Journal of Meteorology Manuscript No. _______________

Severe local storms and the insurance industry

Impacts of the RPI workshop: Tornadoes and Hail, Bermuda, November 2000

By Nikolai Dotzek

DLR–Institut für Physik der Atmosphäre,

Oberpfaffenhofen, D–82234 Wessling, Germany

Received

Corresponding author's address:

Dr. N. Dotzek

DLR–Institut für Physik der Atmosphäre,

Oberpfaffenhofen, D–82234 Wessling, Germany.

eMail: nikolai.dotzek@dlr.de,

Tel: +49–8153–28–1845, Fax: +49–8153–28–1841.

Submitted to *J. Meteor.*

Severe local storms and the insurance industry

Impacts of the RPI workshop: Tornadoes and Hail, Bermuda, November 2000

By Nikolai Dotzek

DLR–Institut für Physik der Atmosphäre,
Oberpfaffenhofen, D–82234 Wessling, Germany
eMail: nikolai.dotzek@dlr.de

Received

Abstract

Relevant topics of a workshop on "Tornadoes and Hail" initiated by the insurance industry are outlined with special emphasis on European severe local storm research. Points of immediate interest for Europe comprise an improved climatology and damage analysis of these storms, both on European and regional scales. Deriving tornado or downburst intensity from post–storm wind damage assessment still presents a challenge. Contemporary concepts suffer from oversimplification while recently proposed new procedures have not yet proven their applicability. Aside from these technical points, data quality control and dissemination of results are important future tasks to educate scientists, insurers, and policy makers about the true tornado threat in Europe.

Keywords: Tornado; Climatology; Intensity; Insurance Industry; Europe

1 Introduction

Tornadoes and hailstorms present a violent threat to society even in Central Europe where their annual total number is smaller than in the United States' tornado belt. To improve knowledge of these storms in the United Kingdom the first private tornado and storm research organisation (TORRO, www.torro.org.uk) was founded in 1974 and later developed its own tornado intensity scale (Meaden, 1976). This

TORRO or T scale is nearly identical to the F scale (Fujita & Pearson, 1973; Fujita, 1981), but comprises twice as many intensity classes — what makes the T scale in principle more attractive to insurance companies performing post–storm damage analyses in densely populated regions. During the last decade of the 20th century, in other European countries similar research groups and networks developed like, for instance, the severe local storms research network TorDACH in Germany, Austria, and Switzerland (cf. www.tordach.org for a list of links to these groups).

More evidence of newly thriving severe local storm research in Europe was the 1st European Conference on Tornadoes and Severe Storms ETSS 2000 in Toulouse, France (www.eurotornado.ou.edu, proceedings were edited by Snow & Dessens (2001) and a summary was given by Elsom (2000) in this journal). This conference brought together many scientists from all over Europe and the US and turned out to be a great success, both scientifically and in raising public awareness of the importance of severe local storm phenomena. Consequently, preparatory work for the 2nd European Conference on Severe Storms ECSS 2002 in Prague, Czech Republic (www.chmi.cz/ECSS2002) is now under way.

Parallel to and independent of the development in Europe, in order to enhance information exchange between scientists and the reinsurance industry the Risk Prediction Initiative (RPI, www.bbsr.edu/rpi) was founded at the Bermuda Biological Station for Research (BBSR, www.bbsr.edu) in the early 1990s. Bermuda was chosen because many reinsurers have moved there in recent years. Due to its geographical position RPI's primary interest is hurricane research which has been the subject of a number of RPI workshops in the past. However, triggered by the severe tornado outbreak of 3 May 1999 in Oklahoma City, RPI sponsors now demanded a workshop on insurance risks due to severe thunderstorms: tornadoes and hail. Being aware of the ETSS conference in Toulouse and the growing momentum of European severe local storm research, RPI also requested detailed information on tornadoes in Europe. The successful two–day event held in Hamilton, Bermuda was worthwhile both for scientists and insurers — and the 2001 hail season in the United States substantiated the urgency of this workshop.

