Effect of Climate Change on Reliability and Durability of Constructions

Professor Dan Dubina

European Erasmus Mundus Master Course
Sustainable Constructions under Natural Hazards and Catastrophic Events
UP Timisoara , 2013-2015, 2nd Semester, Course 2C09

Background and Motivation

- The losses from the extreme weather events has more than doubled since 1980
- There is evidence this trend is driven by climate change
- *In 2007, IPCC Report stated that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."*
- Protecting infrastructure and buildings to cope with these threats is a complex challenge

Natural Hazards : Climate Change & Tectonic Effects

(*F.M. Mazzolani COST C 26 Kick –off Meeting, Brussels 2007)*

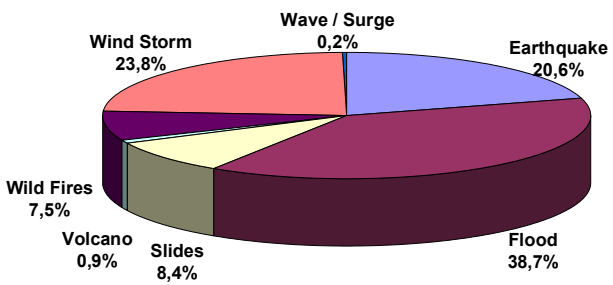
- Flood
- Slides
- Wind Storm
- Wild Fires
- Wave / Surge
- Volcano
- Earthquake

NATURAL DISASTERS
EUROPE

NUMBER OF EVENTS

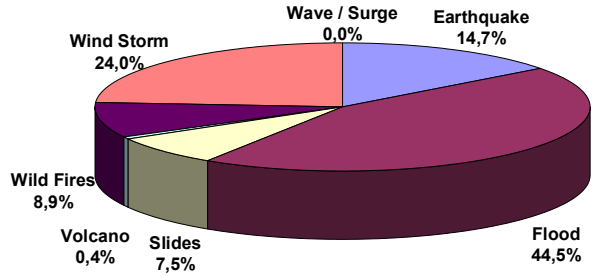
1900-2005

1.125 (100%)



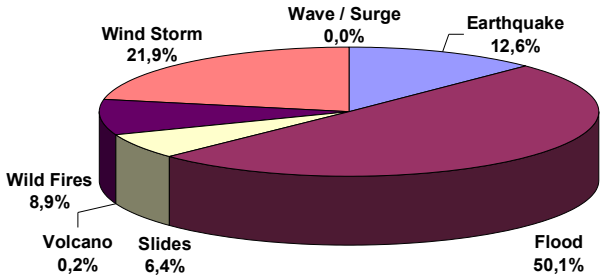
1985-2005

775 (68,9%)



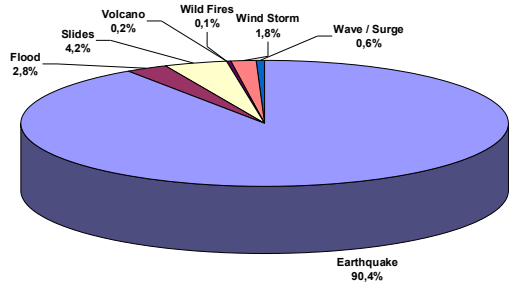
1995-2005

549 (48,9%)

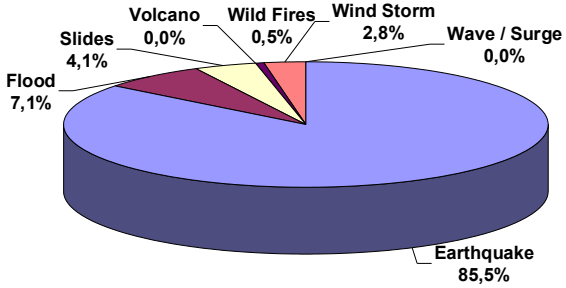


NUMBER OF FATALITIES

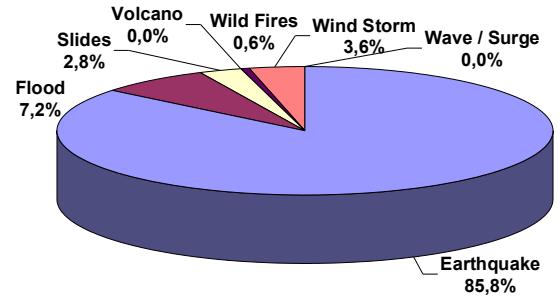
402.890 (100%)



55.168 (13,7%)

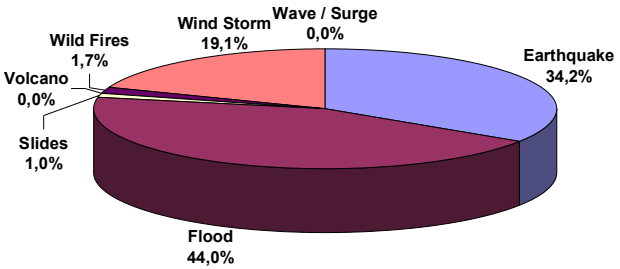


24.210 (6,0%)

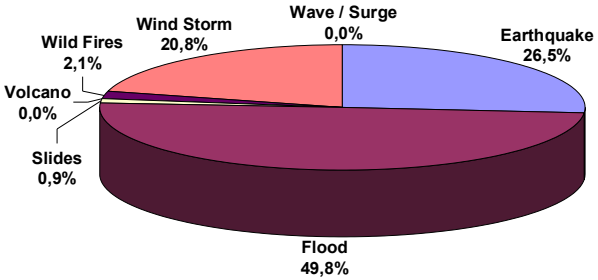


ECONOMIC LOSSES

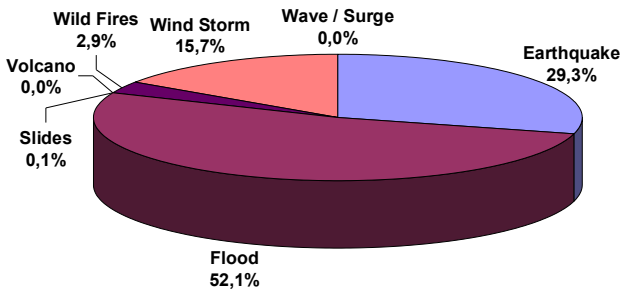
$ 219.171.990.000 (100%)



$ 171.881.290.000 (74,8%)



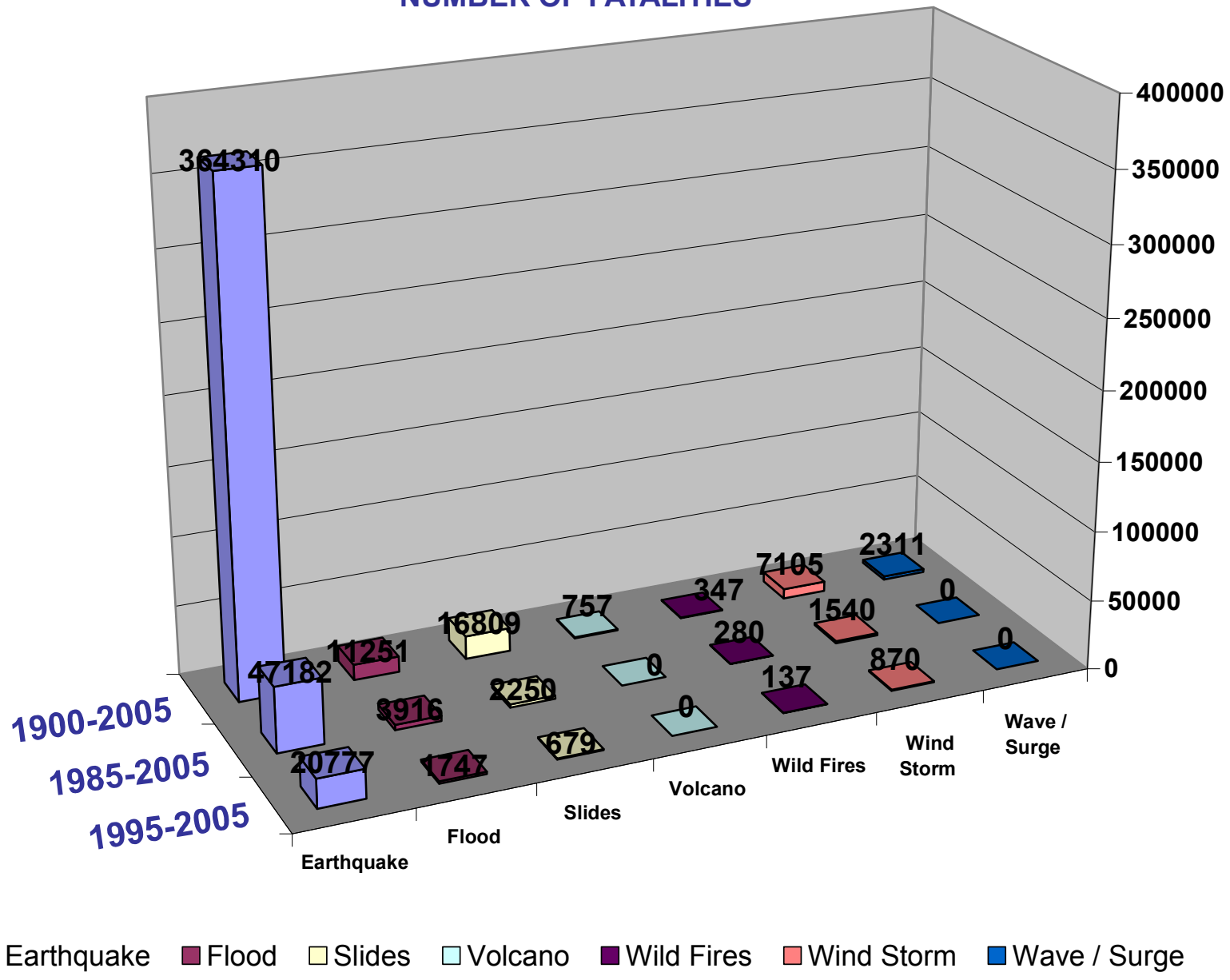
$ 91.822.745.000 (41,9%)



