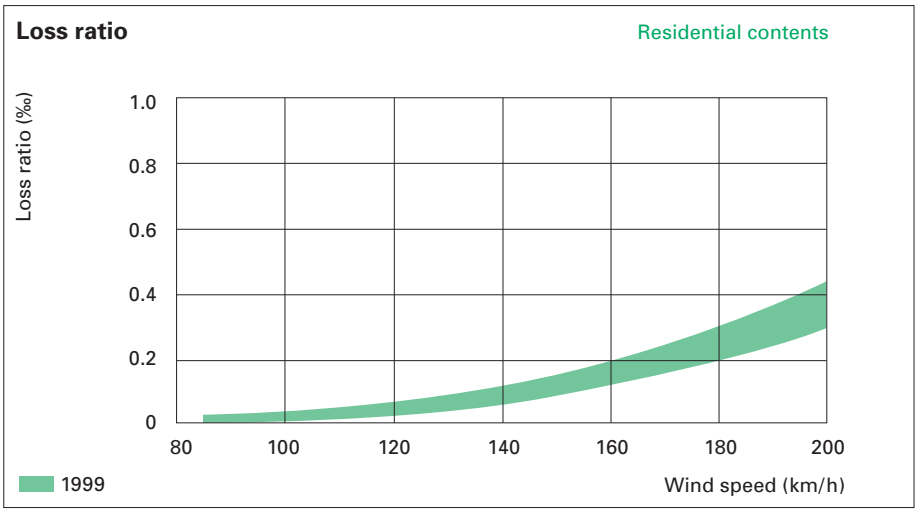
Denmark
Loss parameters as a function of wind speed.

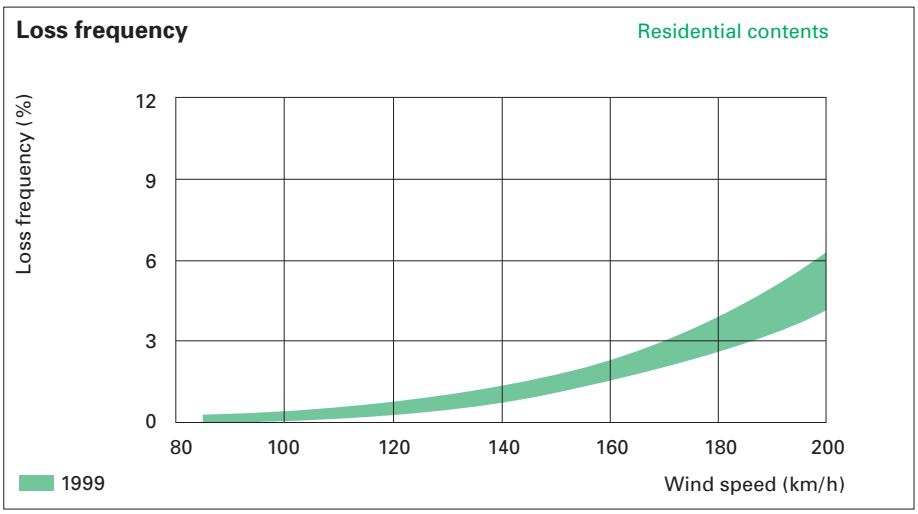


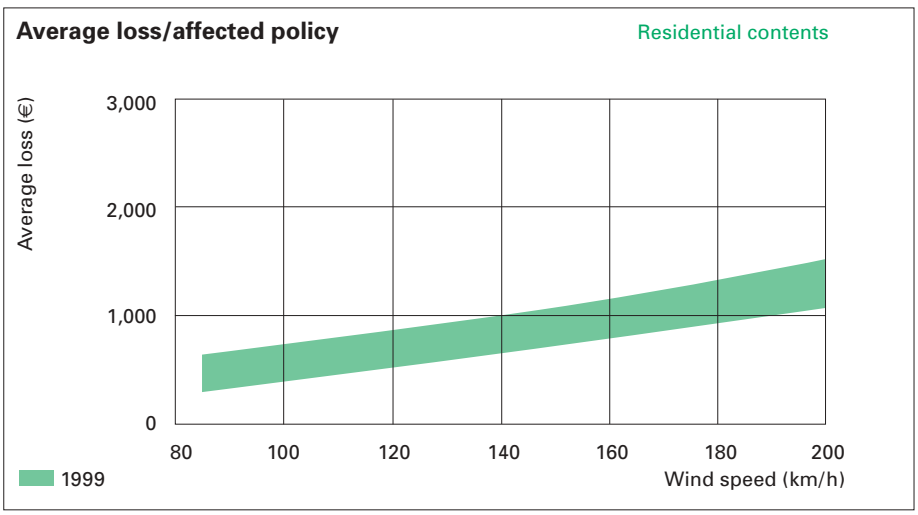




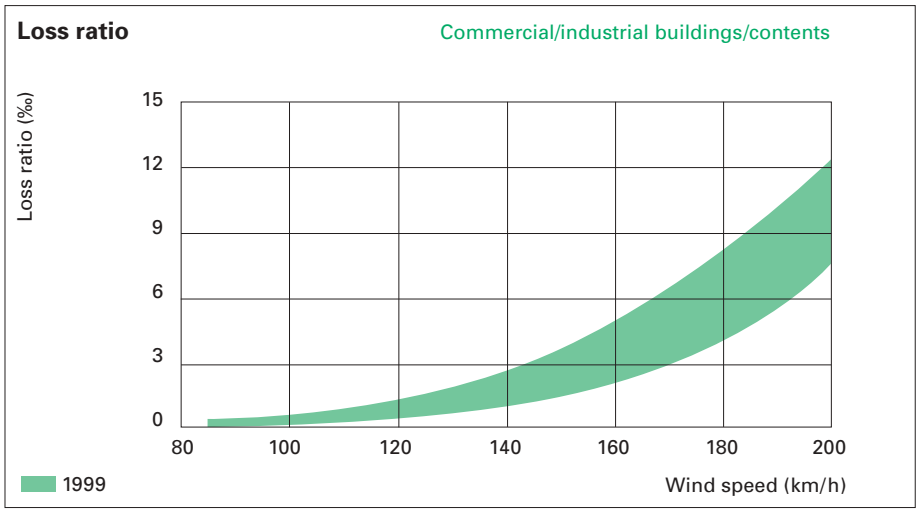
Denmark
Loss parameters as a function of wind speed.

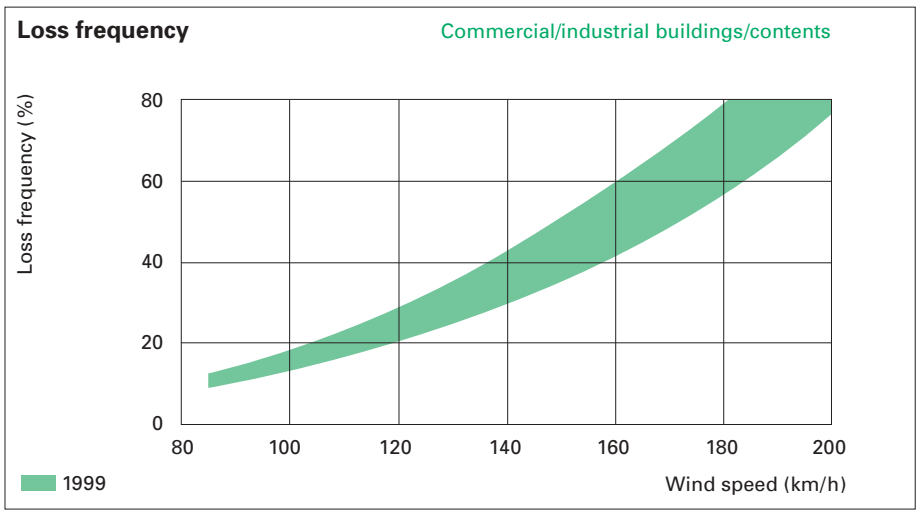


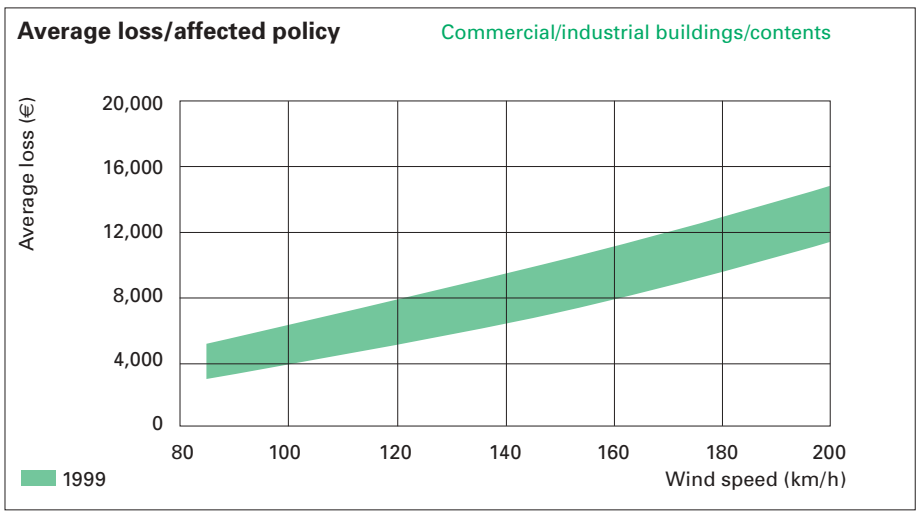




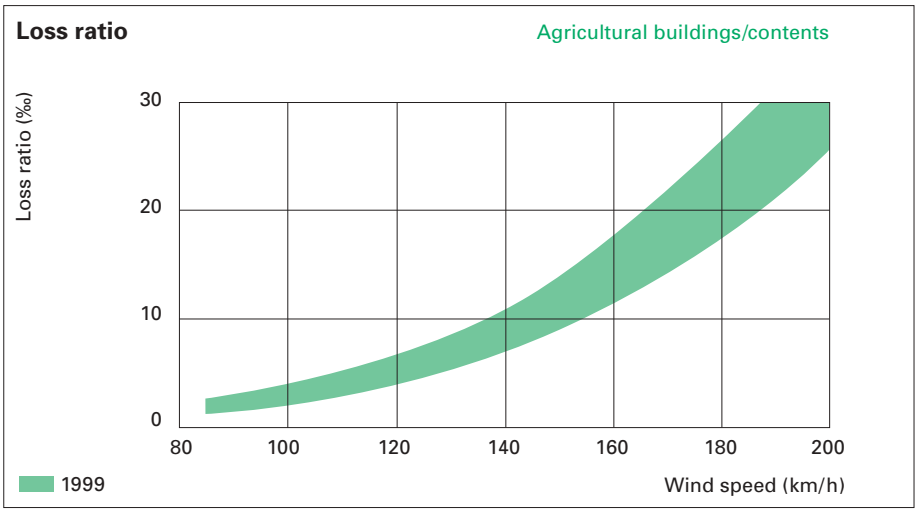
Denmark
Loss parameters as a function of wind speed.