This paper summarizes the main topics of the RPI workshop in Sec. 2. In Sec. 3 a brief overview on key tornado research topics in Europe following the Bermuda workshop is given based on our current knowledge of severe local storms in Europe. Sec. 4 presents the conclusions.

2 Workshop summary

2.1 Tornadoes

The session on tornadoes was opened by two speakers from the University of Oklahoma, Norman: *Howard Bluestein* gave an overview on the state of the art in research on dynamics of tornadoes and their parent thunderstorm cells, before *Joshua Wurman* presented his highly–resolved Doppler radar field measurements of tornado funnels. After that, *David Imy* (Storm Prediction Center SPC, Norman) reviewed current predictive skill in potentially tornadic synoptic situations: the devastating severe local storms of 3 May 1999 in Oklahoma City served as an impressive example. All these three presentations mainly helped to improve the insurers' knowledge on tornadoes.

Topics more directly relevant to the insurance industry were covered in the following talks by two presenters from NOAA's National Severe Storms Laboratory NSSL, Norman: *Charles Doswell* addressed peculiarities in climatological data of extreme events like tornadoes which have to be considered in interpreting the data. This affects both real climatological variations on the regional scale (e. g. orogenic effects) and statistical artifacts like varying reporting frequency as a function of time, tornado intensity and population density. In this context, *Harold Brooks*' talk added more details concerning evolution and representativeness of tornado climatologies in the USA compared to other countries. Some aspects of these two presentations are also treated by Brooks & Doswell (2001). Most remarkably is an apparent universality of tornado intensity distributions worldwide: the only significant difference between, for instance, the USA and Europe appears to be the total number of events per year, while statistical properties of the distributions seem to be nearly identical.

Data gathered and published within Europe (e. g. Meaden, 1976; Elsom & Meaden, 1982; Reynolds, 1999a; Dotzek, 2001; Holzer, 2001; Paul, 2001) were described by *Nikolai Dotzek* (Deutsches Zentrum für Luft- und Raumfahrt DLR, Oberpfaffenhofen) in more detail. During the last years a meaningful image of servere local storm climatology in many European countries has been obtained. What's more, an increasing number of well–documented case studies is now at hand. Following this presentation, methods and concepts to reliably reconstruct tornado funnel windspeeds from observed damage and improved damage statistics were addressed by *Michael Riley* (National Institute of Standards and Technology, Gaithersburg) in his talk on the relation of windspeed and wind damage. Aside from the influence of structural building quality on the degree of damage also other factors play a role, like for instance impact time of the tornado vortex on a given spot, amount and composition of flying debris and the strength of peak wind gusts compared to mean windspeed. While it is a well–known fact that both Fujita and TORRO intensity scales alone do not suffice to characterize the full complexity of tornado vortex windfields at the ground, there are only preliminary concepts for an improved intensity description available at this time (e. g. Fujita, 1992; Dotzek et al., 2000; Hubrig, 2001).

A method for long–term forecasts of tornado activity in the USA was presented by *Mark Bove* (American Reinsurance Company, beforehand Florida State University) by taking into account El Niño / Southern Oscillation effects. In general one can expect a degradation of tornado activity in Texas and the southern Great Plains during El Niño–years. In La Niña–years, on the other hand, more and also more devastating tornadoes are likely to be observed. Statements like these are of course interesting from an insurer's point of view, but significance of this statistical analysis was subject to lively discussions. Concerning such a concept, definitely longer time series of reliable tornado data are necessary to either verify or falsify its applicability.

2.2 Hail

Similar to the tornado session, the session on hail on the second day of the workshop also started with a detailed introduction to the field. *Charles Knight* (National Center for Atmospheric Research NCAR, Boulder) reviewed cloud microphysical processes relevant to hail formation. Most impressive were numerous shown cross sections through large hailstones which allow for reconstruction of hail growth mechanisms. Tumbling motion of large hail which can be detected, for instance, by polarimetric Doppler radar can attain a tumbling frequency of up to 60 Hz and is therefore audible to the human ear. This can serve as an explanation for many severe hailstorm reports from the USA in which before the onset of very large hail at the ground a clearly perceptible dull humming sound was observed. Climatology of hail in the USA was reviewed by *David Chagnon* (Northern Illinois University, DeKalb). Spatial distribution is similar, but not equal to that of tornadic storms. A now available 100–year time series of data allows to detect spatial and temporal trends. These trends which may be persistent for one or even more than one decade can of course heavily bias interpretation of hail suppression experiments usually lasting only a few years.