Earthquake Flood Slides Volcano Wild Fires Wind Storm Wave / Surge

NATURAL DISASTERS
EUROPE

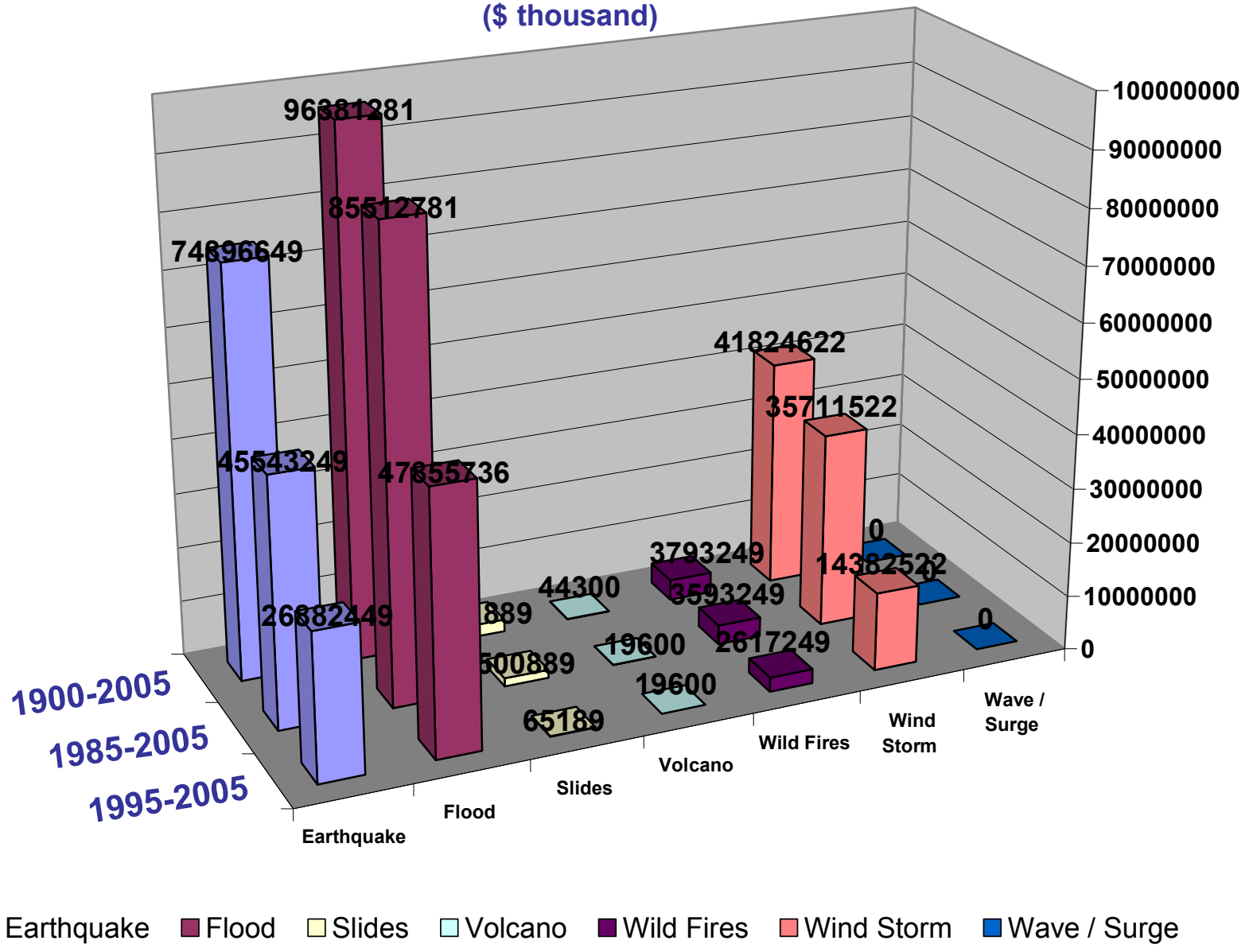
NUMBER OF FATALITIES



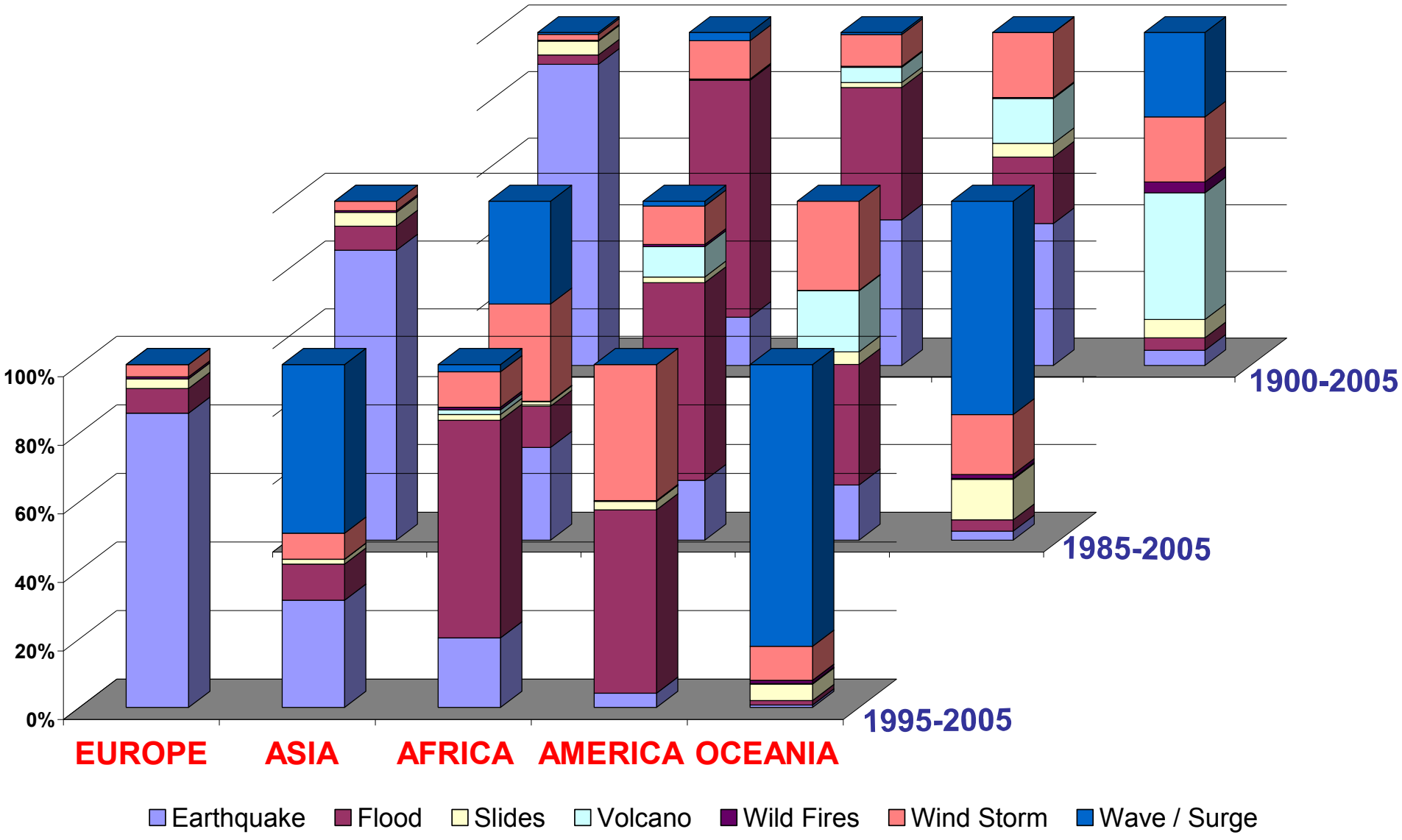
NATURAL DISASTERS
EUROPE

ECONOMIC LOSSES

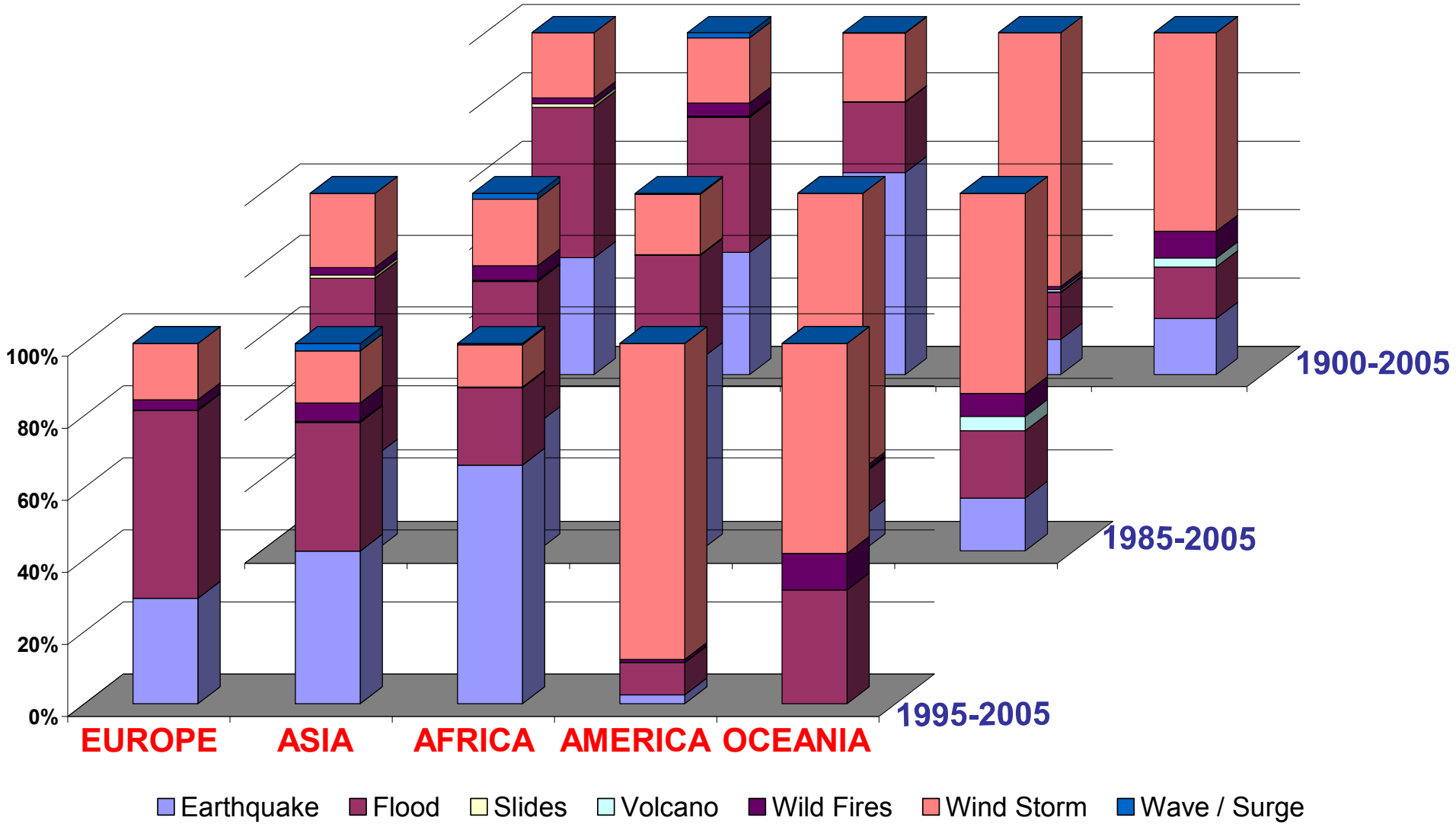
($ thousand)



NATURAL DISASTERS
COMPARISON
FATALITIES



NATURAL DISASTERS
COMPARISON
ECONOMIC LOSSES



NATURAL DISASTERS
EUROPE
1900-2005

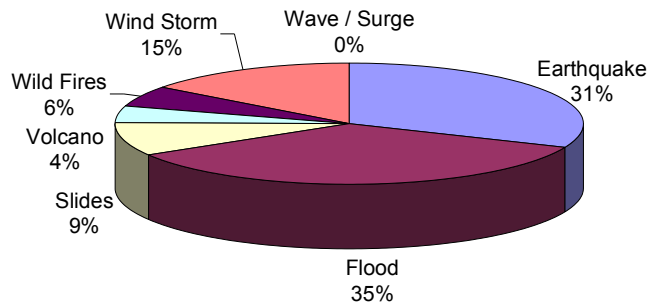
NUMBER OF EVENTS

NUMBER OF FATALITIES

ECONOMIC LOSSES

ITALY

89



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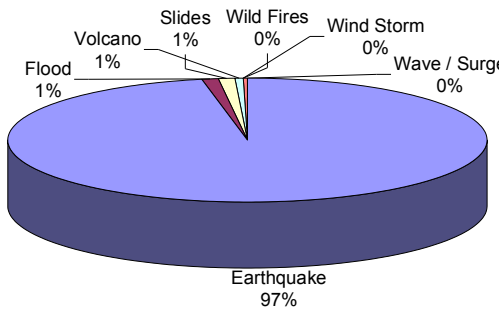
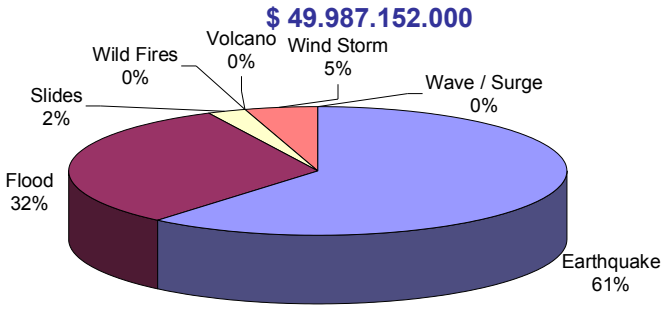
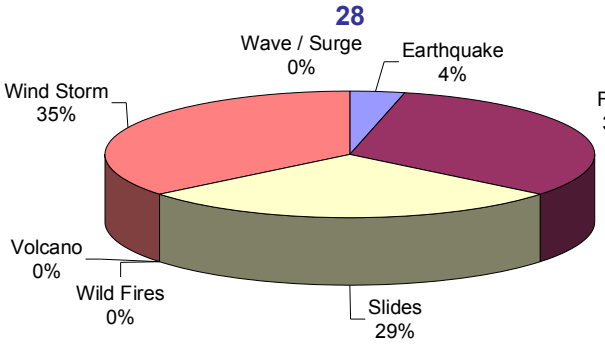