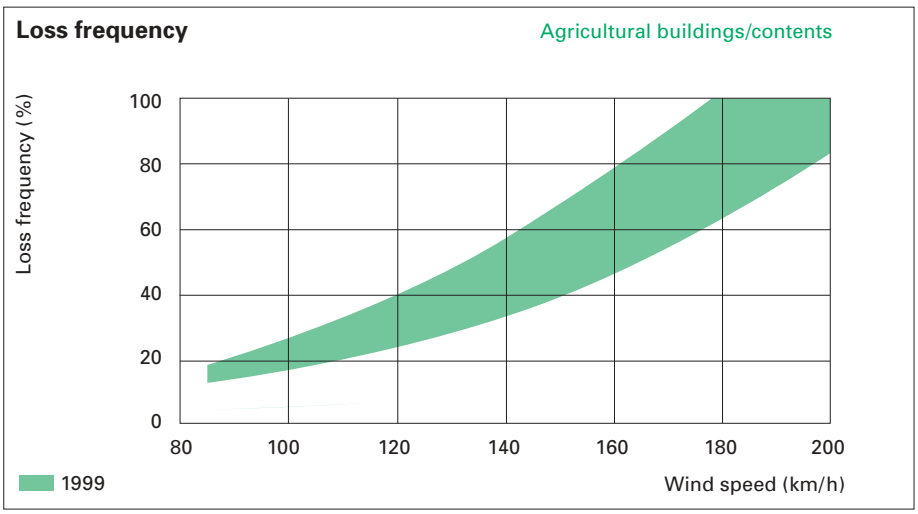


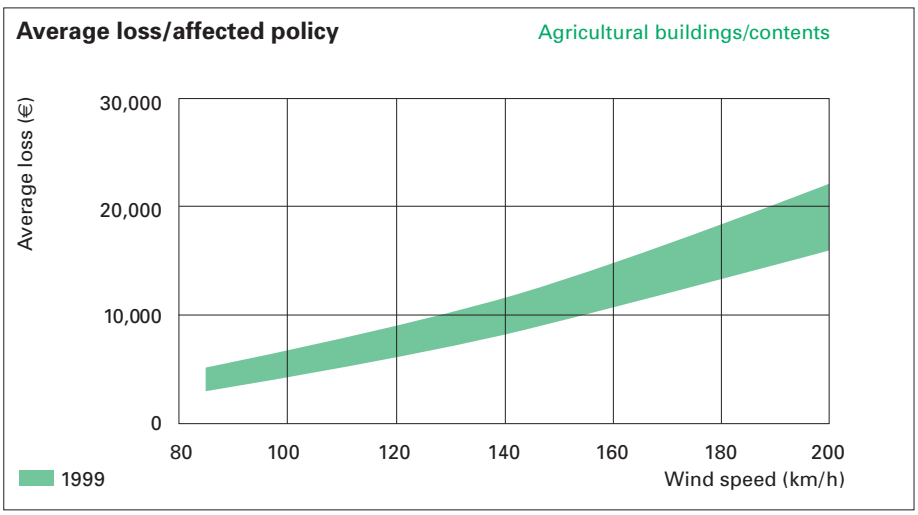




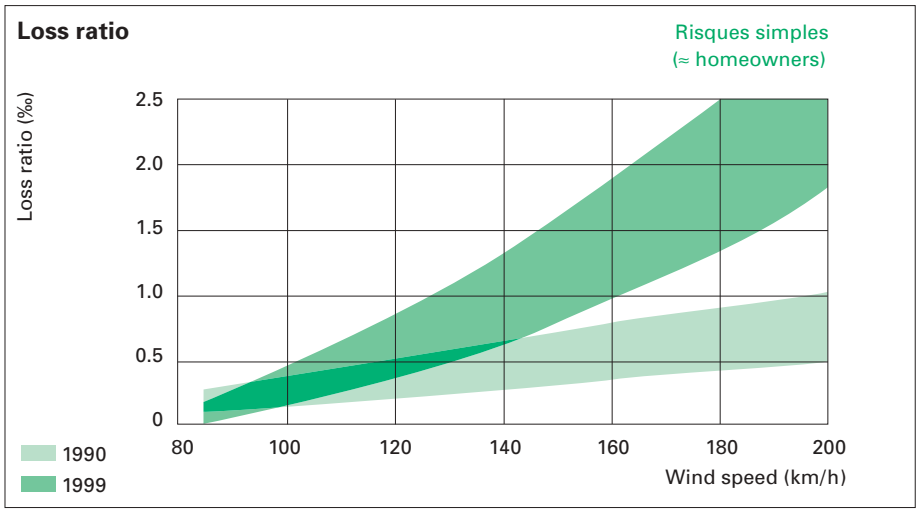
Denmark
Loss parameters as a function of wind speed.

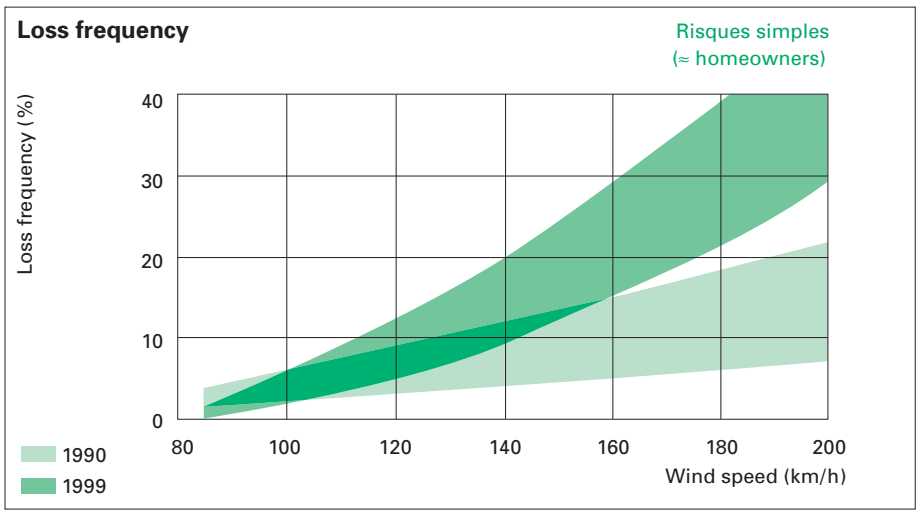


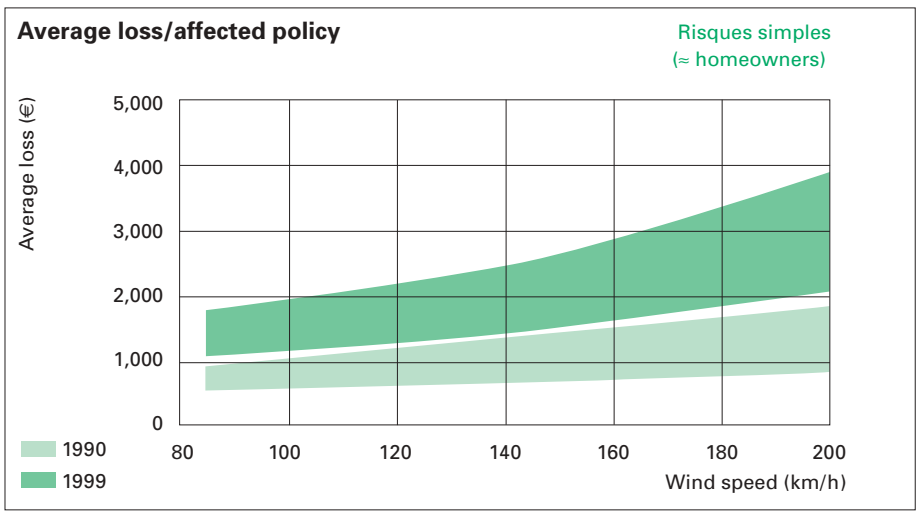




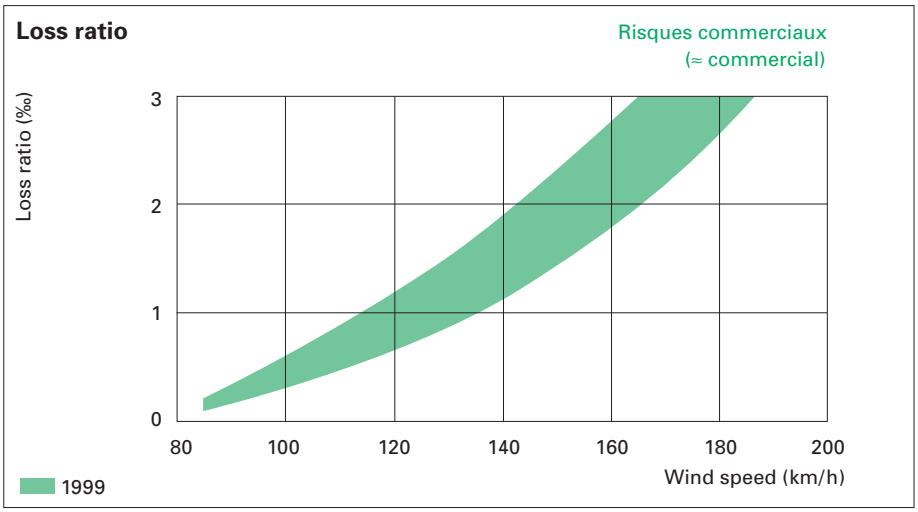
France
Loss parameters as a function of wind speed.

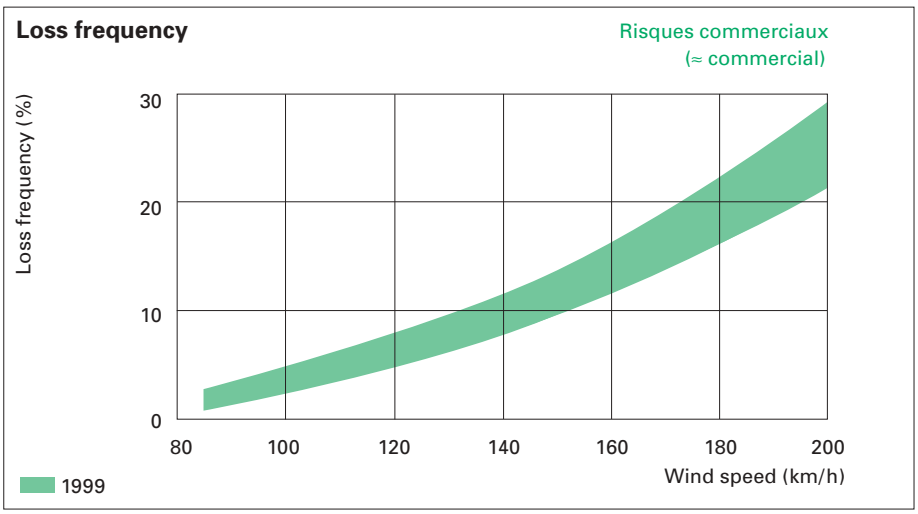


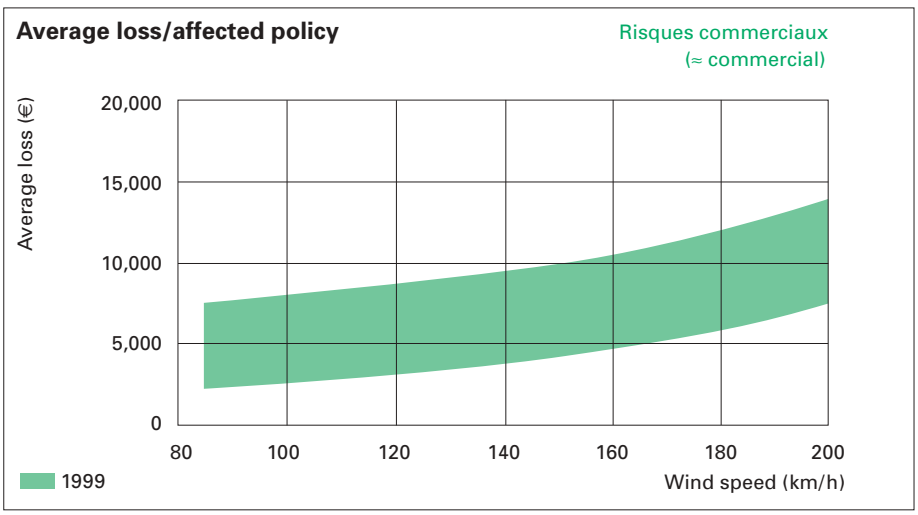




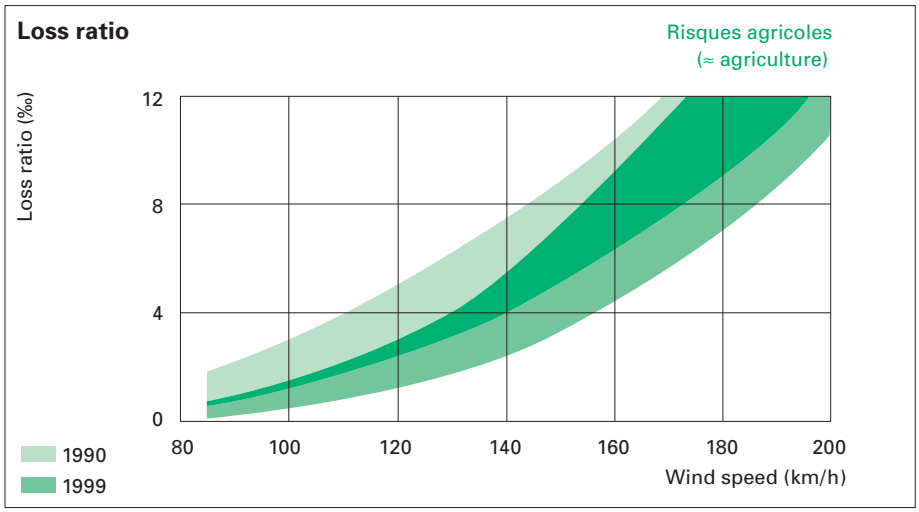
France
Loss parameters as a function of wind speed.