In situ hail experiments, either concerning hail suppression or fundamental cloud physical studies, were described by *Paul Smith* (South Dakota School of Mines and Technology, Rapid City) in the workshop's last presentation. On a global scale there is a strong coupling of hail–prone areas with orography, and serious physical damage due to hail in many countries has led to a variety of hail suppression strategies: Field programs have been launched in several European countries, such as France, Switzerland, Germany, Spain, Greece, Bulgaria, Yugoslavia, and the former Soviet Union. In some of these countries, operational thunderstorm cloud seeding is still being funded. From a scientific point of view, in most field programs usefulness of hail suppression could neither be verified or falsified convincingly on a climatological time scale.

While the basic scientific assumptions underlying hail prevention by cloud seeding with artificial cloud condensation nuclei are sound, a significant and scientifically rigorous testing of the effectiveness of such methods in the field is hardly possible or even impossible in principle. One and the same thundercloud with its environment cannot be examined twice — with and without cloud seeding. Thus science can usually neither prove efficacy nor inefficacy of such an approach.

Nevertheless, hail suppression programs remain attractive from an insurer's point of view, because even a small permanent reduction of yearly losses by a few per cent would result in major monetary savings at least for reinsurance companies and easily more than compensate the cost of any hail suppression program. In this field there is a highly different view of weather modification benefits between scientists and "users", i. e. claimants and (re)insurers. So triggered by these different viewpoints of science and insurance industry, it is very likely that operational hail suppression methods as well as field programs to evaluate these methods will continue in the future.

3 Issues related to European tornado research

Following the RPI workshop in Bermuda some key for severe local storm research tasks for Europe can be identified. They are based on our current understanding of severe thunderstorms and their climatology as well as on information demands by the public and insurance companies. However, their degree of sophistication is limited by the capability of existing private research networks to perform sustainable and coordinated research work.

3.1 Climatology

Even though tornado reports in Europe date back to the Middle Ages, statistically reliable time series of tornado activity only exist from about 1900 on. The still outstanding monograph by Wegener (1917) on tornadoes in Europe gives a thorough treatment of that time's knowledge. Available data density has further increased dramatically after World War II. However, as public awareness of tornadoes varies through the years in different European countries, time series must be interpreted with great care. Even neighboring countries, such as France and Germany, can have only weakly correlated time series of tornado reports due to the different detection efficiency in each country (Dotzek, 2001; Paul, 2001). Two World Wars, changing national boundaries, and the separation of Western Europe from the Eastern bloc during the Cold War have also hindered data acquisition on severe local storms. Although it is too early to judge intra–European tornadic activity trends due to factors such as a rise in mean global temperature, statistics are now detailed enough to provide an assessment of current tornado threat in Central Europe. The analysis of Reynolds (1999b) likely appeared a few years too early to give a good estimate of total number of tornadoes each year in Europe, but it is not very daring to expect that the ECSS conference in 2002 will provide enough information to give this number.

Most continental European tornado climatologies show strong similarities with the US tornado climatology. Diurnal and annual cycles of tornado activity are coupled to those of thunderstorm formation, i. e. the highest number of tornadoes occurs in the late afternoon hours, and from May to September. Depending on the number of waterspouts in each national record, the month with the most tornado outbreaks will be shifted from July (few waterspouts, e. g. Austria) to August (many waterspouts, e. g. Italy). The fewer winter tornadoes in Europe are mostly coupled to cold frontal thunderstorms within strong storm cyclones from the Atlantic Ocean. In summer, the greatest threat is posed by the so called "Spanish plume" (Morris, 1986), a regional weather pattern that brings hot and moist air from the Mediterranean Sea to Central Europe. Any cold air outbreak from the northwest is then likely to induce intense thunderstorm development often accompanied by damaging hail, downbursts, or tornadoes. This scenario is similar to the meteorological conditions conducive to tornado formation in the US tornado alley during spring and early summer.