$ 49.987.152.000



AUSTRIA

28



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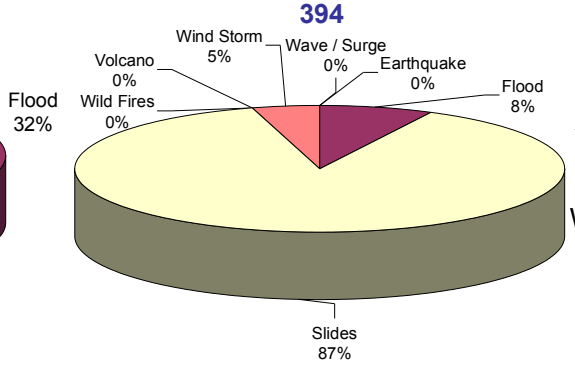
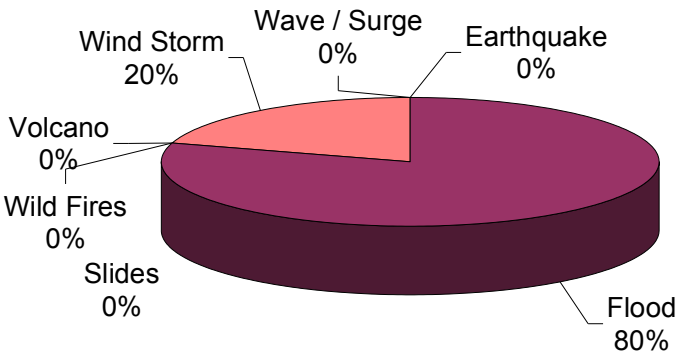


$ 2.668.517.000



BELGIUM

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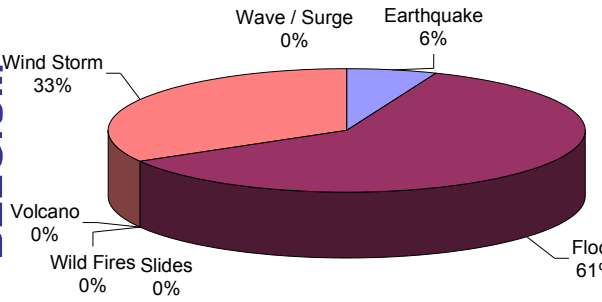

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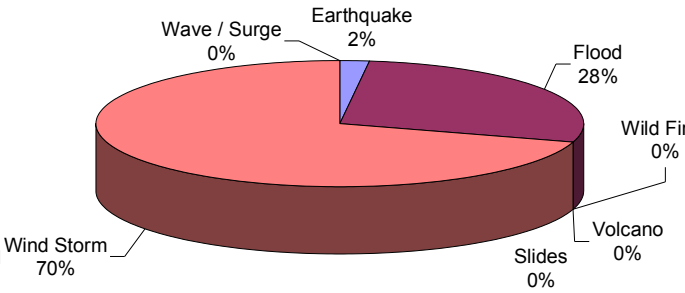
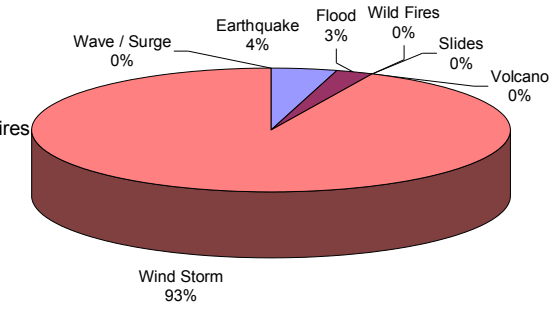
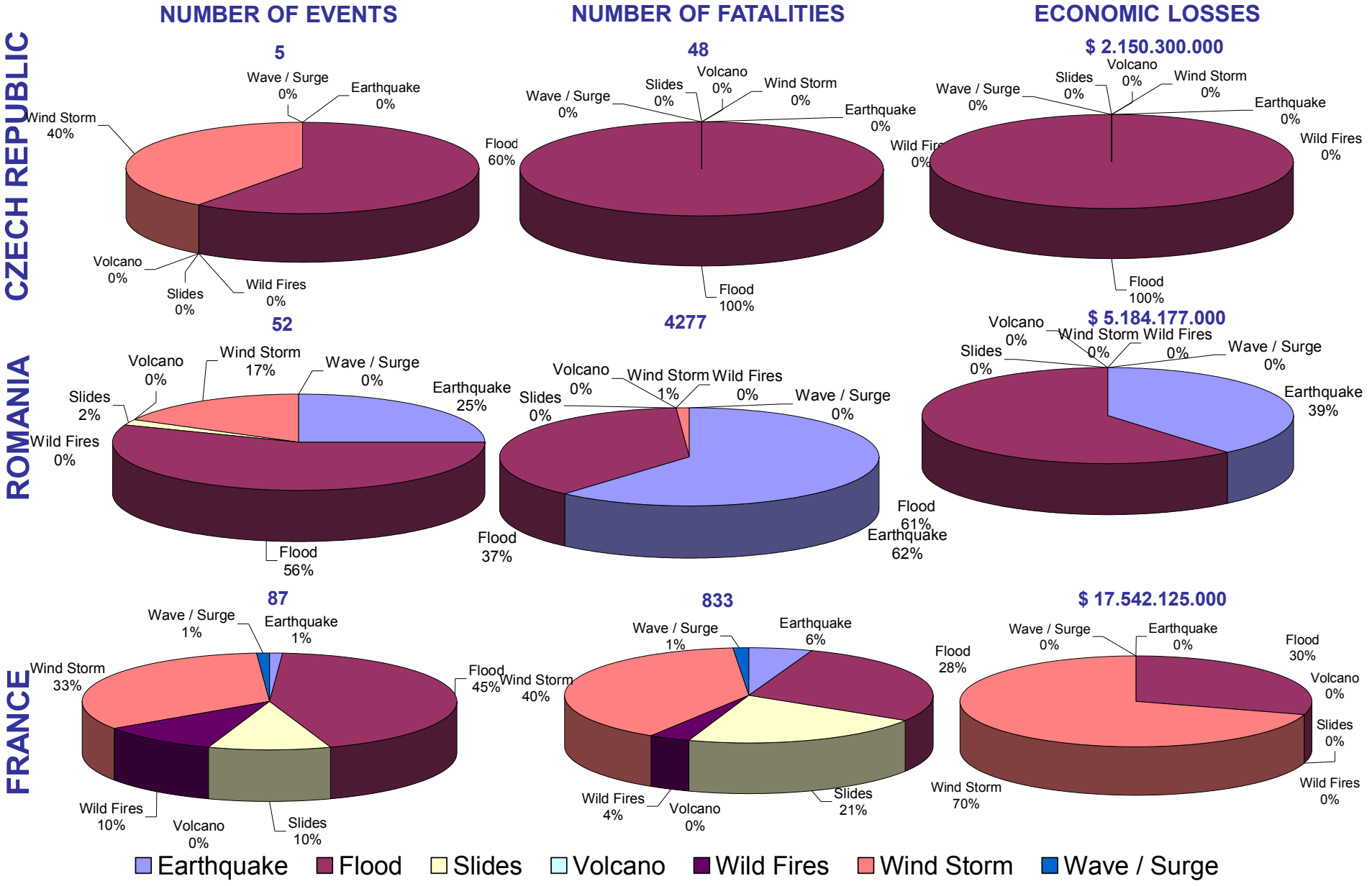