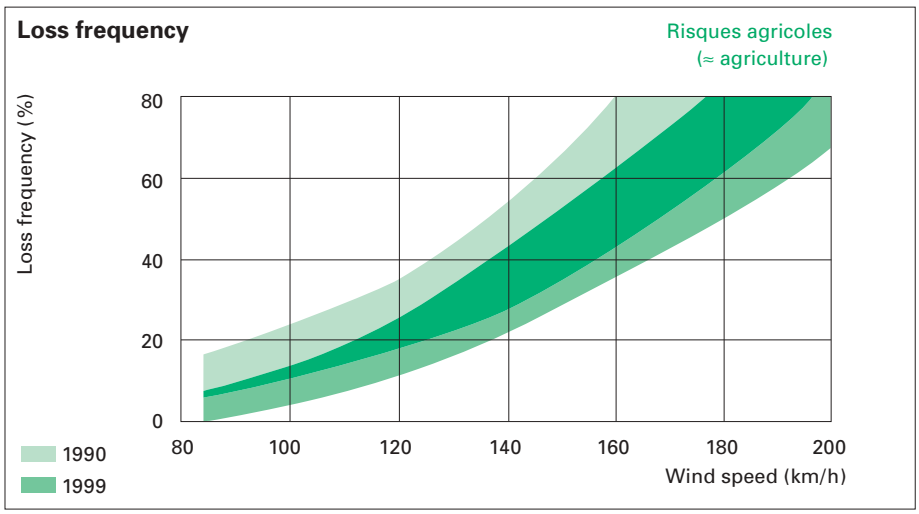


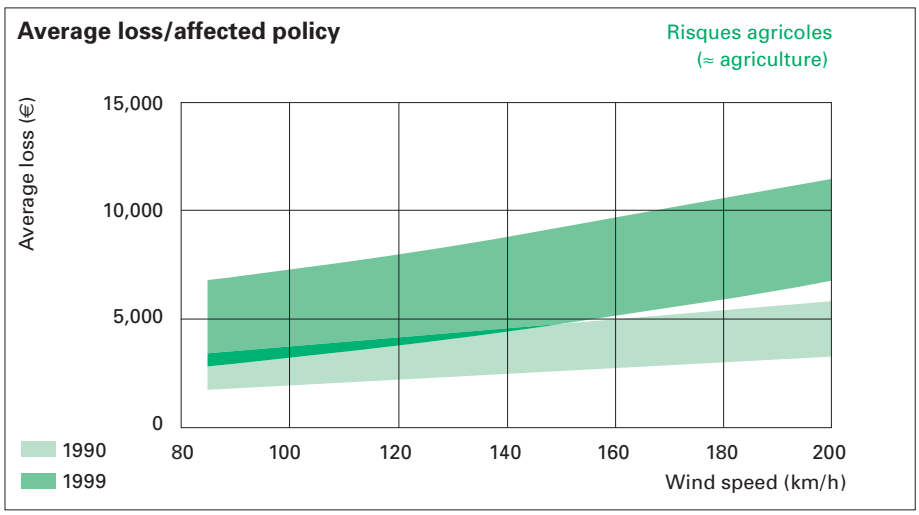




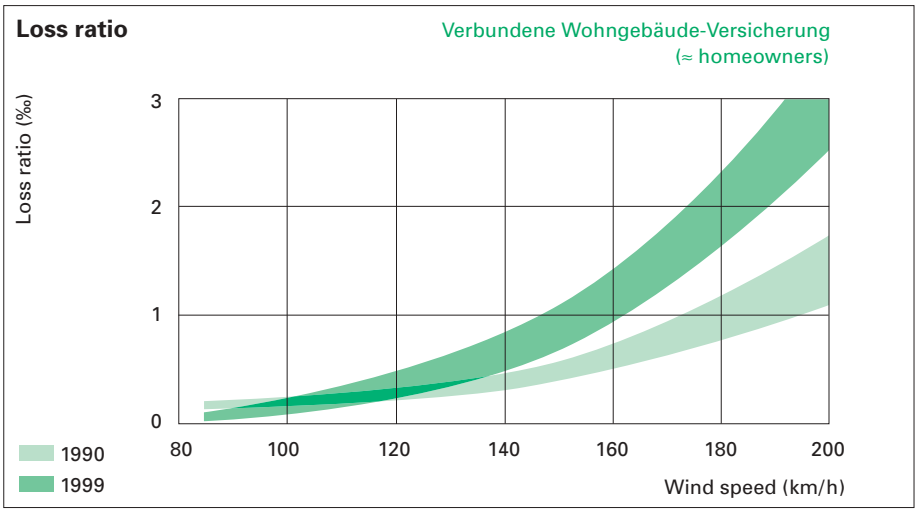
France
Loss parameters as a function of wind speed.

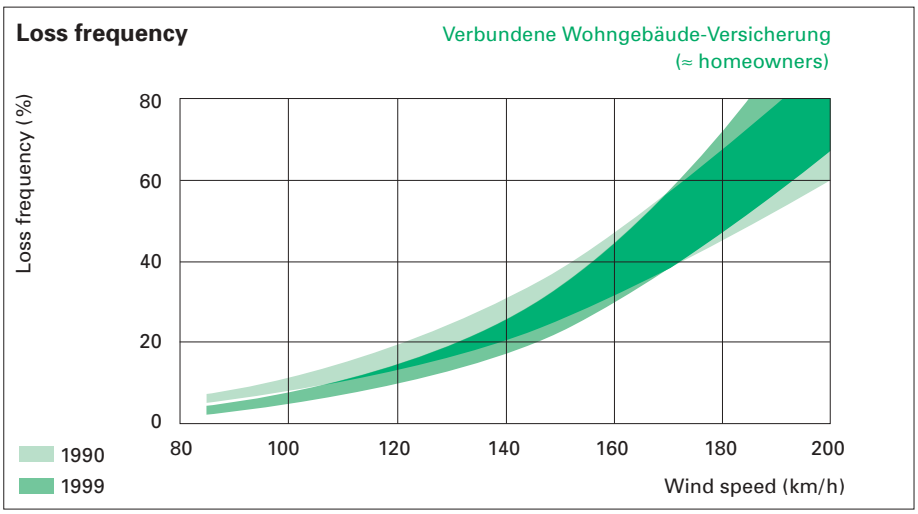


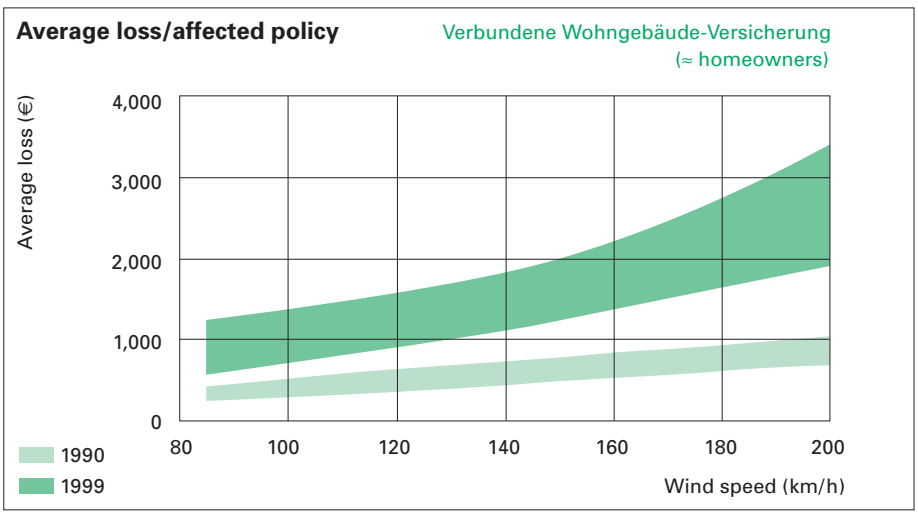




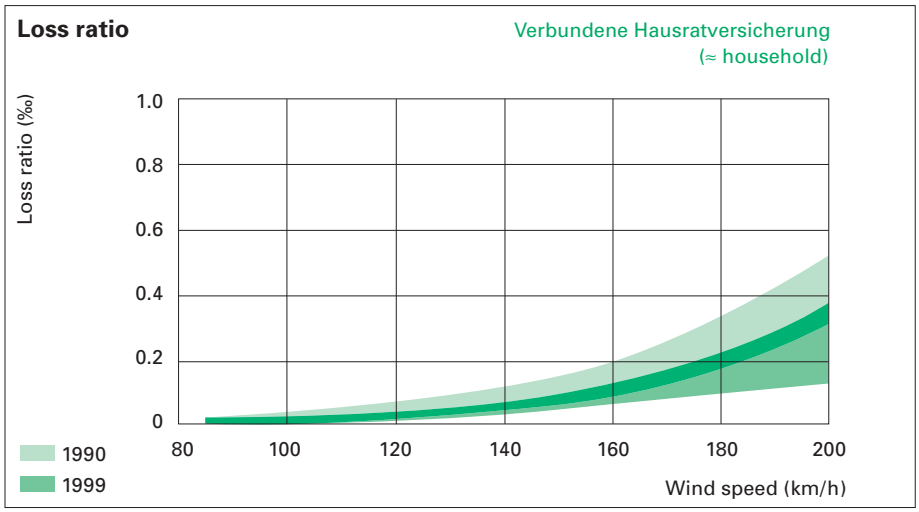
Germany
Loss parameters as a function of wind speed.

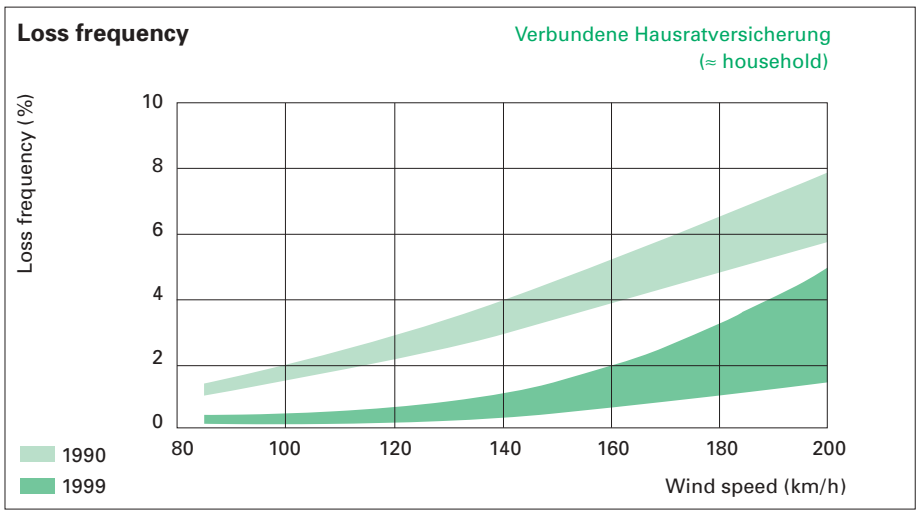


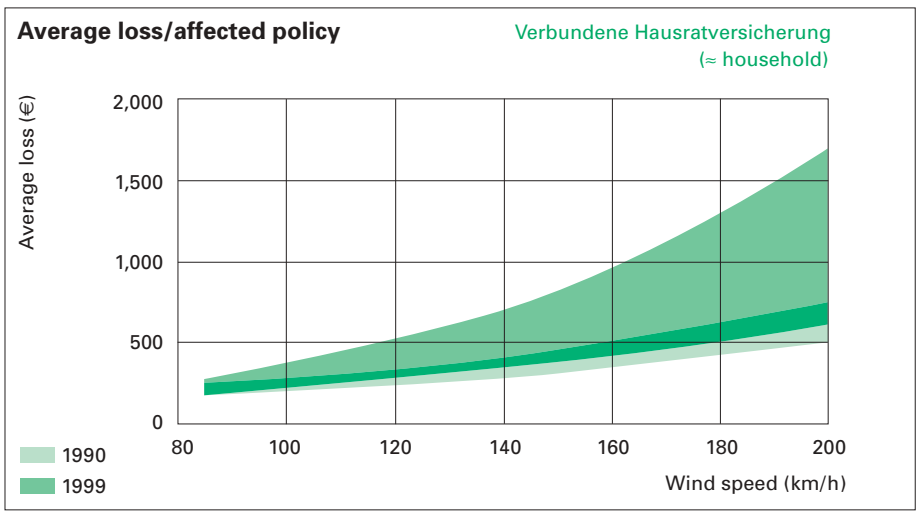




Germany
Loss parameters as a function of wind speed.