Computed with respect to total country area many Central European countries have tornado recurrence densities ranging from 0.1 to above 0.5 tornadoes per year and per 10 000 km^2 — roughly 10 to 20 times less than in the US tornado belt. Typical intensity distributions show an exponential relationship with the Fujita F scale, except for the very weak tornadoes. The situation appears to be similar to US tornado statistics before 1950 when most weak tornadoes were not detected or remained unrecorded. Today US tornado data reproduce an exponential intensity distribution down to F0 intensity; we can expect the same behavior for tornadoes in Europe, as schematically depicted in Fig. 1. Assuming a completely lin–log intensity distribution and taking data from Germany as an example, this shows that today still probably only every third tornado is reported there (Dotzek, 2001). The majority (about 2/3) of tornadoes are weak and only a few per cent are violent, again closely resembling the situation in the United States. So the basic difference between European and US tornadoes appears to be the larger total number of about 1000 per year in the USA. Geographically, tornadoes are more or less homogeneously distributed over the European Plains along the North and Baltic Sea coasts (cf. also Wegener, 1917; Reynolds, 1999b). In hilly and mountainous terrain, however, local terrain forcing becomes increasingly important for tornado formation and can lead to highly variable regional tornado probabilities (Dotzek, 2001). These processes have to be studied in much greater detail than before in Europe. Climatological maps of terrain forcing effects on tornado genesis will be useful both for European insurers and for scientists worldwide.

3.2 Intensity scales

To make tornado intensity estimates comparable from one European country to another (and eventually on a global scale), building strength, population density and land–use (vegetation, soil) characteristics have to be taken into account. This is a well–known fact and has been stressed during the RPI workshop. Reducing available information on strongest wind damage or windspeeds to just one number on the T or F scale results in a big loss of information and can lead to certain ambiguities when individual tornado or downburst events are being compared. Due to this fact different concepts have been developed over the last three decades to overcome the danger of deceptive intensity ratings without losing the advantage of simplicity that conventional T or F scale values offer.

One step in this direction was to include damage path length and width to characterize tornado or downburst intensity (Fujita & Pearson, 1973), but ambiguities concerning building structure or forest vulnerability as a function of tree species and soil type remained. For six structural building classes, Fujita's f scale concept (Fujita, 1992) was designed as an extension of his original F scale. Its matrix–like scheme is depicted in Fig. 2. It offers a simple option to better rate wind damage over residential areas and maintains a single number — the f value — as the output quantity. However, detailed maps of pre–storm building type are necessary to perform a post–storm f scale analysis, and the concept is not applicable over unpopulated areas. Therefore, it has not yet found widespread use.

To circumvent the necessity for maps of building type and yet to more precisely relate wind damage to tornado intensity, Dotzek et al. (2000) recently introduced a revised verbal description of the TORRO and Fujita scales adapted for Central Europe supplemented by typical mean loss ratios $\bar{S}$, cf. Table 1 and Fig. 3:

$$\bar{S} \text{ in } \% \;=\; 100\,\frac{\text{loss occurred in € or US\$}}{\text{reinstatement value in € or US\$}} \quad .$$

The average loss ratio is a commonly available quantity in the insurance industry and can be evaluated by local insurance representatives. Storm intensity could then be inferred from the observed loss ratio for damaged objects, further split into $\bar{S}_{\text{light}}$ for light and $\bar{S}_{\text{strong}}$ for strong buildings in Central Europe. The $\bar{S}$ values have been determined and linked to the adapted verbal description of the TORRO (and, owing to their inherent similarity, also the Fujita) scale of tornado intensity. Wind damage ratings of upcoming years will show the applicability of this method compared to other procedures such as Fujita's f scale concept. Nevertheless the challenge to relate forest damage to storm intensity was only qualitatively addressed in the adapted verbal description of the T scale by Dotzek et al. (2000).