$ 1.117.831.000

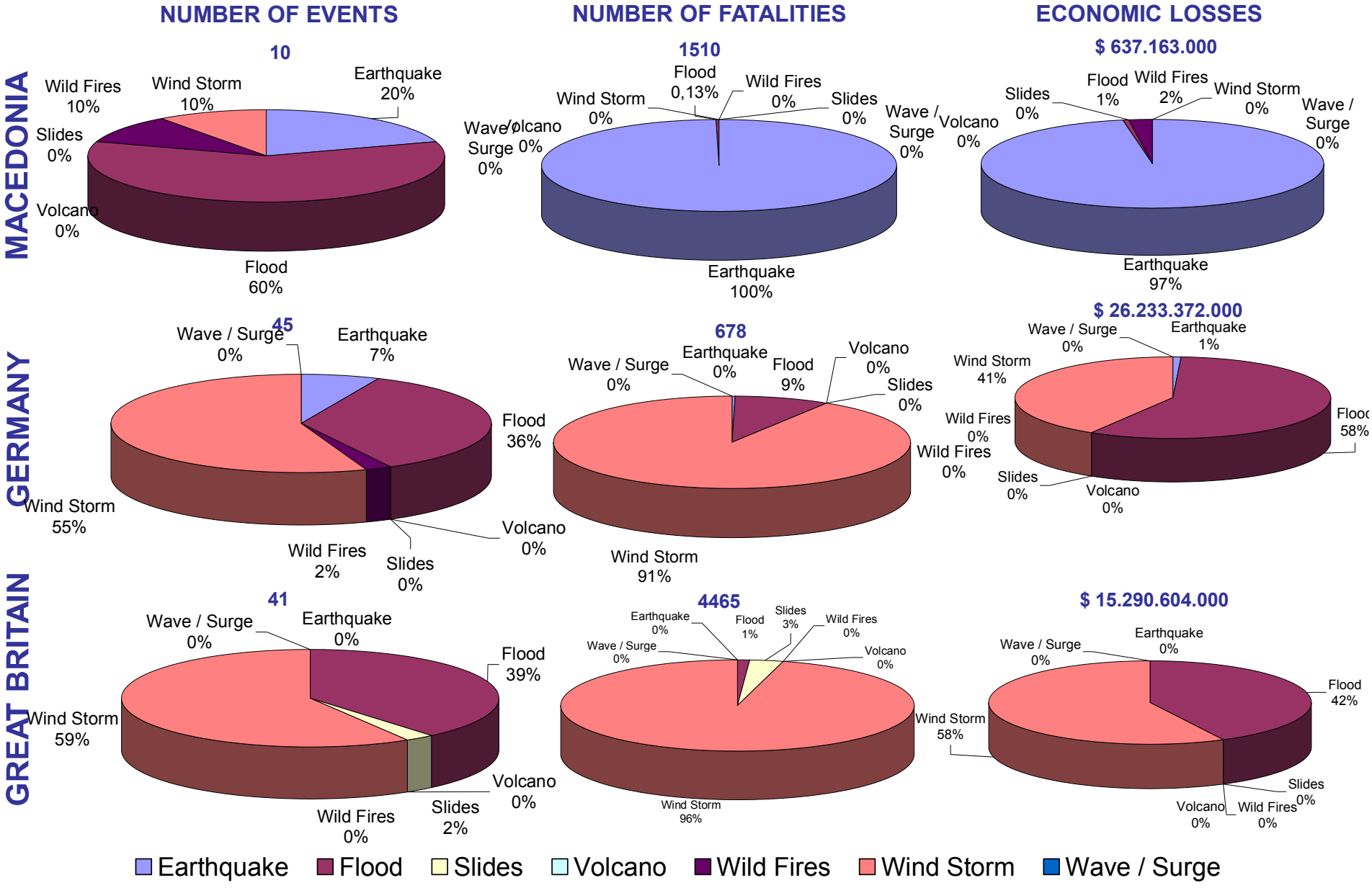


Earthquake Flood Slides Volcano Wild Fires Wind Storm Wave / Surge

NATURAL DISASTERS
EUROPE
1900-2005



NATURAL DISASTERS
EUROPE
1900-2005



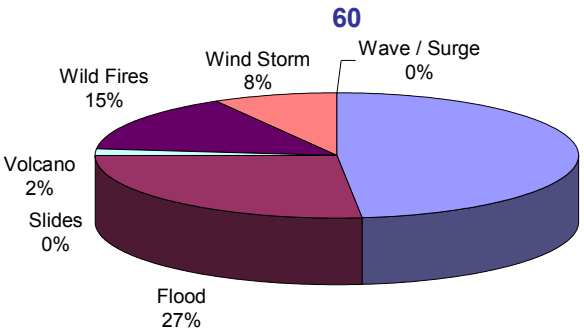
NATURAL DISASTERS
EUROPE
1900-2005

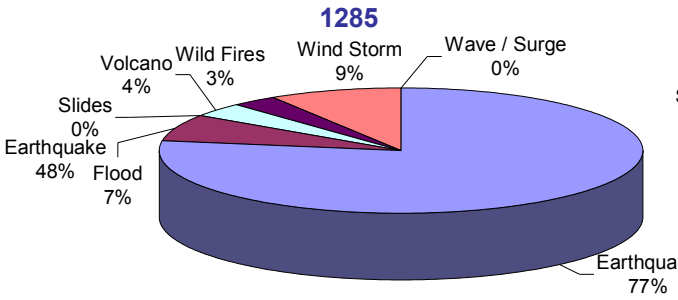
NUMBER OF EVENTS

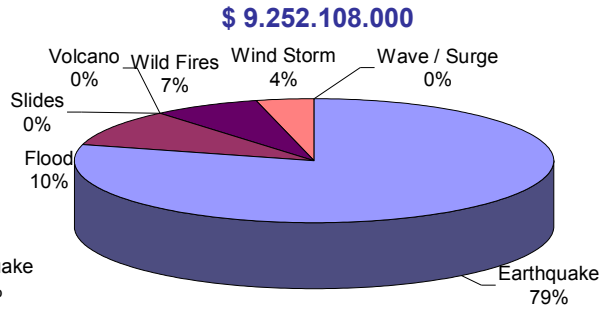
NUMBER OF FATALITIES

ECONOMIC LOSSES

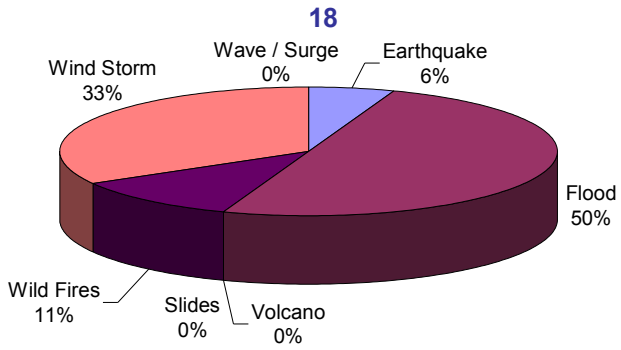
GREECE

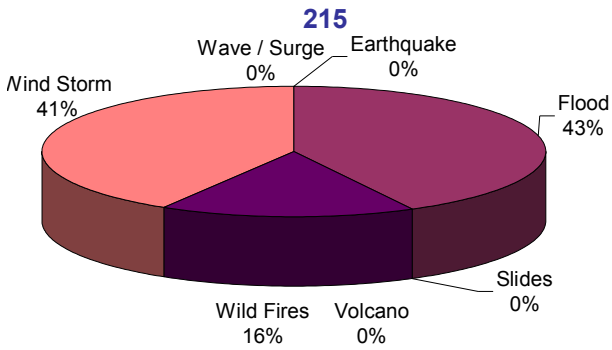


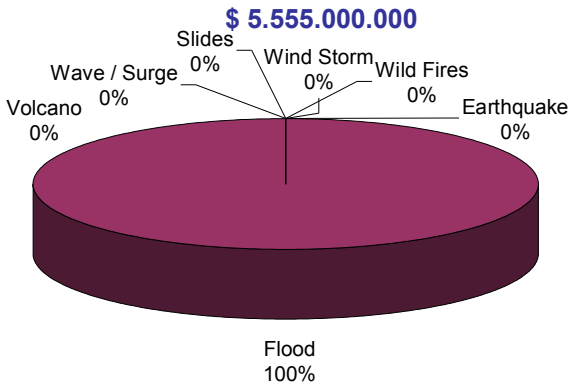




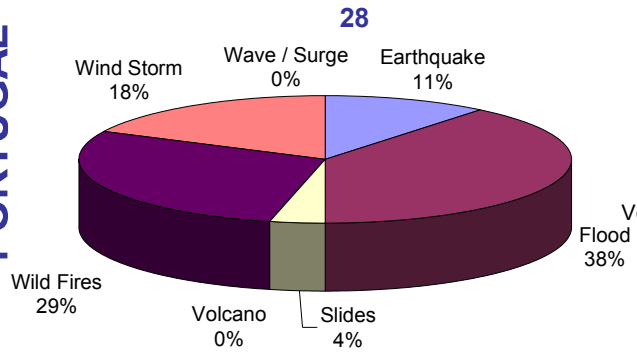
POLAND

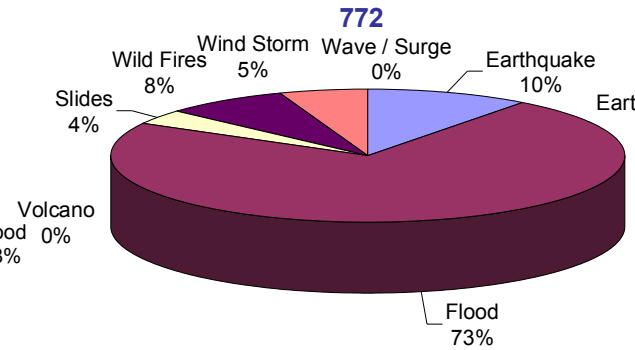


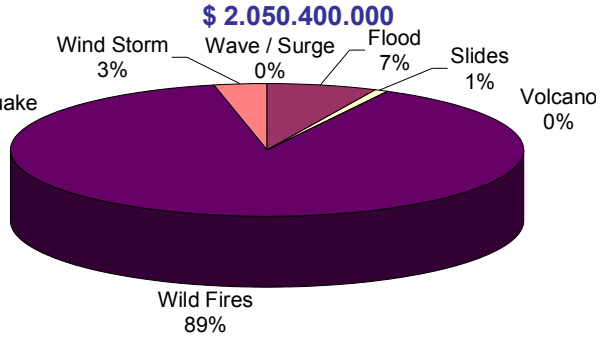




PORTUGAL







Earthquake Flood Slides Volcano Wild Fires Wind Storm Wave / Surge

NATURAL DISASTERS
EUROPE
1900-2005

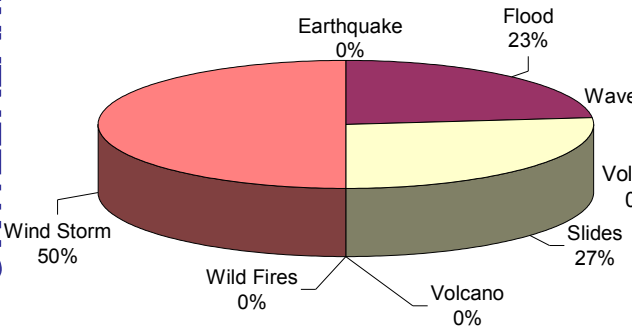
NUMBER OF EVENTS

NUMBER OF FATALITIES

ECONOMIC LOSSES

SWITZERLAND

30



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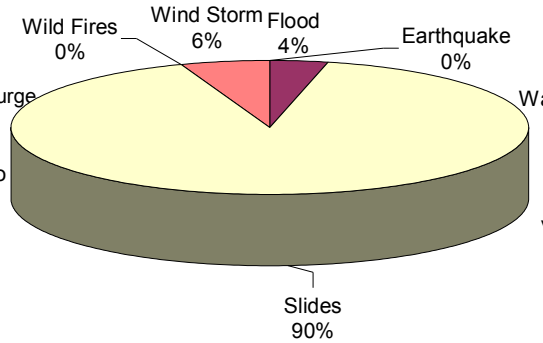
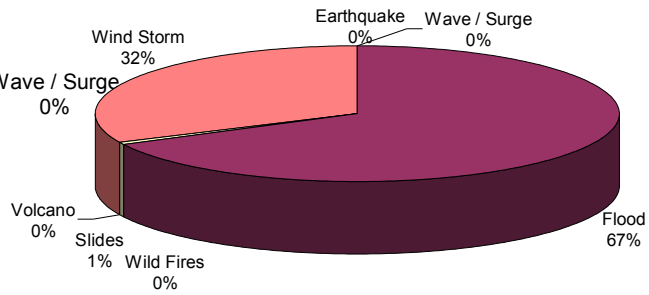
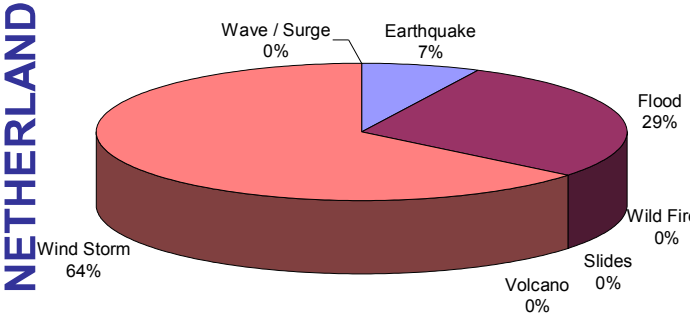