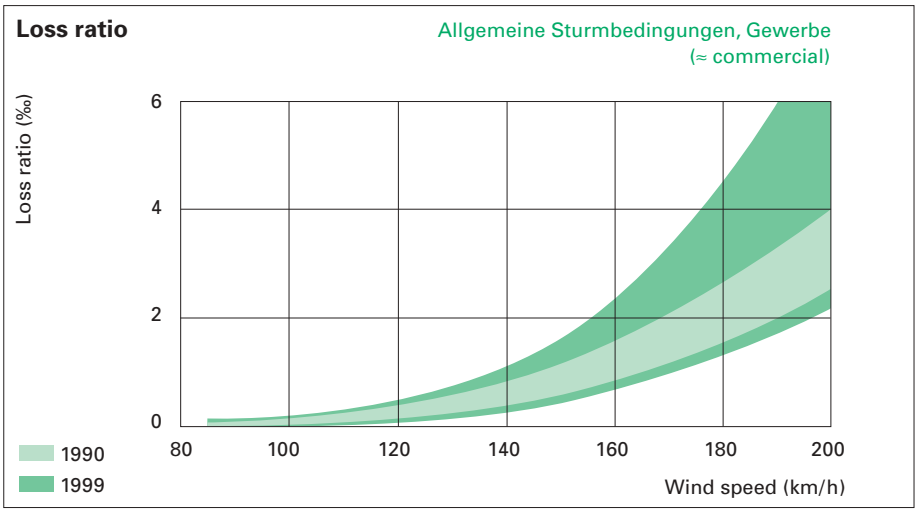


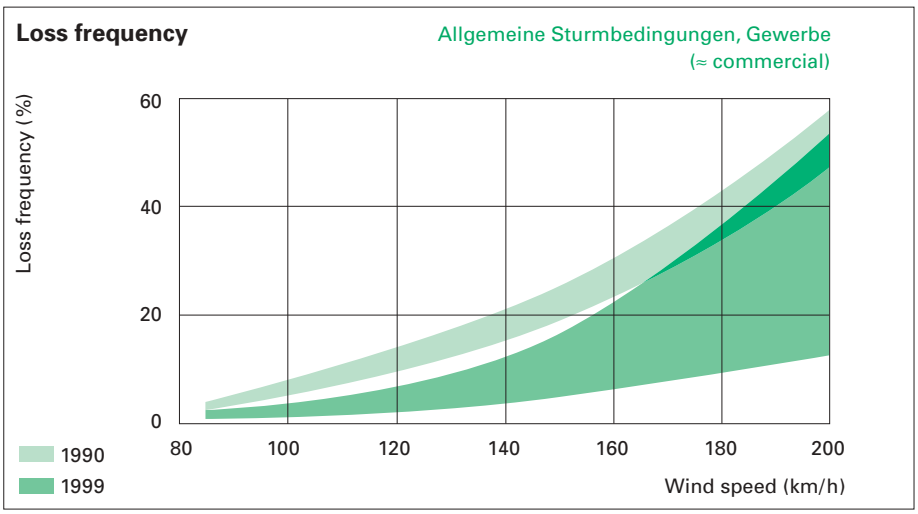


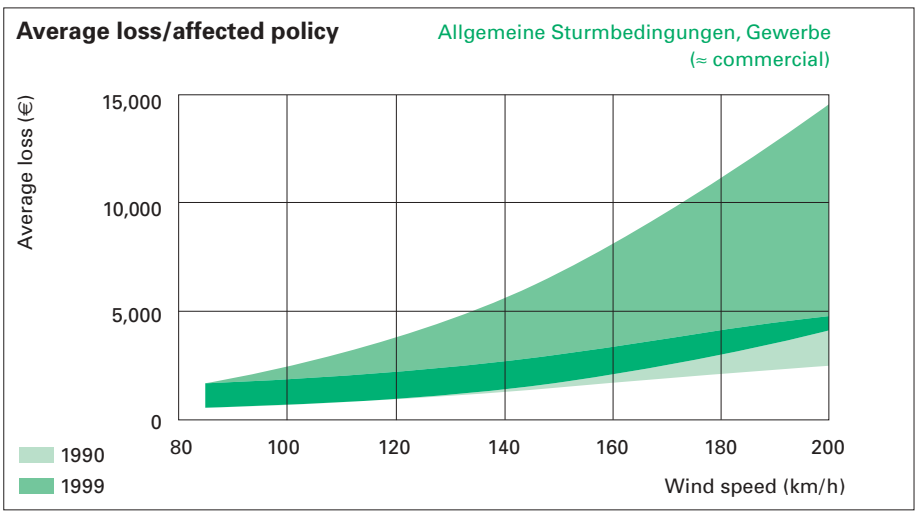
Risques commerciaux

(≈ commercial)

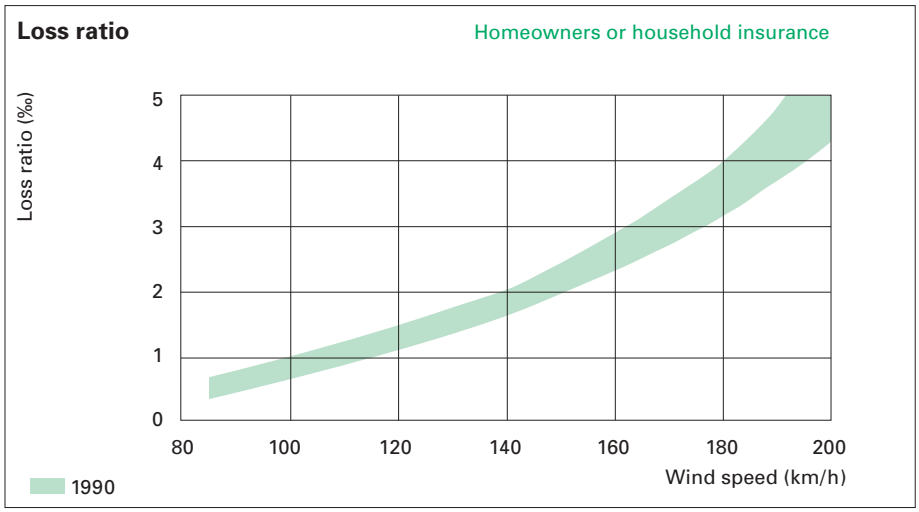
Germany
Loss parameters as a function of wind speed.

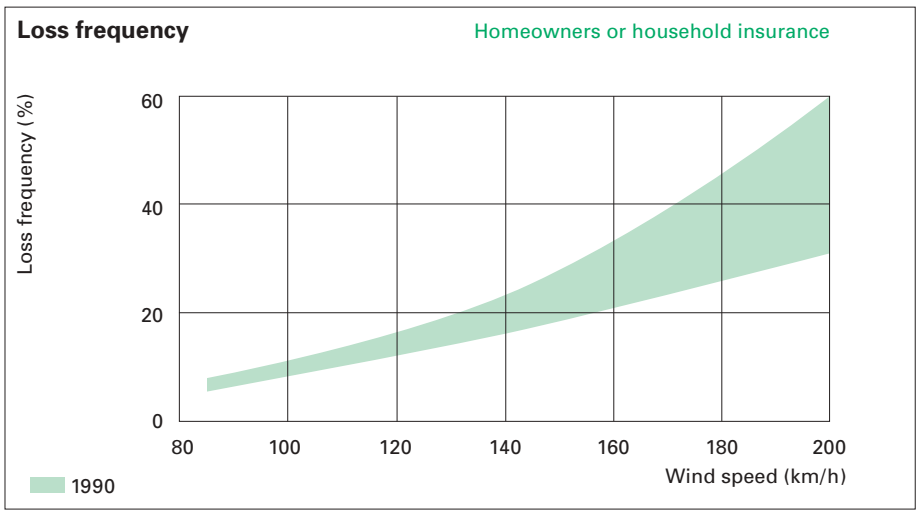


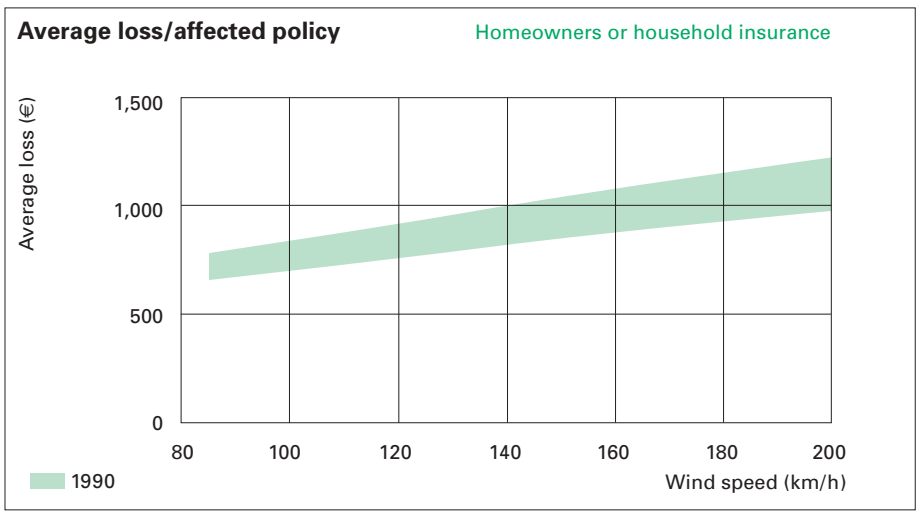




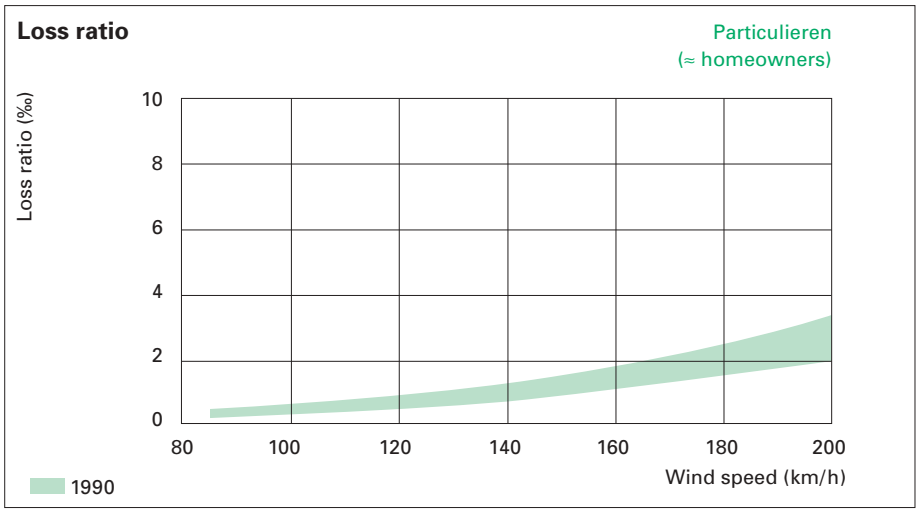
Great Britain
Loss parameters as a function of wind speed.

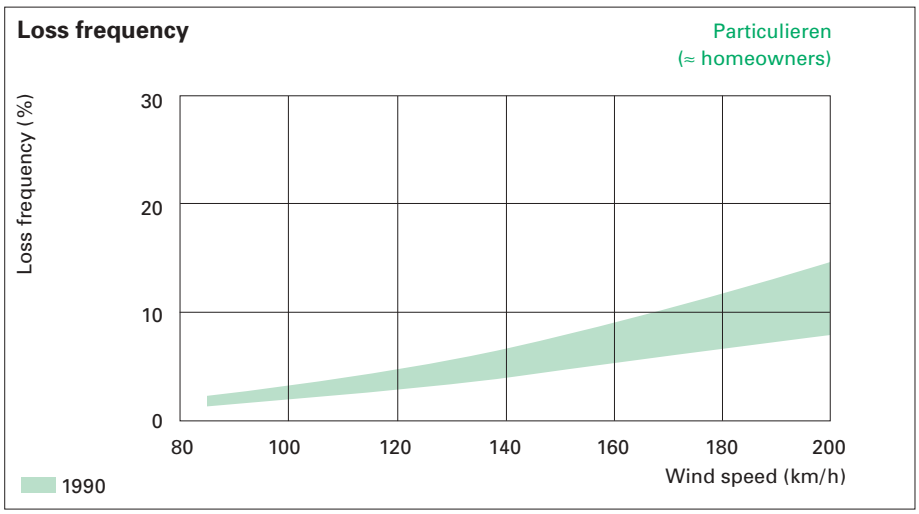


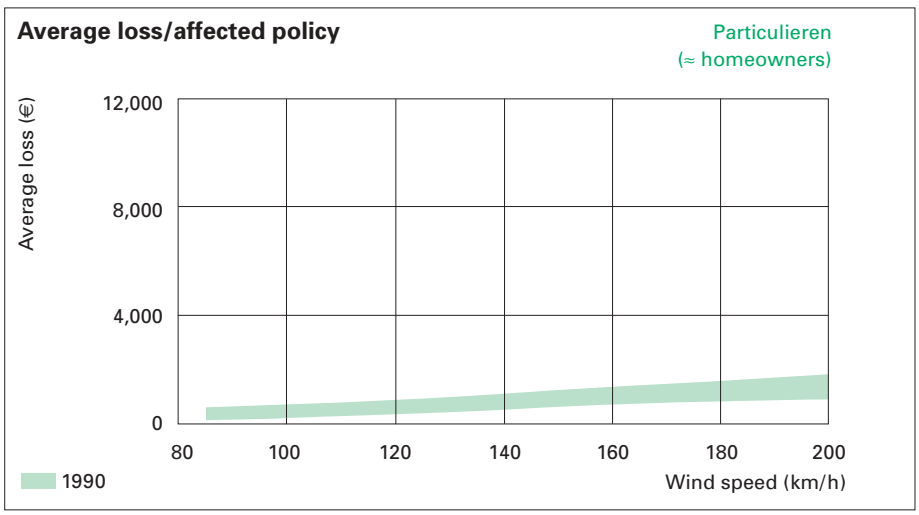




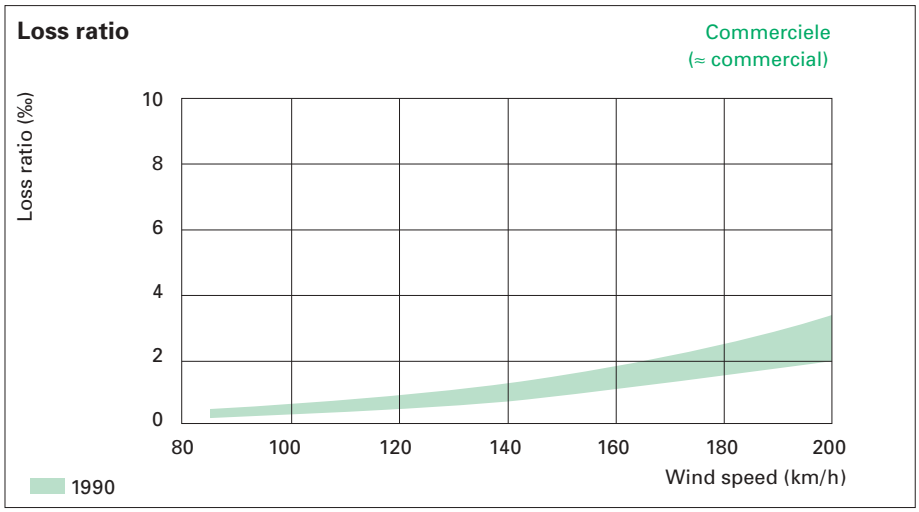
Netherlands
Loss parameters as a function of wind speed.