Wind damage to trees is indeed very difficult to relate to windspeeds. Not only does it depend on tree age or species (e. g. deciduous or coniferous, root system characteristics) but also on the soil type, soil moisture and, last but not least, on forestal characteristics (young or old–growth, compact or patchy, healthy or pre–damaged by earlier storms or pests). Methods to include at least some of these effects were developed very recently during several damage case studies from storm cyclones and severe local storms (e. g. Hubrig, 1999). As shown by Hubrig (2001), up to T5 intensity it is possible to find typical distinctions between separate T scale values. From T6, i. e. F3 on hardly any tree will withstand the storm, and only beginning debarking (from T7–8 on) could yield information on strong or violent storms.

A completely convincing solution to the problem of reliably rating tornado and downburst intensity by a simple procedure, however, is not yet at hand and remains an issue for researchers worldwide.

4 Conclusions

From the RPI workshop on “Tornadoes and Hail” the following conclusions concerning severe local storm research in Europe can be drawn:

- Damage from severe local storms cannot be neglected, as it can approach or even exceed one billion € or US$ per event (hail or tornado / downburst),

- Augmented severe local storm climatologies within Europe are necessary to test recent findings on universal characteristics of tornado statistics, and to provide sound estimates of total and regional tornado threat in Europe,

- Intensity reconstruction from damage will continue to be the main source of information on near–surface storm wind fields (“forensic meteorology”). More representative, but nevertheless simple methods have to be developed for a globally applicable intensity scale,

- Data quality control of existing severe local storm databases and unreserved dissemination of results and raw data is vital for further development of European tornado research. Only in this way the necessary complete picture of severe local storm activity all over Europe can be conveyed to scientists, insurers, and policy makers,

- In turn, an enhanced public appreciation of the work performed by private research groups over many years could facilitate consolidation of severe storm research on the European level.

The final goal of contemporary European private research networks should be to establish a professional severe weather research authority in Europe (a “European Severe Storms Laboratory”, ESSL) being the center of competence for analysis, warning, and climatology of severe local storms for the public, weather services, and the insurance industry.

Acknowledgments

I would like to thank Alois Holzer (Austria), Willi Schmid (Switzerland), and François Paul (France) for their substantial contribution of material during preparation of the RPI workshop, and all other "tornado people" in Europe who communicated their findings to me and thereby helped to arrange a broad overview of European tornado research. Links to all these sources as well as continuously updated further information are available online at www.tordach.org.

References

Brooks, H., C. A. Doswell, 2001: Some aspects of the international climatology of tornadoes by damage classification. *Atmos. Res.*, **56**, 191–202.

Dotzek, N., 2001: Tornadoes in Germany. *Atmos. Res.*, **56**, 233–252. [Available at www.tordach.org]

Dotzek, N., G. Berz, E. Rauch, R. E. Peterson, 2000: Die Bedeutung von Johannes P. Letzmanns "Richtlinien zur Erforschung von Tromben, Tornados, Wasserhosen und Kleintromben" für die heutige Tornadoforschung. *Meteor. Zeitschr.*, **9**, 165–174. [Available at www.tordach.org]

Elsom, D. M., 2000: Report on the Conference on European Tornadoes and Severe Storms, Toulouse, February 2000. *J. Meteor.*, **25**, 181–185.

Elsom, D. M., G. T. Meaden, 1982: Tornadoes in the United Kingdom. *Proc. 12th Conf. on Severe Local Storms*, San Antonio, 55–58.

Fujita, T. T., A. D. Pearson, 1973: Results of FPP classification of 1971 and 1972 tornadoes. *Proc. 8th Conf. on Severe Local Storms*, Denver, 142–145.

Fujita, T. T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. *J. Atmos. Sci.*, **38**, 1511–1534.

Fujita, T. T., 1992: *Mystery of Severe Storms*. Univ. Chicago, 298 pp.

Holzer, A. M., 2001: Tornado climatology of Austria. *Atmos. Res.*, **56**, 203–212.

Hubrig, M., 1999: *Dokumentation der Sturmschäden vom 29. 6. 1997 in Niedersachsens Wäldern durch "Schwere lokale Stürme"*. Mitt. d. Niedersächsischen Landesforstverw. **52** I, 4–139.