$ 2.806.084.000

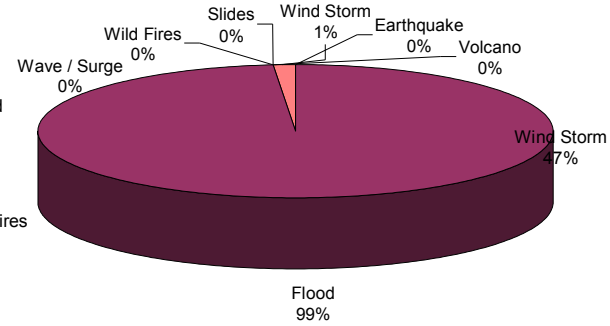


THE NETHERLANDS

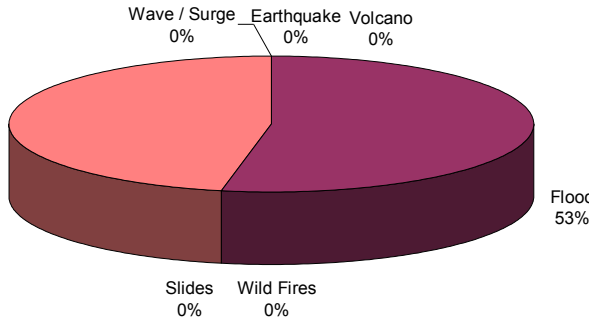
14



2027

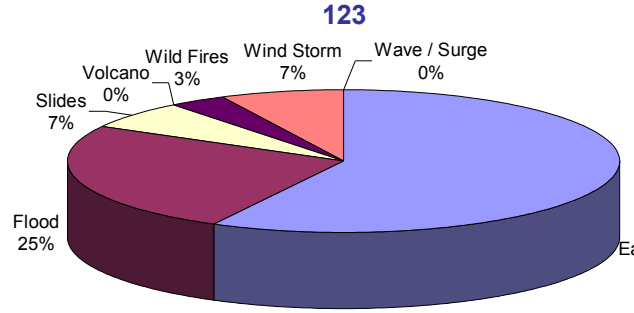


$ 4.022.714.000



TURKEY

123



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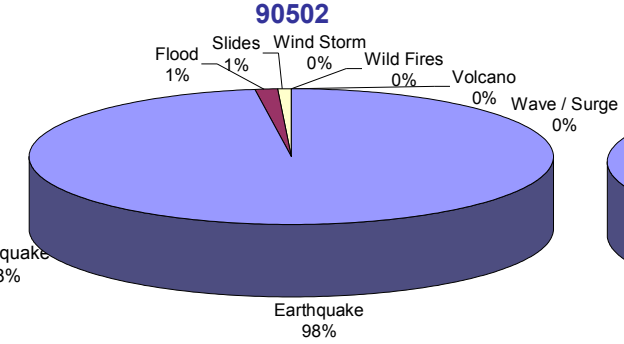
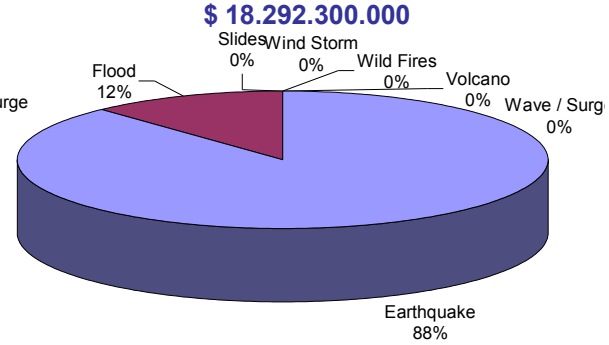
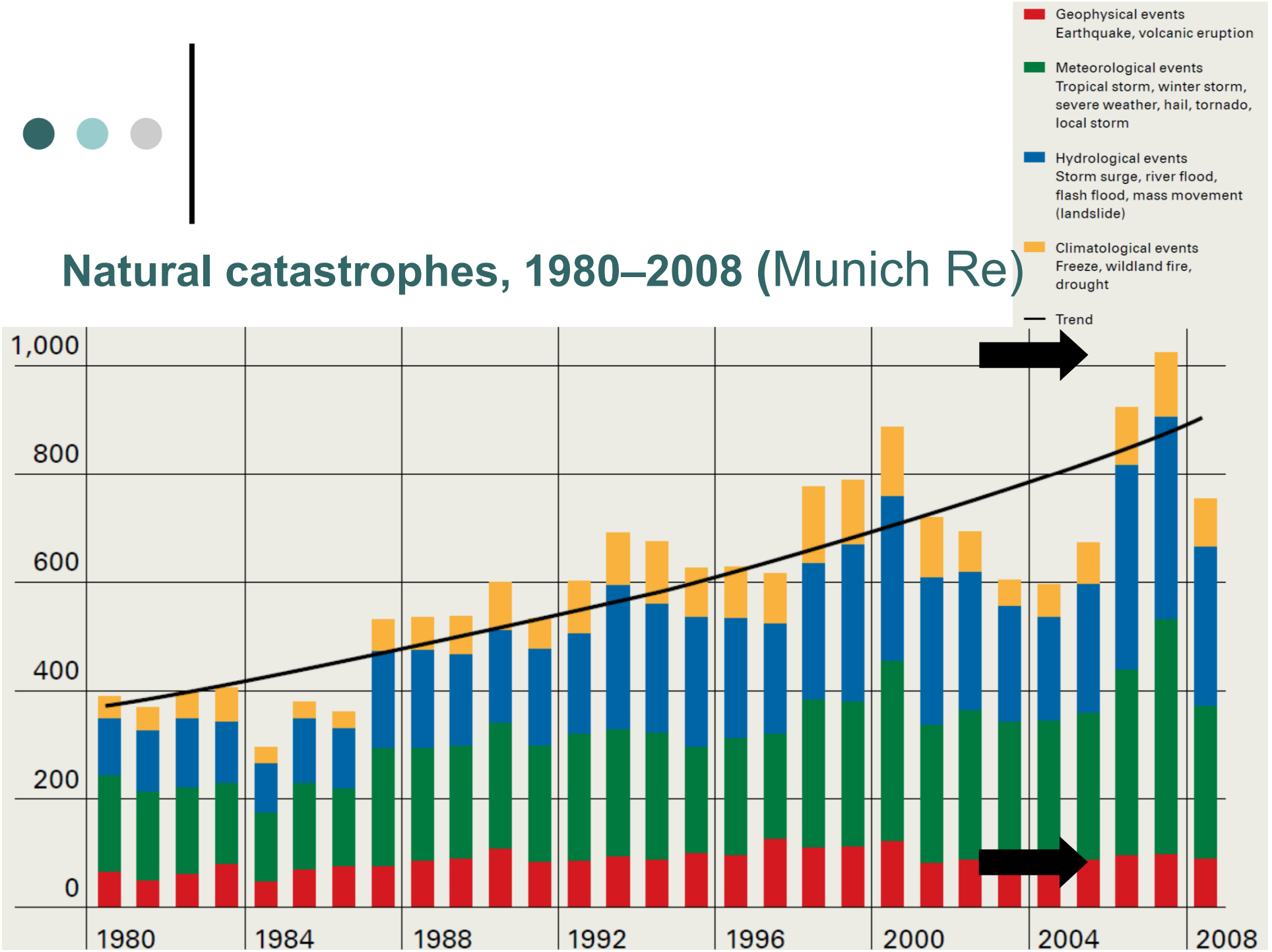


$ 18.292.300.000

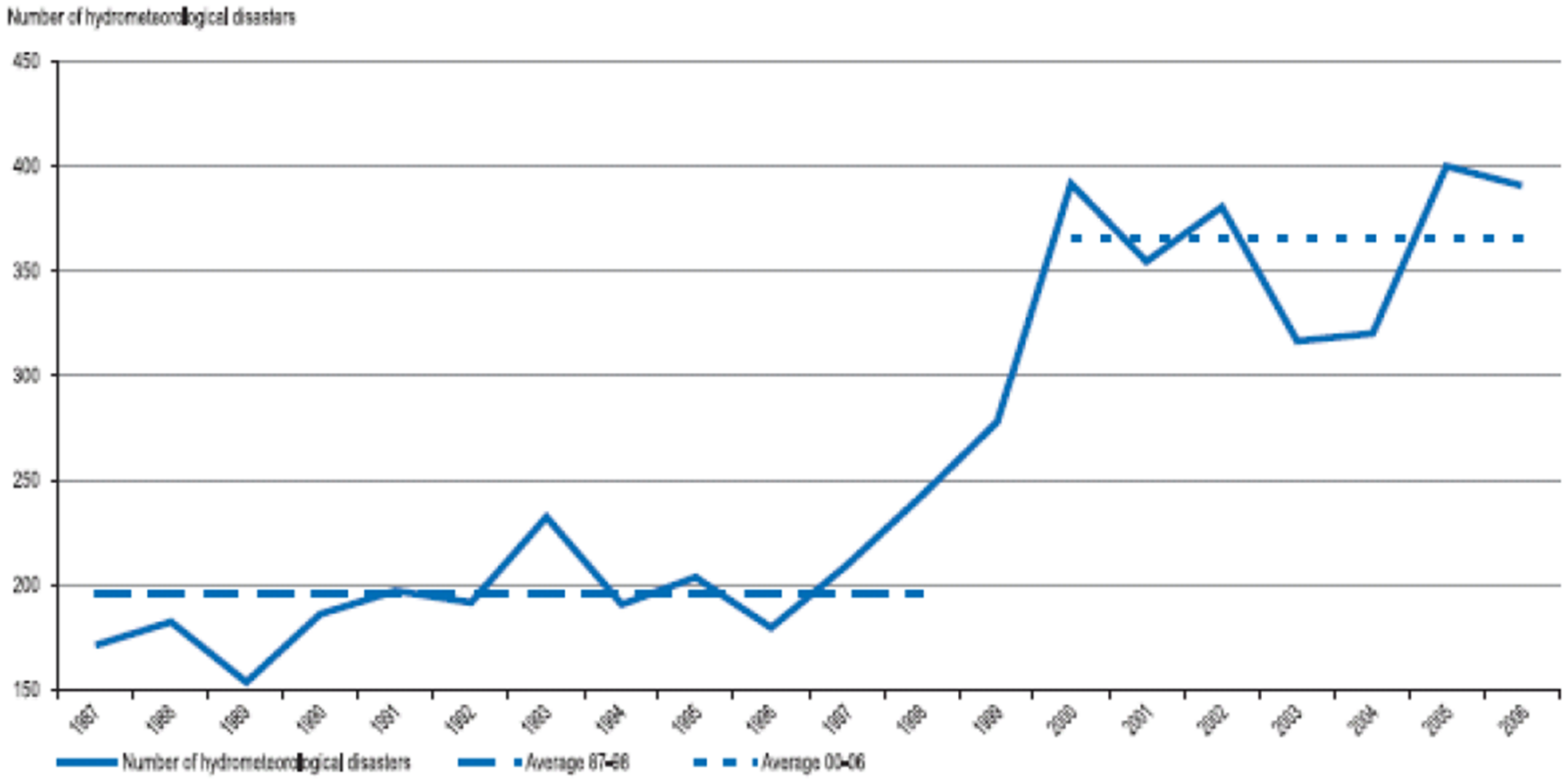


Earthquake Flood Slides Volcano Wild Fires Wind Storm Wave / Surge

Natural catastrophes, 1980–2008 (Munich Re)



Occurrence of hydrometereological hazards, 1987-2006



Centre for Research on the Epidemiology of Disasters (CRED) – Annual Disasters Statistical Review 2006, Brussels, May 2007

Motivation for action

- It is necessary to initiate the systematic survey of climate change effects against constructions, on the aim to provide a coherent approach:
  - Definition and characterization of actions
  - Quantification of the climate-affected material properties
  - Evaluation of the reliability and durability of structures along the designed lifetime
  - Provide reference criteria and background studies for technical regulations
  - Propose intervention strategies.
  - Adaptive Building Technologies (ABT) to face further climate change challenges
- Trans-national cooperation and multi-disciplinary approach are mandatory

Constructed Environment Reliability

- Buildings should remain stable for at least the designed working life (currently 50 – 100 yrs; cultural heritage more)
- The safety margins expressed by the general condition of structural reliability may be strongly affected:

$$E_d < R_d$$

E_d – load effect

R_d - resistance

- Both terms are influenced by the climate change:

Climate change may influence the return period of extreme weather events (heavy loads of snow or extreme winds) which results in an increase of loads E_d

Changes in temperature, humidity, levels of precipitation, wind, frequency of extreme weather and emissions reduce the durability of the materials and their resistance R_d. Rate of degradation strongly increased reducing construction life.