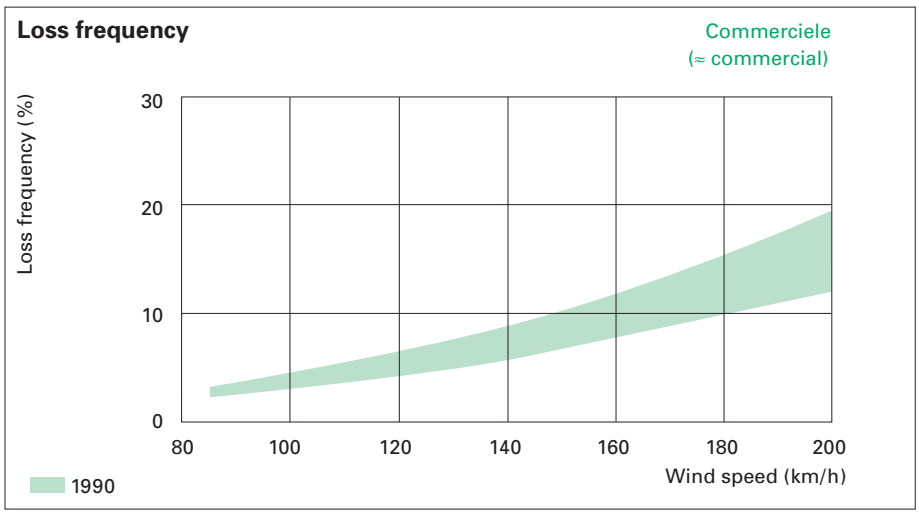


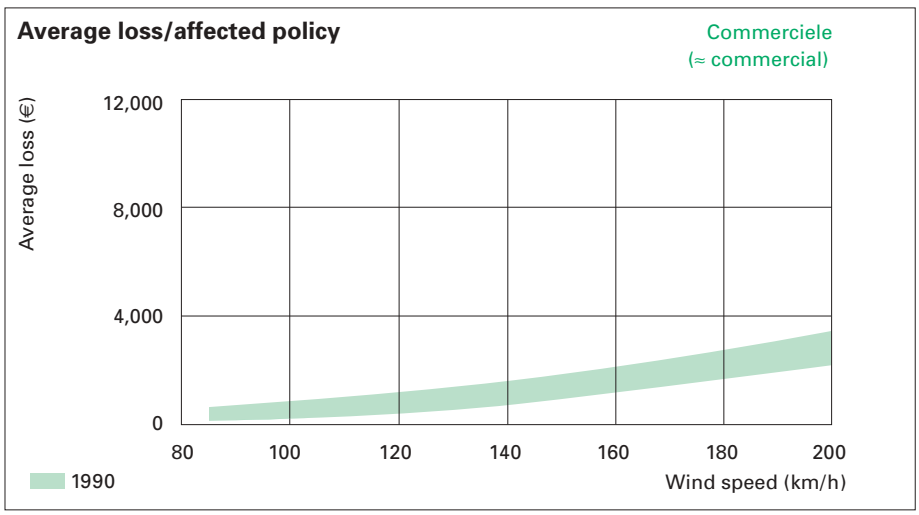




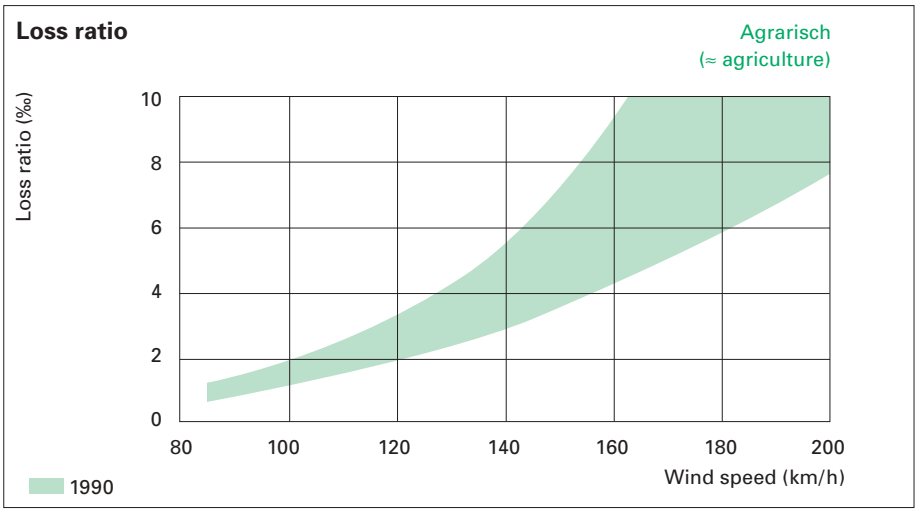
Netherlands
Loss parameters as a function of wind speed.

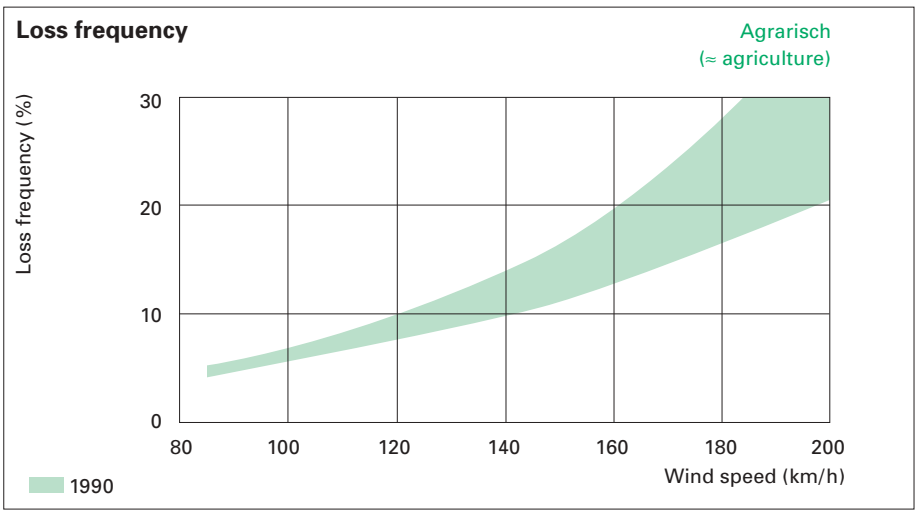


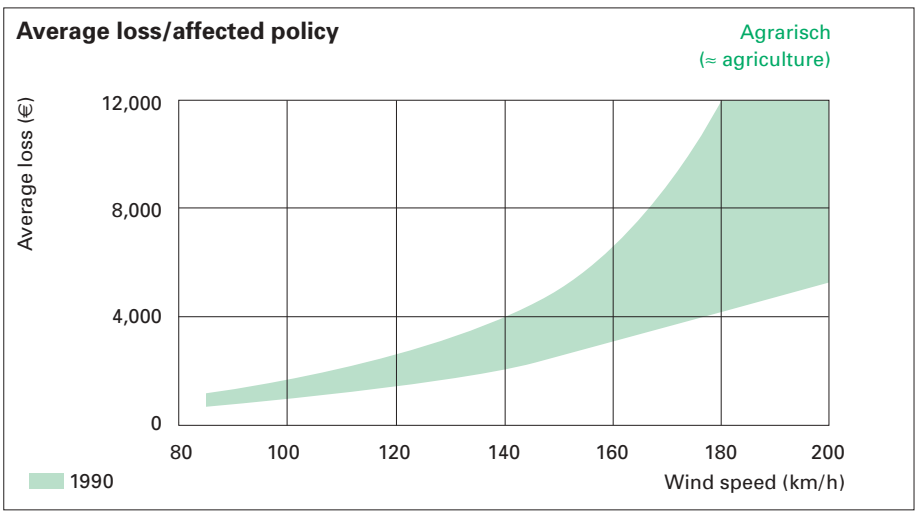




Netherlands
Loss parameters as a function of wind speed.







New findings on windstorm vulnerability in Europe

Windstorm vulnerability in Europe – comparison of 1999 data with experience in 1990

	Loss ratio	Loss frequency	Average loss
Denmark	Directly comparable data for 1990 only partially available; 1999 loss ratios for residential buildings and commercial risks (in some cases much) higher than in the other countries in the 1990 and 1999 analyses; increase in loss ratios with the wind speed around the exponent of 4 to 5.	In all risk classes comparable with the 1990 experience in other European countries.	Average losses within the expected range.
France	The lack of direct information on sums insured restricts the possibility of comparing 1999 and 1990; the 1990 loss experience tends to be confirmed, but higher loss ratios observed in 1999 at high wind speeds.	At average wind speeds comparable with the 1990 loss experience; at high wind speeds considerably higher loss frequencies than extrapolated using the 1990 data.	Average losses considerably higher than in 1990, but within the expected range.
Germany	Very good comparable data for 1990 losses available; main new finding from Lothar: at high wind speeds loss ratios rise more steeply than extrapolated on the basis of 1990 data.	For homeowners comparable with the 1990 loss experience; for household and commercial risks lower than 1990.	Average losses considerably higher than in 1990, but within the expected range.

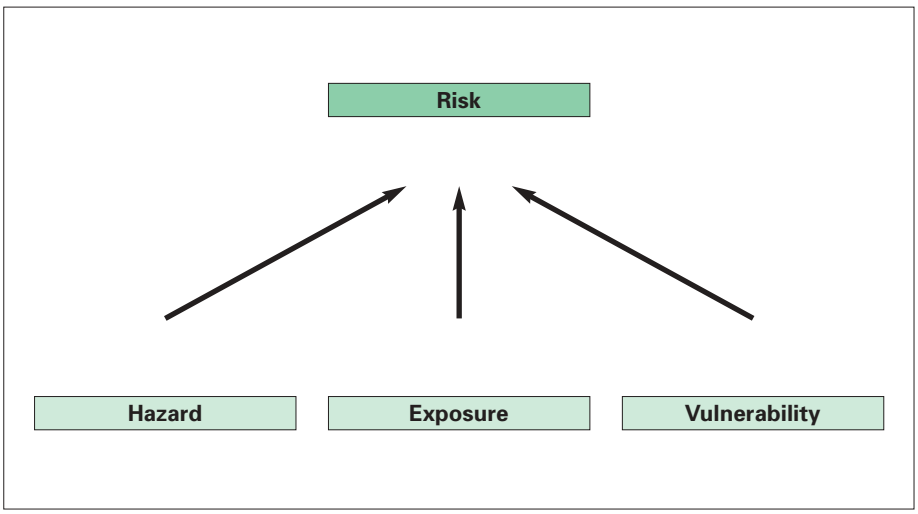
5 Windstorm loss potentials in Europe – accumulation aspects

5.1 Preliminary considerations

Anatol, Lothar, and Martin provided (further) evidence that losses from winter storms in Europe are capable of assuming the dimensions of major catastrophes for the insurance industry and that many market players were still too optimistic in their assessment of the loss potential from such windstorms – which is particularly remarkable given the fact that only a few years had passed since the 1990 gales.

What data are required for a sound assessment of the windstorm risk in Europe?

Generally speaking, risk analyses of natural hazards may always be traced to the following point of reference:



"Risk" is defined as the (exceedance) probability of loss amounts.

The decisive factor for estimating loss probabilities (return periods) is an optimum knowledge of the three parameters that determine the risk: hazard, exposure, and vulnerability.

Hazard
The windstorm hazard at any specific location may be described with the aid of the probability of certain wind speeds. Using meteorological data from the past, statistical methods are applied to estimate the return period of windstorm intensities (wind speeds) at individual weather stations. In addition to the quality of the historical recordings, the factors that are of major significance when determining the windstorm hazard are the chosen statistical extrapolation method and the consideration of possible changes in the wind climate. The risk analysis of geographically dispersed portfolios requires a wider definition of hazard. In addition to estimating the wind speed probabilities at individual meteorological stations, it is necessary to examine the spatial and temporal correlation of higher wind speeds from the same event at several locations (determination of wind fields).