Hubrig, M., 2001: Tornado- und Downburst–Schadenskala für Holzgewächse basierend auf der Skalierung nach TORRO angepasst für Mitteleuropa (TorDACH). *2nd Forum Katastrophenvorsorge*, Leipzig, 24–26 September 2001.

Meaden, G. T., 1976: Tornadoes in Britain: their intensities and distribution in space and time. *J. Meteor.*, **1**, 242–251.

Morris, R. M., 1986: The Spanish plume — testing the forecaster's nerve. *Meteor. Mag.*, **115**, 349–357.

Paul, F., 2001: A developing inventory of tornadoes in France. *Atmos. Res.*, **56**, 269–280.

Reynolds, D. J., 1999a: A revised tornado climatology of the UK, 1960–1989. *J. Meteor.*, **24**, 290–321.

Reynolds, D. J., 1999b: European tornado climatology, 1960–1989. *J. Meteor.*, **24**, 376–403.

Snow, J. T., J. Dessens (Eds.), 2001: Proceedings of the Conference on European Tornadoes and Severe Storms, Toulouse, February 2000. *Atmos. Res.*, **56**.

Wegener, A., 1917: *Wind- und Wasserhosen in Europa*. Vieweg, Braunschweig, 301 pp.

Tables

Table 1: TORRO and Fujita scales of tornado intensity compiled to an equivalent windspeed v given in $\mathrm{m\,s^{-1}}$ and $\mathrm{km\,h^{-1}}$. The velocity range Δv of each T–scale step and mean loss ratios $\bar{S}_{\mathrm{light}}$ and $\bar{S}_{\mathrm{strong}}$ for Central Europe are also shown (cf. Fig. 3).

					significant							
	weak				strong				violent			
Fujita	F0		F1		F2		F3		F4		F5	
TORRO	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
v in $\mathrm{m\,s^{-1}}$	17 – 25	25 – 33	33 – 42	42 – 51	51 – 61	61 – 71	71 – 82	82 – 93	93 – 105	105 – 117	117 – 130	130 – 143
v in $\mathrm{km\,h^{-1}}$	76 ± 14	104 ± 14	135 ± 16	167 ± 16	202 ± 18	238 ± 18	275 ± 20	315 ± 20	356 ± 22	400 ± 22	445 ± 23	491 ± 23
Δv in $\mathrm{m\,s^{-1}}$	8	8	9	9	10	10	11	11	12	12	13	13
$\bar{S}_{\mathrm{light}}$ in %	0.05	0.10	0.25	0.80	3.0	10.0	30.0	90.0	100	100	100	100
$\bar{S}_{\mathrm{strong}}$ in %	0.01	0.05	0.10	0.25	0.80	3.0	10.0	30.0	60.0	80.0	90.0	95.0

Figure captions

Figure 1: Schematic diagram of most contemporary European tornado intensity distributions (solid, also valid for the USA before 1950) and expected future changes (arrows) to a likely universal lin–log distribution (dashed).

Figure 2: The f scale concept (after Fujita, 1992) modifying the original F scale values (Fujita & Pearson, 1973; Fujita, 1981) according to building strength.

Figure 3: Loss ratios $\bar{S}_{\mathrm{light}}$ (circles) and $\bar{S}_{\mathrm{strong}}$ (squares) from Dotzek et al. (2000) for light and strong outbuildings in Central Europe (cf. Table. 1).