Loads effects

- At present, design engineers are not fully aware of the effects of climate change in their design
- The consequences for constructions may increase the incidence of failure or damage
- Extreme climate actions:
  - Wind
  - Snow
  - Land Slide and Scour
  - Rain

ers are not fully
nate change in

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- Extreme climate actions:
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  - Snow
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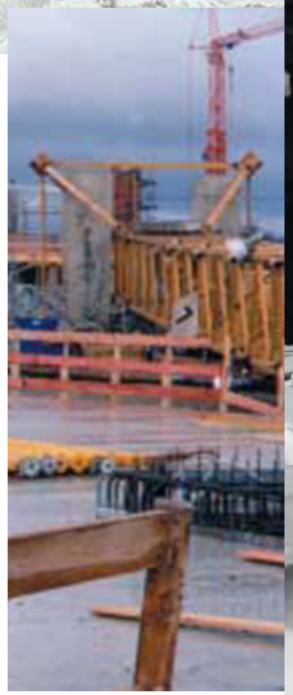

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Winter storms Anatol, Lothar and Martin, December 1999

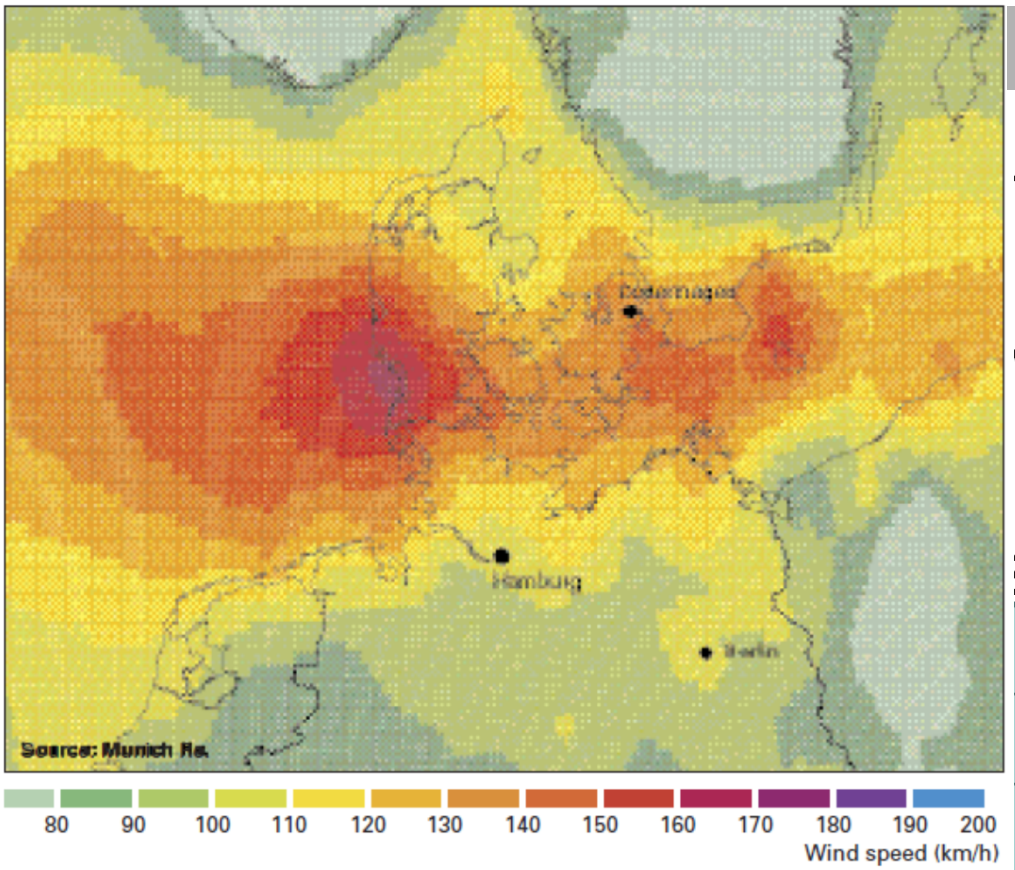
- Peak winds speed over 160 km/h in large areas, eg. over 170 km/h in Paris (in some exposed locations up to 260 km/h)
- over 160 fatalities, over 10,45 losses (€ bn)
- extreme losses in the forestry sector

Country	Insured losses (€m)
Denmark	2 000
France	6 900
Germany	750
Switzerland	800
Total	10 450

Winter storms Anatol, Lothar and Martin, December 1999

Anatol

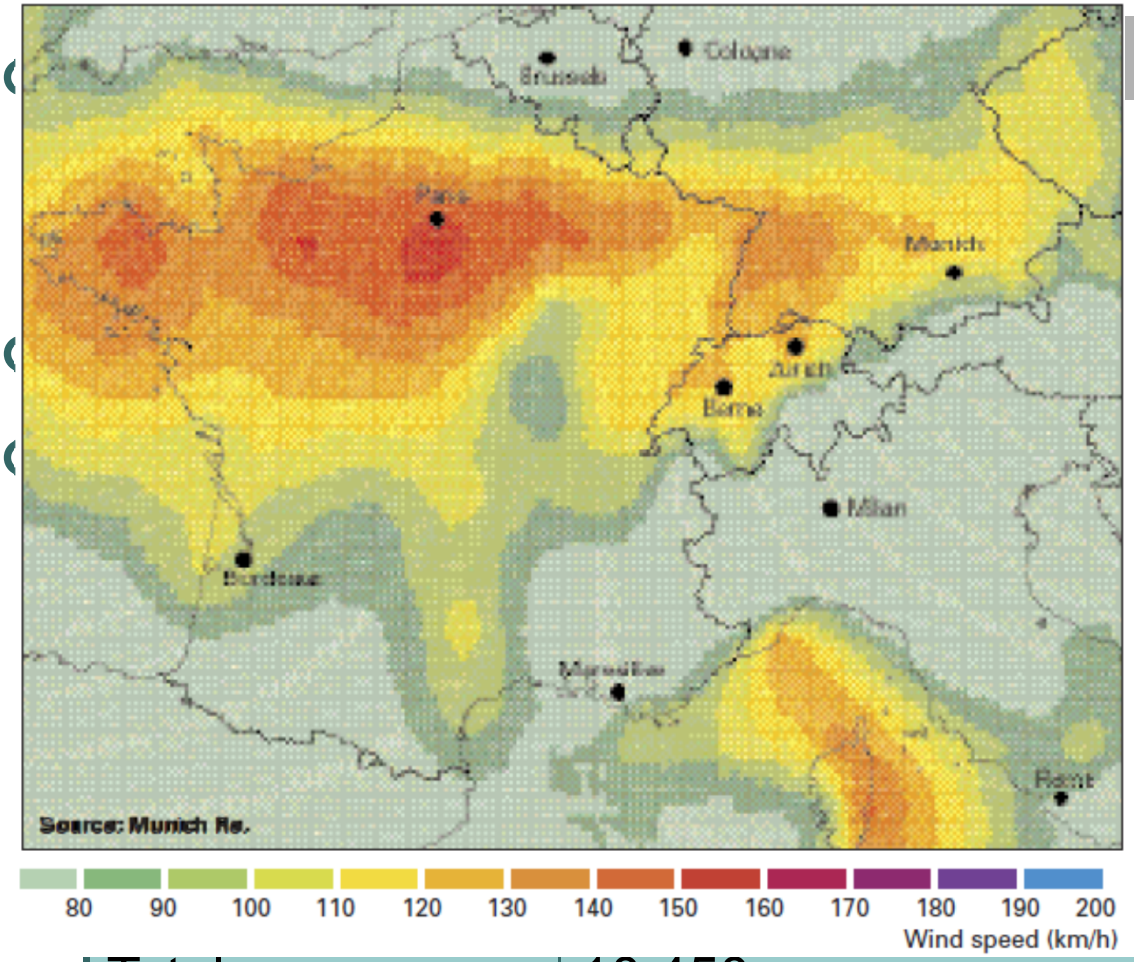
- n/h in large
- ris (in some n/h)
- osses (€ bn)
- sector



Germany	750
Switzerland	800
Total	10 450

Winter storms Anatol, Lothar and Martin, December 1999

Anatol



Lothar

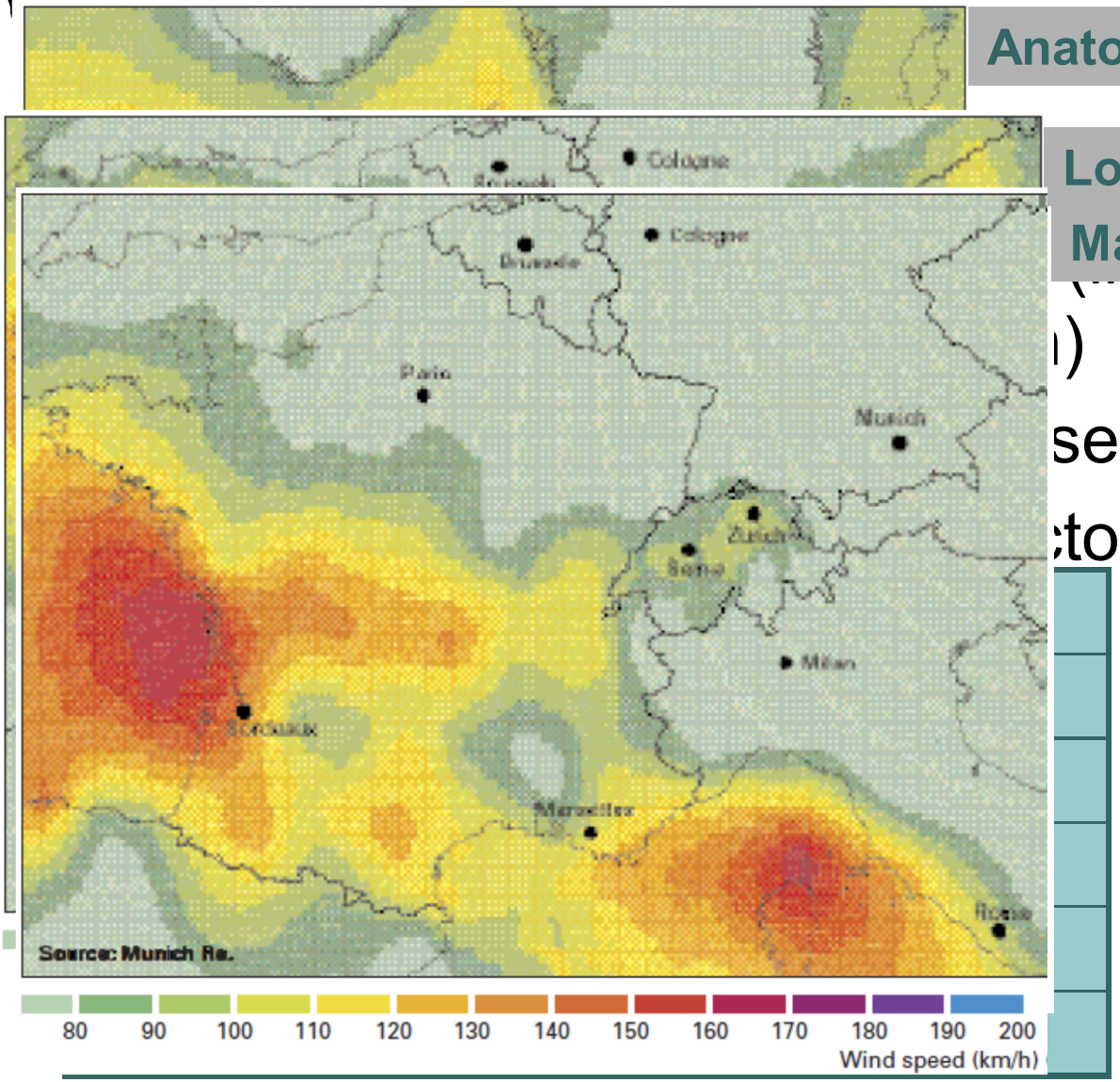
(in some

ses (€ bn)