Exposure
Since the hazard is usually a parameter of differing spatial dimensions and the vulnerability depends on the type of risk involved (see below), a windstorm-risk analysis requires exposures divided up geographically and by risk class (simplified: class of insurance). The CRESTA system provides a structure that is suitable for nearly all European countries (cf. http://www.CRESTA.org).

Vulnerability
Because of the predominantly massive construction of buildings in Europe, structural damage is usually the exception even when wind speeds are high. The main types of loss involve damage to the outside shell of the buildings, i.e. roofs, façades, and windows. In recent years there has also been a more pronounced trend towards buildings with outside attachments (pergolas, awnings, satellite antennae), which are potentially more prone to being damaged at high wind speeds than the buildings themselves.

The other main factors connected with windstorm losses are
– the design features and the state of repair of roofs,
– the design features of windows,
– the height, type, and health of trees in the vicinity of buildings,
– the early warning of the population and subsequent precautions (e.g. closing of windows and doors), and,
– in the event of insured losses, the insurers' adjustment practice.

These factors show that windstorm vulnerability is a dynamic parameter which can change in the course of time and therefore needs to be adjusted constantly in accumulation studies (cf. “New findings on windstorm vulnerability in Europe” on page 52 and the Munich Re exposé “Winter Storms in Europe: Analysis of 1990 Losses and Future Loss Potentials”).

5.2 Occurrence probability of windstorm market losses

The significance of major historical windstorm events in Europe is demonstrated vividly in the table on page 56.

For selected countries the historical windstorm losses of recent decades were extrapolated to the price levels of 2001, and a loading was estimated for the change in the wind climate expected as a result of the increasing effect of global warming. On this basis it was possible to produce loss frequency statistics on a country-by-country basis. These statistics formed the basis for the occurrence probabilities shown in the table below.

Occurrence probabilities of market losses

Windstorm market loss in €bn	Belgium*	Denmark*	France*	Germany*	Great Britain*	Netherlands*	Europe*
0.5	15–20	8–12	8–12	3–6	2–4	8–12	<1
1.0	40–60	20–40	12–15	8–12	8–12	15–20	1
2.5	>150	80–100	30–50	20–40	15–20	50–80	3–5
5.0			60–80	70–90	20–40	>100	8–12
10.0					70–90		20–30

*Return periods in years
Source: Munich Re, Geo Risks Research Department.

The data on historical losses used as a basis for this table should in no way be regarded as complete. The calculated occurrence probabilities must therefore be interpreted as rough approximations which are ridden with uncertainties. It should also be noted that a change in the underlying exposure distribution would lead to different results.

Some major historical windstorm events in Europe

Country	Date	Event, area	Fatalities	Overall loss in €m
Austria	1990, January-March	Winter storms	3	200
Belgium	1990, January-March	Winter storms	15	870
Denmark	1981, 24th/25th November	Gale	9	280
	1990, January-March	Winter storms		160
	1999, 3rd/4th December	Winter storm Anatol	7	2,600
France	1967, 25th June	Tornados, north		40
	1982, 6th-9th November	Gale	14	430
	1987, 15th/16th October	Gale "87J", northwest	4	1,400
	1990, January-March	Winter storms	66	1,650
	1998, 1st-5th January	Winter storms		140
	1999, December	Winter storms	92	12,000
Germany	1164, February	Storm surge: Julianenflut	20,000	
	1219, January	Storm surge, North sea	36,000	
	1287, December	Storm surge, North sea	50,000	
	1362, January	Storm surge, Große Manndränke	100,000	
	1532, November	Storm surge, Nordstrand/Eiderstedt	5,000	
	1570, November	Storm surge, North Sea	9,000	
	1625, February	Storm surge, Baltic Sea	9,100	
	1634, October	Storm surge, North Sea	8,400	
	1717, December	Storm surge, North Sea	11,500	
	1825, February	Storm surge, North Sea	800	20
	1962, February	Storm surge, North Sea	347	1,200
	1967, February	Gale, North Sea	40	600
	1968, 10th July	Tornado, Pforzheim	2	60
	1972, 12th/13th November	Lower Saxony gale	54	700
	1976, 2nd–4th January	Capella gale	27	450
	1990, January–March	Winter storms	64	3,800
	1994, 27th January	Winter storm Lore	6	360
	1998, 27th–29th October	Winter storm Xylia	5	130
	1999, December	Winter storms	18	1,800
	2001, 3rd August	Severe storm	1	750
Great Britain	1588, 21st September	Gale (Sinking of the Spanish Armada)	20,000	
	1703, 6th/7th December	Gale, south	8,125	
	1976, 2nd–4th January	Capella gale	24	200
	1987, 15th/16th October	Gale 87J, south	13	1,600
	1990, January–March	Winter storms	85	4,100
	1991, 5th/6th January	Winter storm Undine	30	700
	1997, 23rd–25th December	Winter storm Yuma	7	230
	1998, 1st–5th January	Winter storms	15	470
	1998, 24th October	Winter storm Winnie	3	250
	1998, 26th/27th December	Winter storm Silke	5	170
Italy	1973, 26th October	Gale, Palermo		170
	2001, 17th/18th July	Severe storm, tornado		200
Luxembourg	1990, January–March	Winter storms		300
Netherlands	1281, January	Storm surge, Zuidersee	80,000	
	1421, November	Storm surge	100,000	
	1953, January/February	Storm surge	1,932	6,450
	1990, January–March	Winter storms	21	1,500
Poland	1928, 6th July	Tornado, Warsaw	82	
Switzerland	1990, January-March	Winter storms	4	160
	1999, 26th December	Winter storm Lothar	12	1,500
Europe	1976, 2nd–4th January	Capella gale	82	1,600
	1987, 15th/16th October	Gale 87J	17	3,000
	1990, January–March	Winter storms	272	12,800
	1999, December	Winter storms	>150	18,500

As at November 2001. Hail events are not included. Loss figures in original values, converted into €.
Source: Munich Re NatCat*SERVICE*.

5.3 Methods of estimating market loss potentials

Looking back into the meteorological past is one of the main bases for defining windstorm scenarios for the purpose of estimating accumulation losses in Europe. This information is not complete, however, and does not permit any conclusions as to the effect of changing climatic conditions on the windstorm hazard in the future. In this study we adopted two approaches in order to estimate market windstorm accumulation potentials and their probabilities in individual countries and for Europe as a whole:

1. We carried out a statistical analysis of historical windstorm losses and
2. evaluated past meteorological data and extrapolated wind fields (wind speeds, geographical size) assuming a medium-term and long-term change in the windstorm hazard in Europe on the basis of new climatological models.

ad 1. Distributions of loss amounts
In principle all continuous distributions may be used for this. In the case of frequent but minor losses, exponential distributions have proven to be a suitable means of representing loss amount distributions. In the case of exponential distributions, however, the probabilities given to medium and relatively large losses tend to be too low and consequently the return periods are too long. Better estimates of rare large loss events are produced by the so-called Burr distribution or – as a special form – a generalized Pareto distribution.

The Burr distribution has the following distribution function:

$$F(x) = 1 - \left(1 + \left(\frac{x}{x_0}\right)^{\tau}\right)^{-\alpha} \qquad \text{für } x>0,\ x_0>0,\ \alpha>0,\ \tau>0$$

The resulting density function is as follows:

$$f(x) = \frac{\alpha\tau \left(\frac{x}{x_0}\right)^{\tau}}{x\left(1 + \left(\frac{x}{x_0}\right)^{\tau}\right)^{\alpha+1}} \qquad \text{für } x>0,\ x_0>0,\ \alpha>0,\ \tau>0$$

A Pareto distribution is a Burr distribution using π=1 and $x-x_0$ instead of x. Before adjusting, threshold values must be chosen to be the upper and lower limits of the adjustment. The maximum value of the distribution is defined by the highest simulated market loss from the selected windstorm scenarios.

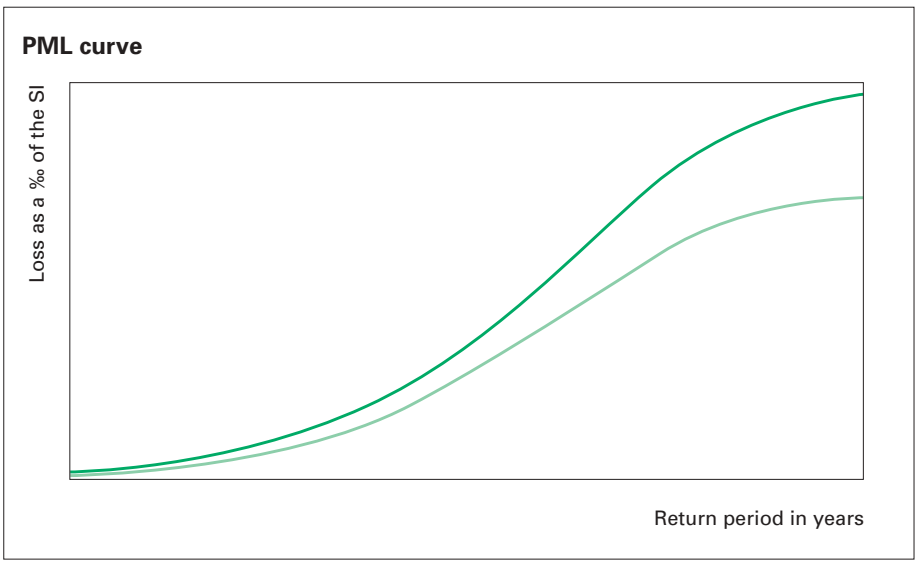
ad 2. Wind fields and windstorm scenarios
The wind fields of historical windstorms over Europe have not been recorded systematically or analysed by meteorological research institutes or meteorological services. Since the wind speed data from many weather stations is based on relatively short time series (mostly only for the past 30–50 years), the reconstruction of earlier windstorms requires the synopsis of data from other sources including recordings of atmospheric pressure and reports on the damage caused. On account of the many different processing steps that need to be taken before the production of the wind fields, the results of these reconstructions always bear the individual handwriting of the respective scientists (or groups of scientists). The development of Munich Re's Europe windstorm model is based on the following method being applied in the definition of windstorm scenarios:
– the analysis of historical wind speeds at up to 1,400 meteorological stations in Europe,
– the analysis of studies on windstorm catastrophes of recent centuries, and
– the extrapolation of the future windstorm hazard on the basis of historical data assuming a medium-term and long-term change in the wind climate as a result of global warming.

Potential increase in the windstorm hazard in Europe and possible effects on loss potentials

It is not yet possible to carry out a scientifically sound quantification of the expected increase in severe wind events over Europe using climatalogical models (cf. Special topic 2: "Climate change – Is the windstorm risk changing too?"). We therefore had to find an approach of our own that reflects our own loss experience. This involved

– adjusting our wind field scenarios based on empirical data by means of a loading on the highest expected wind speeds, which leads to higher simulated maximum losses and hence to higher threshold values in the adjustment, and
– modifying the average annual frequency of loss events (loss frequency) based on observations of the past.

The following graph shows the effects of the changed adjustment parameters on a selected PML curve. The maximum wind speed was raised by 10% and the loss frequency by 50%.



Standard distribution of loss amounts

Distribution of loss amounts assuming increased maximum wind speeds (+10%) and loss frequency (+50%)

5.4 Windstorm scenarios – Examples of wind fields with a loss return period of 100 years

Based on the market loss estimates (cf. table on page 55) and the analysis of historical wind fields of recent decades in these countries, windstorm scenarios with various occurrence probabilities were developed for each of the stated regions.

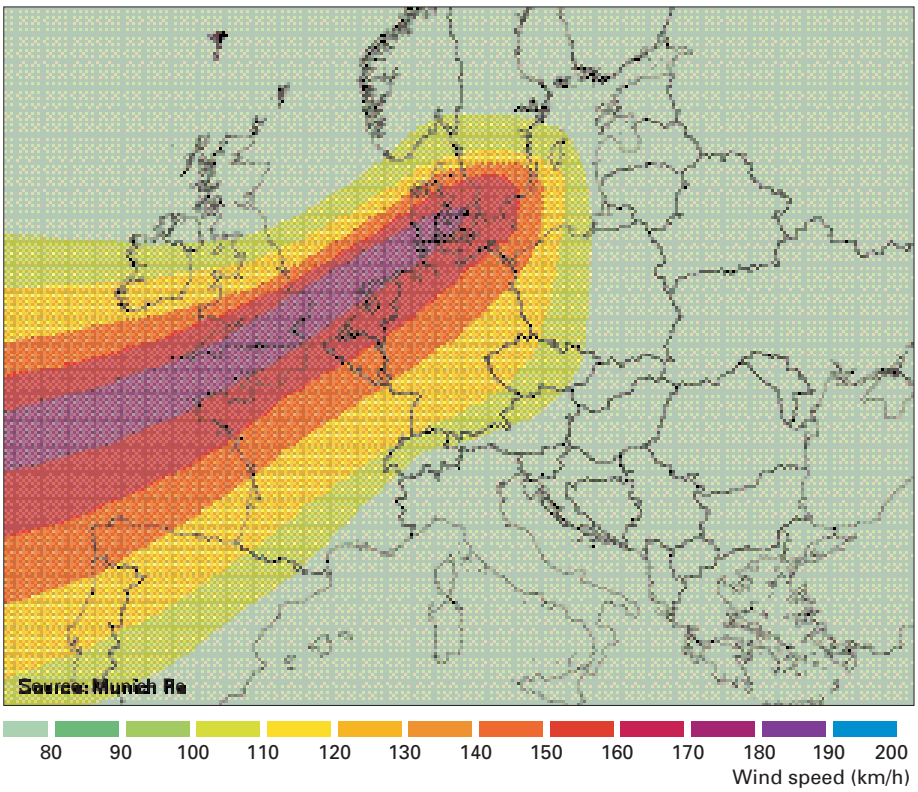
The wind field scenarios determined in this way may serve as an indication for considering the aspect of accumulation. A single countrywide windstorm scenario can never represent a maximum event for all possible geographical exposure distributions. A windstorm scenario conceived for a whole country may, given unfavourable circumstances, fail to estimate the maximum loss for a portfolio with a regional bias. A company writing business throughout a country should, on the other hand, be able to use a countrywide scenario to calculate the possible loss accumulation.