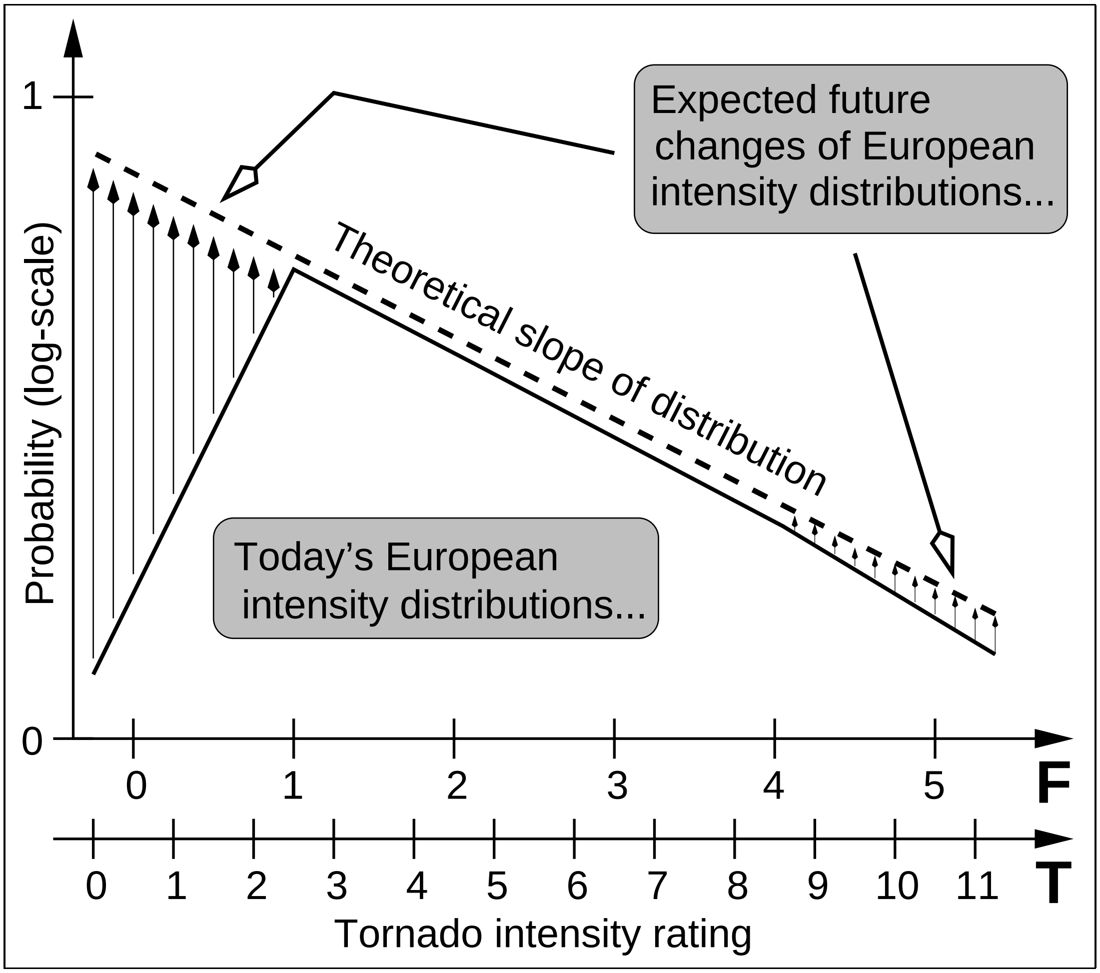
1
0
Probability (log-scale)
Expected future changes of European intensity distributions...
Theoretical slope of distribution
Today's European intensity distributions...
0 1 2 3 4 5 F
0 1 2 3 4 5 6 7 8 9 10 11 T
Tornado intensity rating

Figure 1

Damage: f scale	Little Damage	Minor Damage	Roof Gone	Walls Collapse	Blown Down	Blown Away
	f0	f1	f2	f3	f4	f5

Windspeed: F scale							
	17 m/s	33	51	71	93	117	143
	F0	F1	F2	F3	F4	F5	
	61 km/h	119	184	256	335	421	515

To convert f scale into F scale, add the appropriate number

Weak Outbuilding	-3	f3	f4	f5	f5	f5	f5
Strong Outbuilding	-2	f2	f3	f4	f5	f5	f5
Weak Framehouse	-1	f1	f2	f3	f4	f5	f5
Strong Framehouse	0	F0	F1	F2	F3	F4	F5
Brick Structure	1	-	f0	f1	f2	f3	f4
Concrete Building	2	-	-	f0	f1	f2	f3