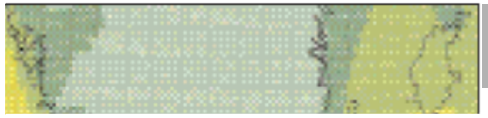
tor

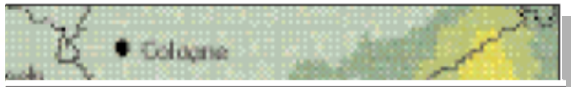
Total	10 450

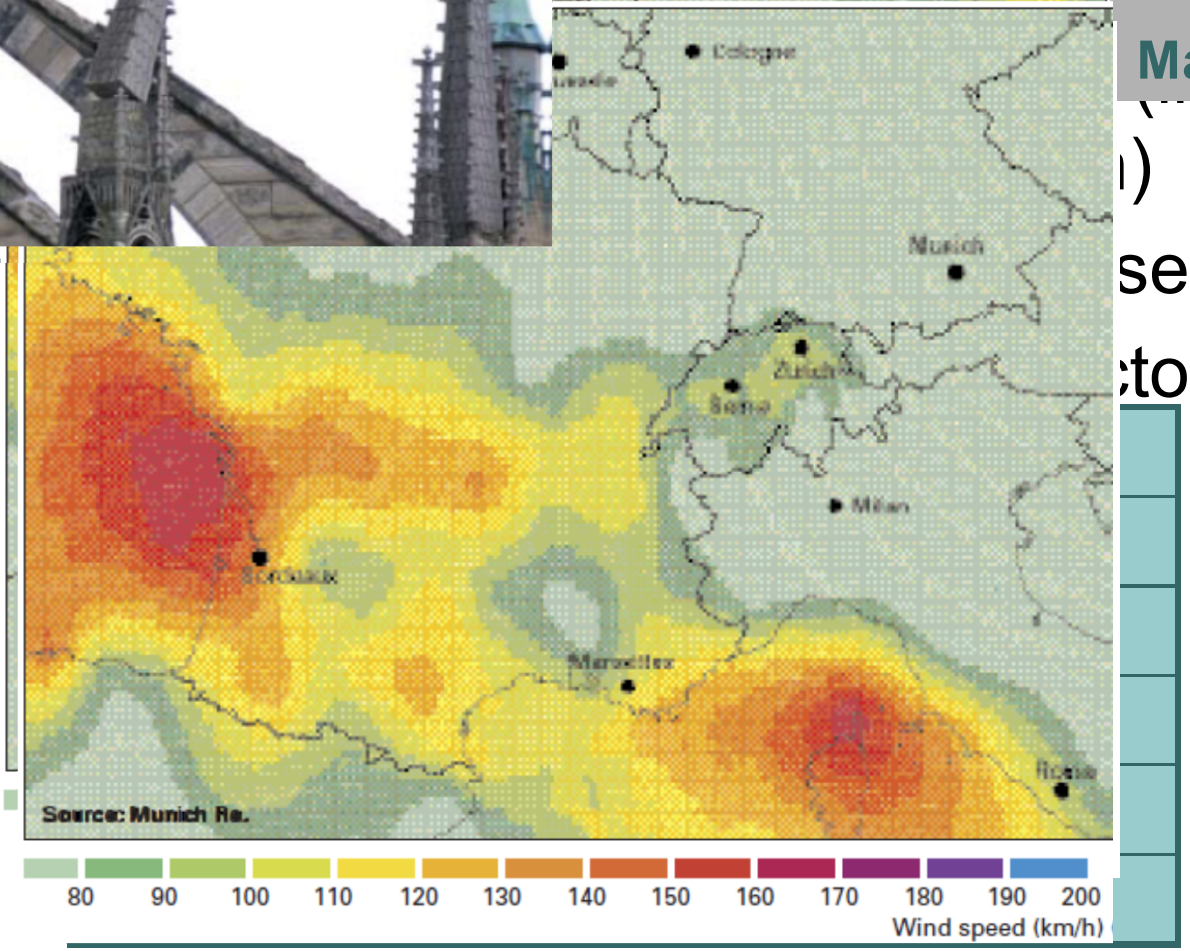
Winter storms Anatol, Lothar and Martin, December 1999



Winter storms Anatol, Lothar and Martin, December 1999







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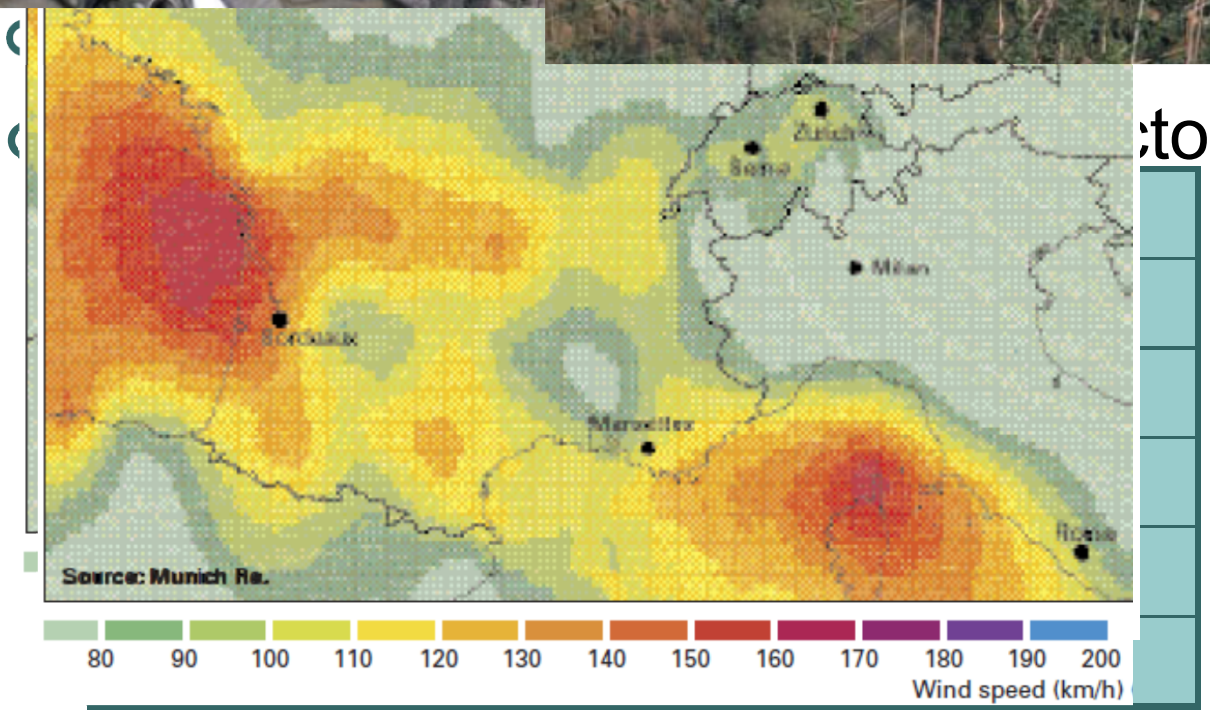
Winter storms Anatol, Lothar and Martin, December 1999



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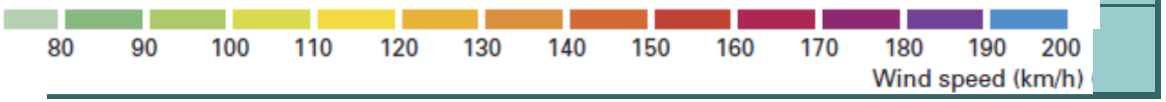

Heavy snow winter, 2005/2006

- Many buildings collapsed, including large buildings:
  - Bad Reichenhall ice rink, Exhibition hall in Kattowitz/Poland, Market in Moscow
  - Large snow load corroborated with deficiencies in design and maintenance, lack of robustness
- Hundreds of fatalities, billions of euros damages

- 2005/2006

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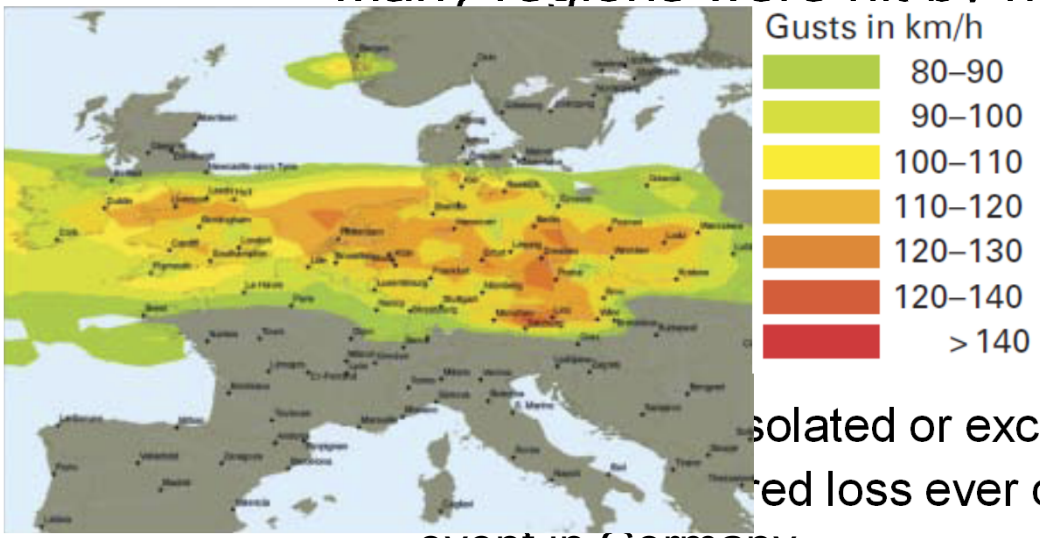
Winter Storm Kyrill in Europe, January 2007

- Many regions were hit by hurricane-force gusts (up to 200 km/h)
- Thunderstorms, accompanied by hailstorms, also tornadoes.
- Losses: 7.8 bn euro, 49 fatalities
- Conclusions:
  - Kyrill is not an isolated or exceptional case
  - the largest insured loss ever caused by a winter storm event in Germany,
  - We have to be prepared for further events costing as much and even more.
  - We expect winter storm activity to increase – particularly in the long term – as a result of climate change.

Source: Munich Re

Winter Storm Kyrill in Europe, January 2007

- Many regions were hit by hurricane-force gusts



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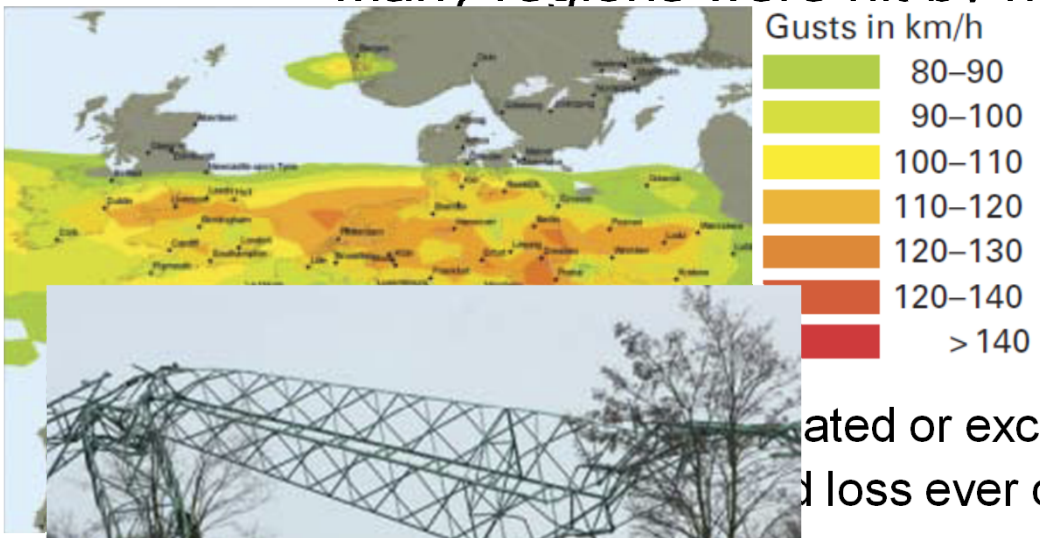

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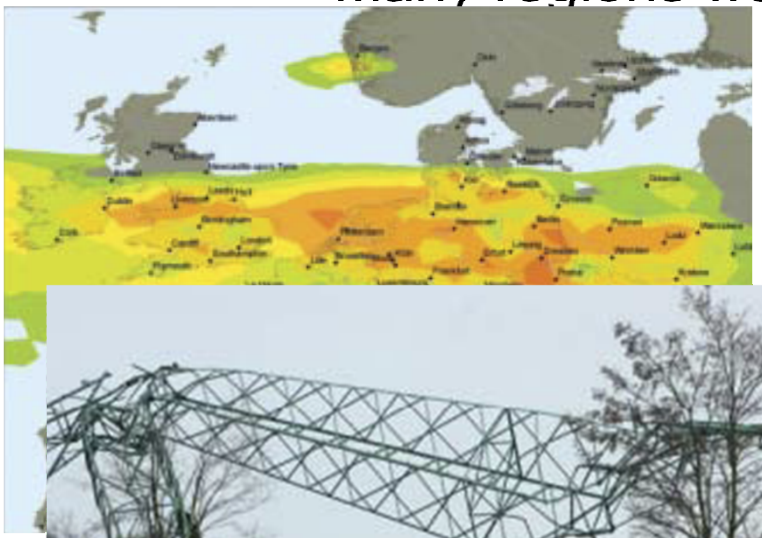