In the following a selected windstorm scenario is shown per region for a return period of approx. 100 years.

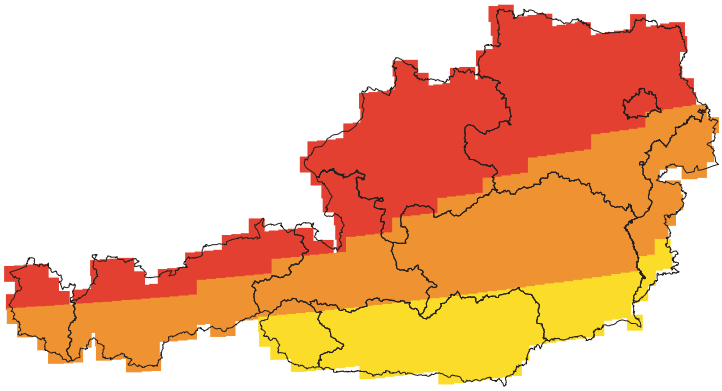
It should be noted that the loss events on which this is based are derived from a relatively narrow time window. The derived occurrence probabilities of wind field scenarios can therefore only provide a rough approximation of the loss to be expected.

The “Super Daria” scenario is based on the analysis of historical wind fields over Europe. Its track is modelled on that of Daria. The wind field determined for the “Super Daria” scenario should produce an accumulation loss of the stated return period for an insurer writing business throughout Europe. For an insurer whose activities are limited to a single country, however, the wind field scenario may under certain circumstances not be suitable for accumulation estimates.

"Super Daria" gale
The wind field of a possible gale scenario.

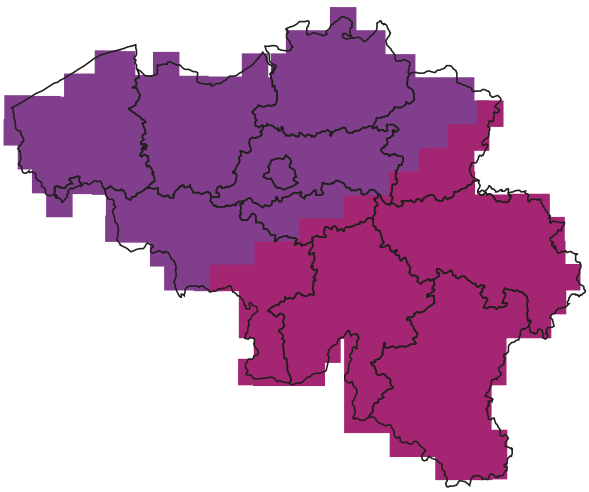


Windstorm scenario for Austria
with a return period of 100 years.

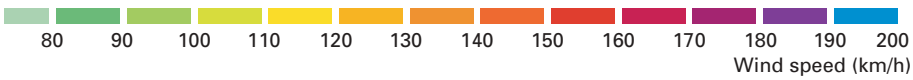


Source: Munich Re

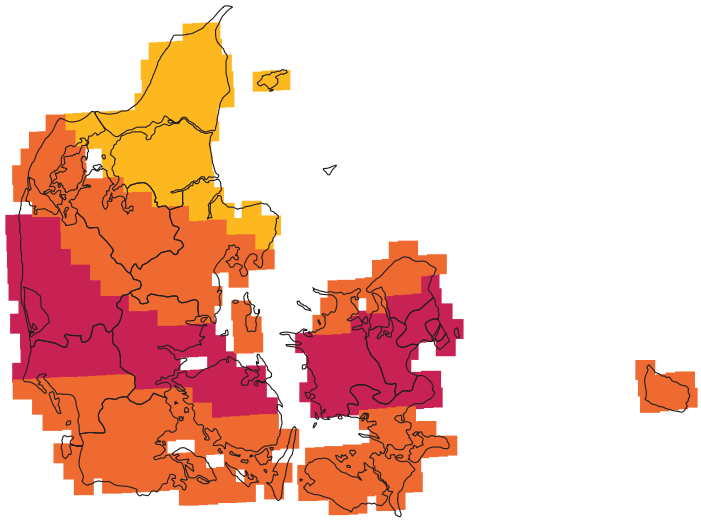
Windstorm scenario for Belgium
with a return period of 100 years.



Source: Munich Re

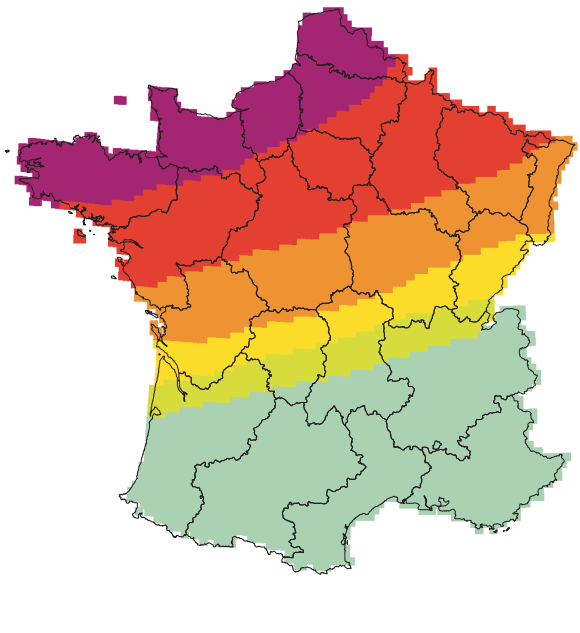


Windstorm scenario for Denmark
with a return period of 100 years.



Source: Munich Re.

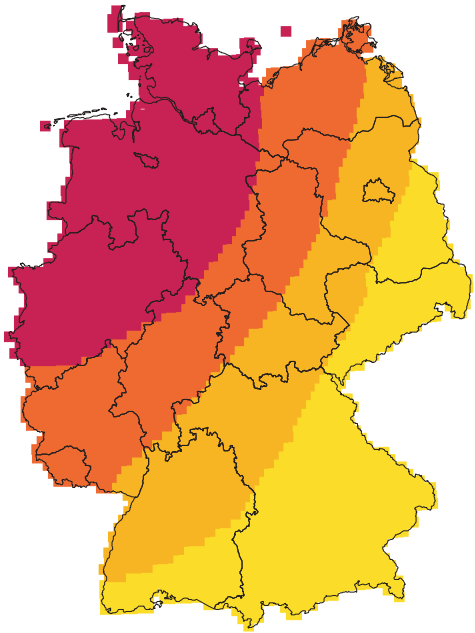
Windstorm scenario for France
with a return period of 100 years.



Source: Munich Re.

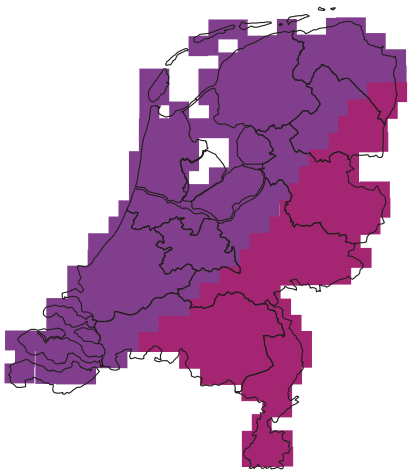
80 90 100 110 120 130 140 150 160 170 180 190 200
Wind speed (km/h)

Windstorm scenario for Germany
with a return period of 100 years.



Source: Munich Re.

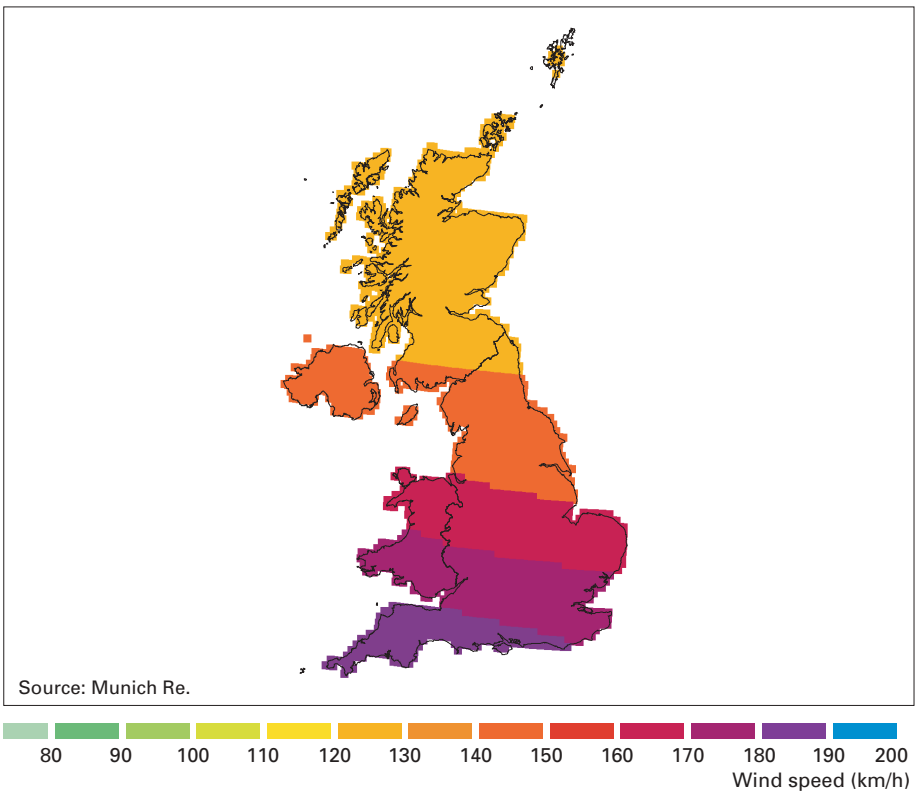
Windstorm scenario for the Netherlands
with a return period of 100 years.



Source: Munich Re.

80 90 100 110 120 130 140 150 160 170 180 190 200
Wind speed (km/h)

Windstorm scenario for the United Kingdom
with a return period of 100 years.



Special topic 1: The frequency of windstorms in Europe

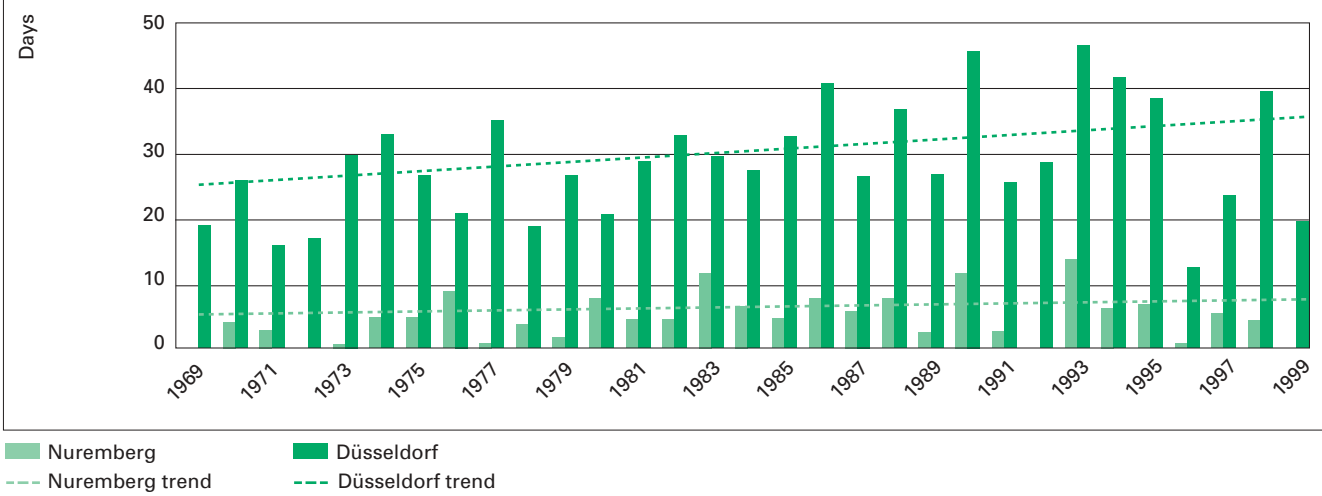
Unlike the strength of earthquakes (release of energy), which may be defined using a single physical parameter (magnitude), the "strength" of winter storms can only be defined using auxiliary parameters like maximum (local) wind speeds, central pressure, windstorm duration, and the geographical expanse of the storm field. As the recording of these parameters in the past has been incomplete and of very irregular quality, the informational value of nearly every time series of windstorms in Europe is limited.