Figure 2

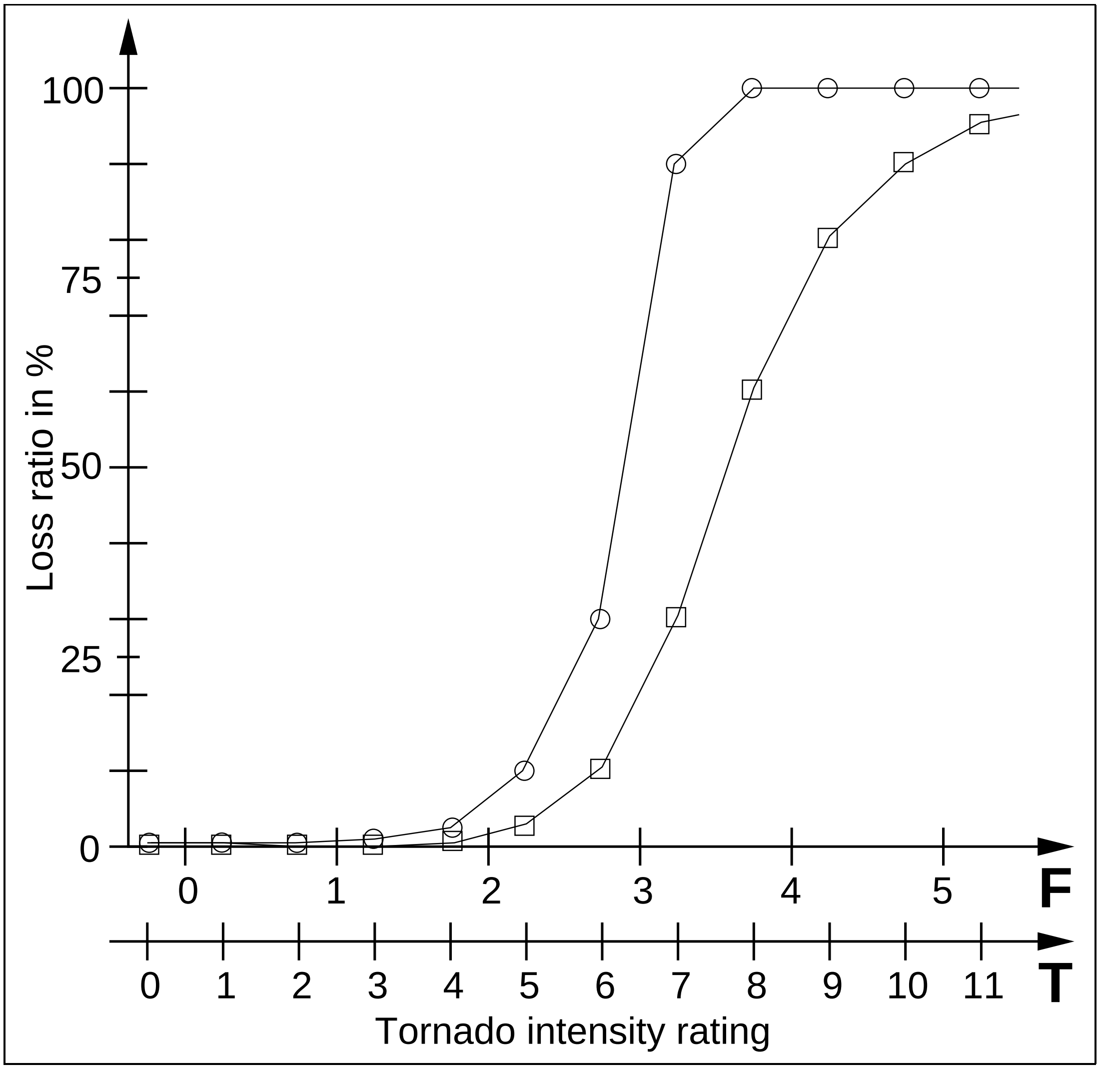
100
75
50
25
0
Loss ratio in %
0
1
2
3
4
5
F
0
1
2
3
4
5
6
7
8
9
10
11
T
Tornado intensity rating

Figure 3