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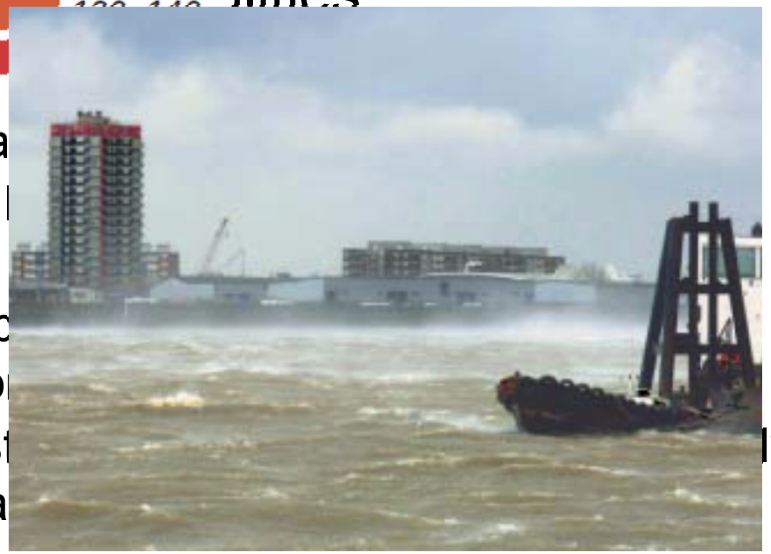


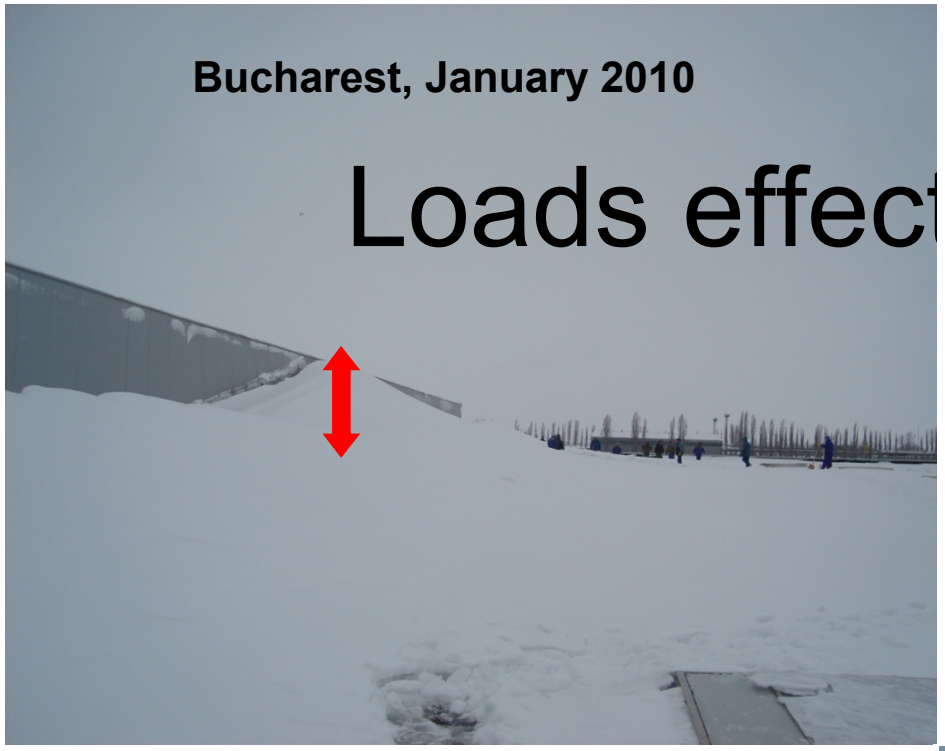
Source: Munich Re

Winter 2009/2010

- Bad winter weather in decades
  - Snow and ice hit airports, roads and railways (e.g. stuck trains in Channel Tunnel, thousands of flights to/from major European airports cancelled or delayed)
  - Exceptional snowfalls and snowdrifts (damages to roofs, infrastructure)

Loads effects

- EN 1991-1-3: Eurocode 1: Actions on Structures: Part 1-3: Snow Loads - already proposed to take into account exceptional snow:
  - Exceptional fall (e.g. larger than code provisions in snow-prone areas or snow in non-snow prone areas)
  - Exceptional drift
- Difficulties in indicating areas affected by exceptional falls (national responsibility) and in the correct evaluation of snow drift (it can be 4-5 times larger than undrifted snow)
- Snow drift is particularly very dangerous on very large roofs !!!!



- Two adjacent buildings
  - 120x80m, 13.0m height
  - 180x80m, 9.5m height
- Snow drifting
- Accumulation up to 4.0m of snow
- Undrifted snow 1.0m
- Very large deformations of the roof, purlins and panels severely damaged
- Structural collapse prevented

- Snow was removed from the roof in the drifted area
- Repairing, upgrading necessary:
  - Purlins will be replaced
  - Panels will be replaced or strengthened
  - Local strengthening at main girders

Last years disasters

- February 2010, Madeira floods and mudslides
- At least 50 people died and at least 120 were injured
- Over 225 mm of rainfall over the Island.

Last years disasters

2010, Madeira floods and

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Last years disasters

Last years disasters

Very recent disasters

- February 2010, floods in western France. Over 50 people died
- May 2010, floods in south-eastern France
- June 2010, twenty people died in the worst floods to hit southern France since 1827. Up to 400 mm of rain in 48 hours

Very recent disasters

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Very recent disasters

Very recent disasters

- June – July 2010, worst flood to hit Romania in four decades (e.g. 200 mm of rainfall in two hours)
- Over 20 people died, over 750 mil. Euro losses
- Intensity of rain associated to a returning period of 200 yrs.

Scour effects

- Scour – erosion resulting from the shear forces associated to flowing water or waves
- Affects foundations, bridge piers
- Similar effects occur in case of bank and coastal protections or in case of retaining walls
- Have been the cause of several failures
- Scour depth prediction need to be reevaluated, for the safety and economy

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Resistance of materials

- Products for construction works need to satisfy essential requirements for at least the design working life (Council Directive 89/106/EEC), e.g.:
  - Mechanical resistance and stability
  - Safety in use

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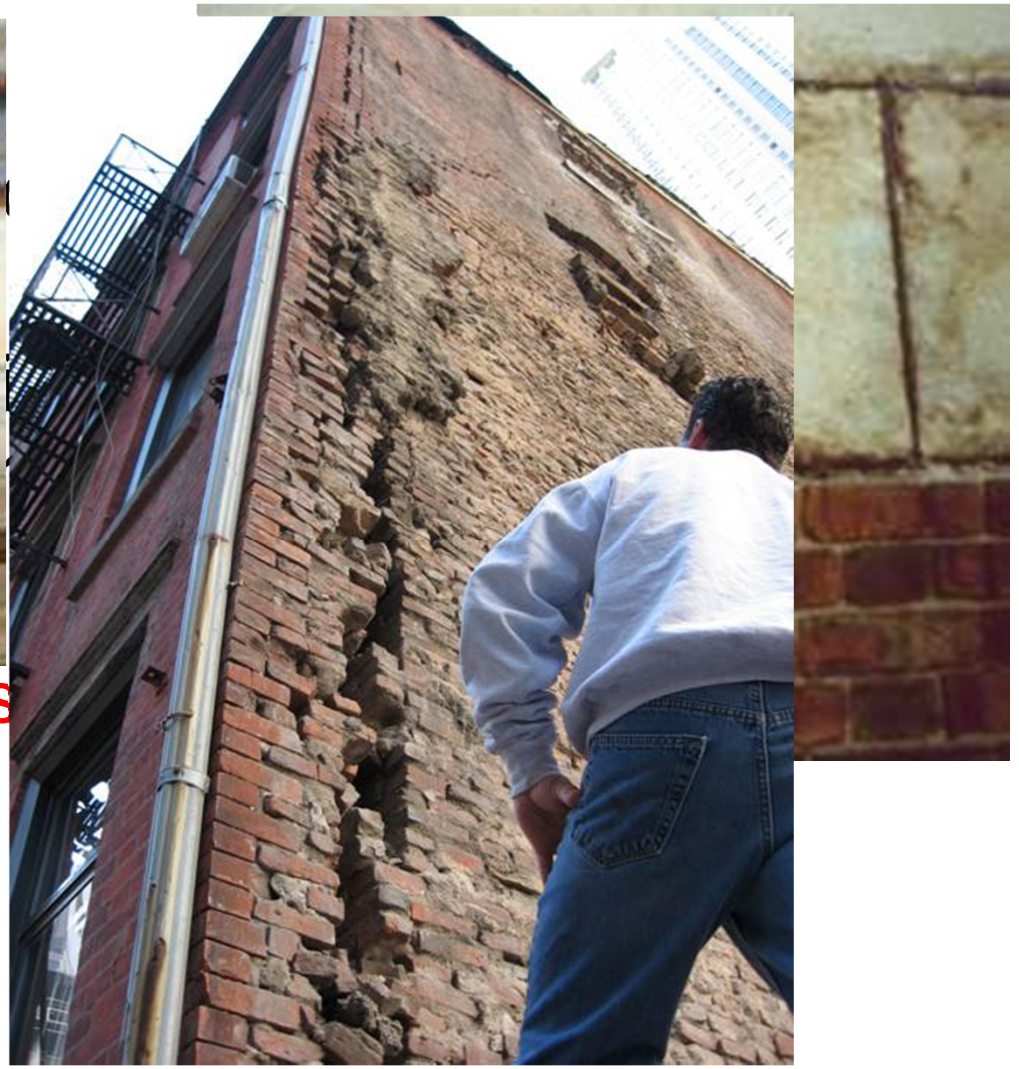

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Impact on Structural Safety and Durability

Risk and impact of climate change on built heritage (30th Session of WHC, Vilnius 2006)

Climate indicator	Climate change risk	Physical, social and cultural impacts on cultural heritage
Atmospheric moisture change	– Flooding (sea, river) – Intense rainfall – Changes in water table levels – Changes in humidity cycles – Sea salt chlorides	– Physical changes to porous building materials and finishes due to rising damp – Subsoil instability, ground heave and subsidence – Relative humidity cycles/shock causing splitting, cracking, flaking and dusting of materials and surfaces – Corrosion of metals
Temperature change	– Diurnal, seasonal, extreme events (heat waves, snow loading) – Changes in freeze-thaw and ice storms, and increase in wet frost	– Deterioration of facades due to thermal stress – Damage inside brick, stone, ceramics that has got wet and frozen within material before drying – Inappropriate adaptation to allow structures to remain in use: roofs failure, pipelines , electric and communication networks failure, etc
Wind	– Wind-driven rain – Wind-transported salt – Wind-driven sand – Winds, gusts and changes in direction	– Static and dynamic loading of historic or archaeological structures – Structural damage and collapse
Climate and pollution	– pH precipitation – Changes in deposition of pollutants	– Corrosion of metals
Climate and biological effects	– Proliferation of invasive species – Spread of existing and new species of insects (e.g. termites)	– Collapse of structural timber and timber finishes

Note: Only issues related to the current Action are mentioned here

Integrated approach for protection and prevention

- An integrated approach making the synergy of knowledge belonging to different disciplines
  - climatology
  - science of materials
  - building physics
  - civil and structural engineering
  - cultural heritage
- There is a strong need for systematic risk and vulnerability studies to evaluate and model the physical and structural impacts of climate changes on constructions
- Recommendations for preventive measures are necessary
- Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) of Constructions have to take into account the effect of climate change on constructions because it influences their maintenance and life-time

Scientific focus

- R&D Activities within following scientific thematic areas:
  - Evaluate **climate change effects** with incidence for durability of building material and reliability of constructions
  - **Develop models** for characterization of mechanical properties of materials subjected to progressive degradation induced by clime effects
  - Apply **Performance Based Models and Methods** for structural evaluation and robust design
  - Develop and apply **Intervention strategies** to preserve and/or enhance safety and durability of building stock

Concluding Remarks

- Climate change effects are of big concern
- Europe will not be spared
- Besides emissions and thermo-energetic issues, safety and durability of constructions is of concern
- Early action to adapt constructions (e.g. materials, systems, technologies, maintenance, technical regulations) to climate change will prevent potential damage and minimise economical loss and threats to human health