The fact that these analyses are limited to known historical extreme events also means that, when estimating the return periods of severe windstorms, there are uncertainties in the results due to the lack of a definition of such events – and hence to the question of how complete the corresponding windstorm catalogues really are.

Individual events like Anatol, Lothar, and Martin do not allow any conclusions to be drawn as to the future frequency and expanse of heavy gales in Europe either, even if record wind speeds are measured.

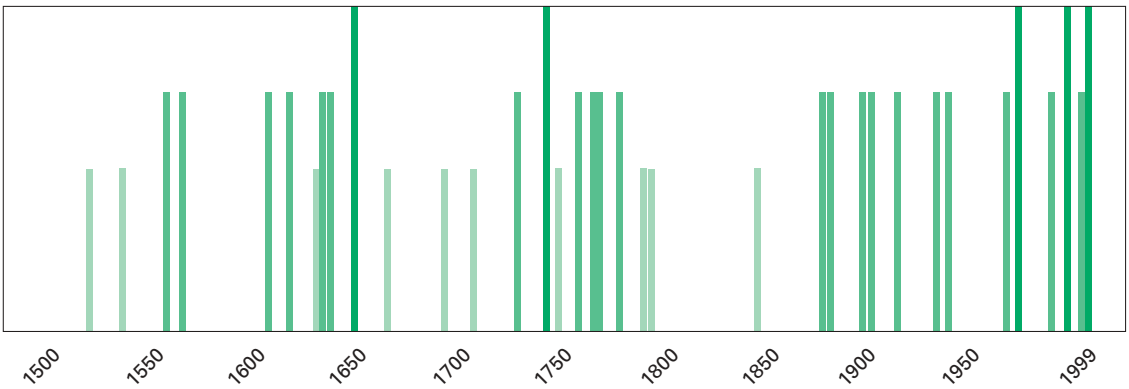
Computer climate models still produce rather inconsistent simulation results in the forecasting of complex extreme events like winter storms. The results of more recent calculations increasingly point to a rise in the frequency of strong low-pressure systems in central Europe (see also Special topic 2: "Climate change – Is the windstorm risk changing too?").

Number of days with winds of at least Beaufort 8 in Nuremberg and Düsseldorf
1969–1999



Source: Deutscher Wetterdienst, 2000.

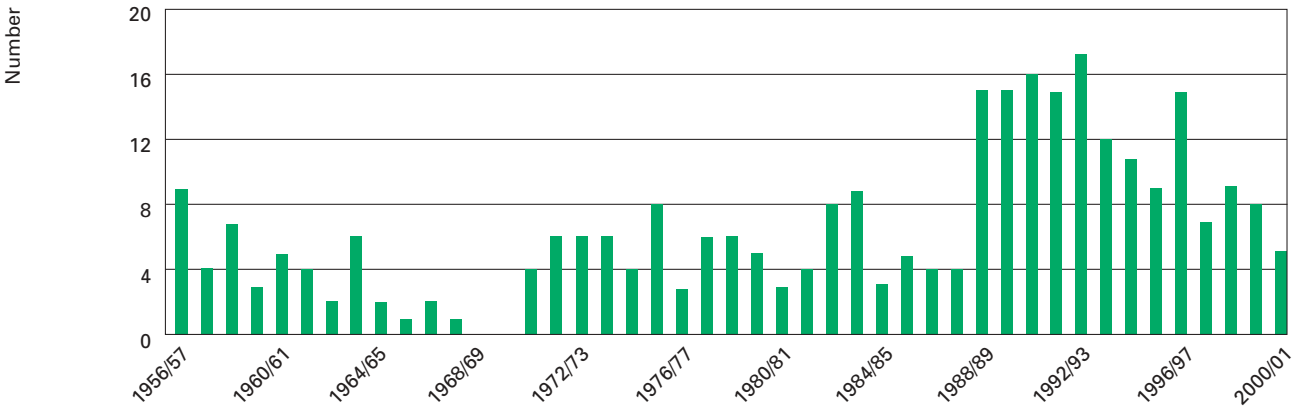
Frequency of heavy and extreme winter storms in Switzerland
1500–1999



unverified storms heavy storms extreme storms (Varying bar heights for better differentiation)

Source: Pfister, 1999; amended from WSL, 2001.

Development of intense lows (<950 hPa) over the North Atlantic and Europe
1956/57–2000/01



Source: Deutscher Wetterdienst, 2001.

Conclusion:
The above graphs suggest that there has been an unfavourable change in the wind climate in past decades and centuries – at least in parts of Europe.
As explained at the beginning, these time series are to be observed critically. They do not present an unconditionally verified basis for the extrapolation of the frequencies and intensities of winter storms to be expected in the future. But even if it is not yet possible to make quantitative statements on the development of windstorm activity, there are mounting indications of an increasing windstorm hazard in Europe. If risk carriers act responsibly, they will take these indications seriously and account for them in their considerations.

Special topic 2: Climate change – Is the windstorm risk changing too?

The effects of climate change on windstorm events in Europe are a matter of controversial discussion, even on scientific committees. Even with the computer models used today, climate modellers and meteorologists are still unable to deliver reliable quantitative estimates, as the birth and course of windstorms are extremely complex, dynamic processes in both spatial and temporal terms. Scientific studies focussing on the effects of climate change in Europe are therefore usually very cautious in what they say. An example of this is given by the EU's comprehensive ACACIA report ("Assessment of Potential Effects and Adaptations for Climate Change in Europe", Brussels 2000). An increase in windstorm frequency is not considered proven but is held to be "possible". The general increase in precipitation volumes in the winter half-year, on the other hand, is deemed scientifically proven. Individual winter storms will consequently be "moister", i.e. rainier, a fact that will influence windstorm losses as a whole and have a significant effect on individual losses.

But even if scientific proof is still lacking in terms of the windstorm risk, we must – in line with the precautionary principle – expect the situation in central Europe to get worse, which means that the frequency and intensity of both winter storms and local windstorms will increase.

In 2001 the Intergovernmental Panel on Climate Change (IPCC), the international team of climatologists set up the United Nations, published its third status report. It predicts that the mean global temperature will increase between 1.4°C and 5.8°C by the end of this century.

As far as windstorm activity is concerned, the following effects are probable:

– The degree of warming in each region of the earth will vary, which means that some regions will be significantly hotter, some will change slightly, and some will even cool down. This will inevitably affect pressure relationships and dynamics in the atmosphere. If the temperature and pressure gradients between the moderate and polar regions increase, the circulation in the atmosphere must be expected to accelerate and there will be an intensification of windstorms. Basically speaking, the greenhouse effect is increasing the input of energy into the global atmospheric "heat engine", which will "shift into top gear" as a result.

– In cold winters with large amounts of snow a cold and rigid mass of air forms over central and eastern parts of Europe. Meteorologists speak of a "blocking" high-pressure system, as this air mass blocks west-to-east streams. Consequently the low-pressure vortices coming in from the North Atlantic are generally diverted north or south before they reach western and central parts of Europe. However, in the milder winters that are to be expected – according to ACACIA the number of so-called "cold winters" (the coldest of ten winters in the climate period from 1961 to 1990) will gradually decrease in the period up to 2020 – this cold high-pressure system will become weaker on account of the lack of snow cover. Fewer winter storms will therefore be forced to veer towards Scandinavia or into the Mediterranean region. They will be able to

penetrate deeper into the continent and hence hit the countries in central Europe harder. Recent climate models support the supposition that the areas with the highest windstorm activity over the North Atlantic will gradually shift eastwards, which means closer to the west coast of Europe.

– Global warming leads to an intensification of convection processes in the atmosphere. Also, the number of lightning strokes increases steeply in a warmer atmosphere, a phenomenon with which we are familiar in the Tropics, for instance. Our investigations in Germany show that the number of lightning strokes increases exponentially with the temperature of the atmosphere. As a rule, for example, about 20,000 lightning strokes are registered in months with an average temperature of 15°C, whereas more than 150,000 strokes must be expected at an average of 20°C. In a warmer atmosphere, therefore, more frequent and more intensive thunderstorms and severe storms with hailfall are to be expected.

– In many countries of southern Europe, but also in central parts of Europe, prolonged periods of heat and drought must be expected in the summer months. During or after heat waves, however, it is not unusual for there to be particularly large and devastating storms (e.g. intense precipitation events or storm and hail fronts) capable of causing losses regionally of several hundred million euros, as numerous severe storms in the past years have vividly demonstrated. Here are just a few selected examples from Austria and Germany in the period 2000/2001:
  - 3rd/4th July 2000 – hailstorm: Austria (Tyrol, Salzburg, Styria); economic loss: > €100m; insured loss: €90m
  - 6th/7th July 2001 – severe storm: Germany (Saarbrücken, Baden-Württemberg, Bavaria, Saxony); economic loss: €350m; insured loss: probably > €200m
  - 3rd August 2001 – hailstorm: Germany (Bavaria); economic loss: €750m; insured loss: probably > €500m.

It would certainly be exaggerating to develop horror scenarios for Europe as a result of climate change, of which there are now clear signs. On the whole, however, there is no doubt that in a warmer climate it will be necessary to expect much more frequent and more intensive windstorm and severe storm events.

Terminology, abbreviations

ACACIA	Assessment of Potential Effects and Adaptations for Climate Change in Europe; study by the European Union on the effects of climate change in Europe
AStB	General windstorm insurance terms and conditions for commercial business in Germany
Average loss	Key figure in loss statistics Calculation: relationship between overall loss and the number of policies affected by losses (as a function of wind speed)
Beaufort-Scale	(12-stage) scale developed by Admiral Beaufort in 1805 for estimating wind force and wind speed
CRESTA	Catastrophe Risks Evaluating and Standardizing Target Accumulations (system for recording and controlling accumulated exposures)
Deductible	The amount of an insured loss carried by the policyholder
DWD	Deutscher Wetterdienst (German meteorological service)
IPCC	Intergovernmental Panel on Climate Change; set up by the United Nations to carry out research on global climate change
Loss frequency	Key figure in loss statistics Calculation: relationship between the number of policies/risks affected by losses and the total number of policies/risks (as a function of wind speed)
Loss ratio	Key figure in loss statistics Calculation: relationship between loss and sum insured (as a function of wind speed)
PML	Probable maximum loss (not the same as “worst case”)
Portfolio	All the objects covered by an insurance company (also called “risks”)
SMA	MeteoSwiss (Swiss meteorological institute)
SI	Sum insured
UTC	Universal Time Coordinated (world time, previously Greenwich Mean Time)
VGV	Homeowners insurance in Germany
VHV	Household insurance in Germany
Vulnerability	The susceptibility of a system (structure, facility, state, enterprise, etc.) to damage by outside effects
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research

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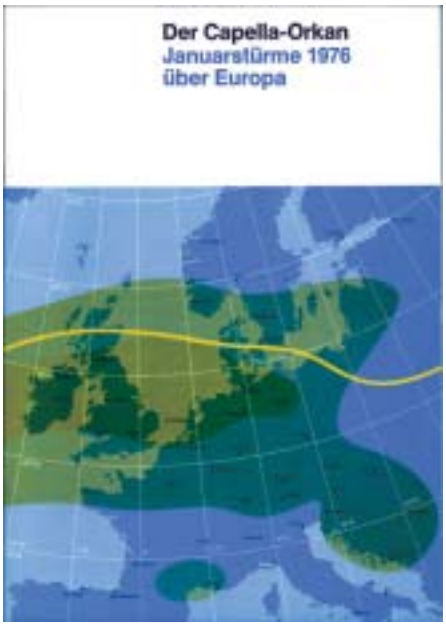

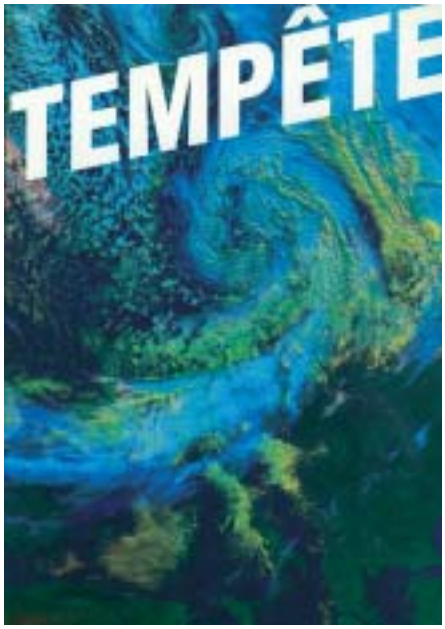

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