Topic 6: Natural Hazards and Risk Management

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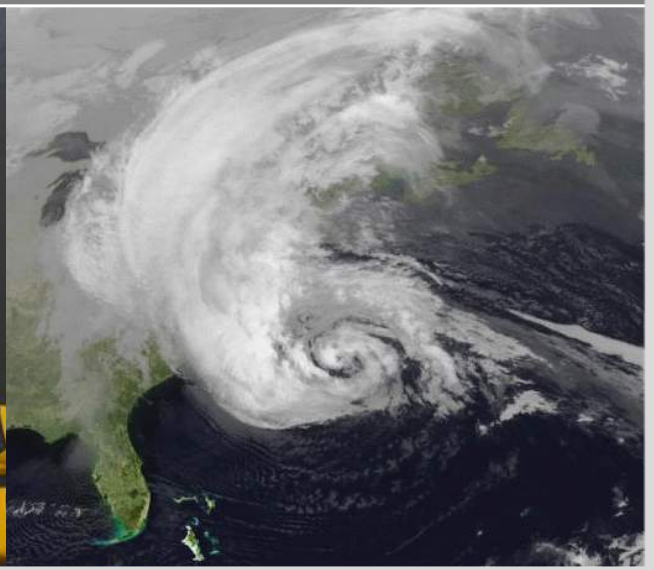


Agenda…

Extreme events…

Risk estimation: Hazard, Vulnerability, Statistics…

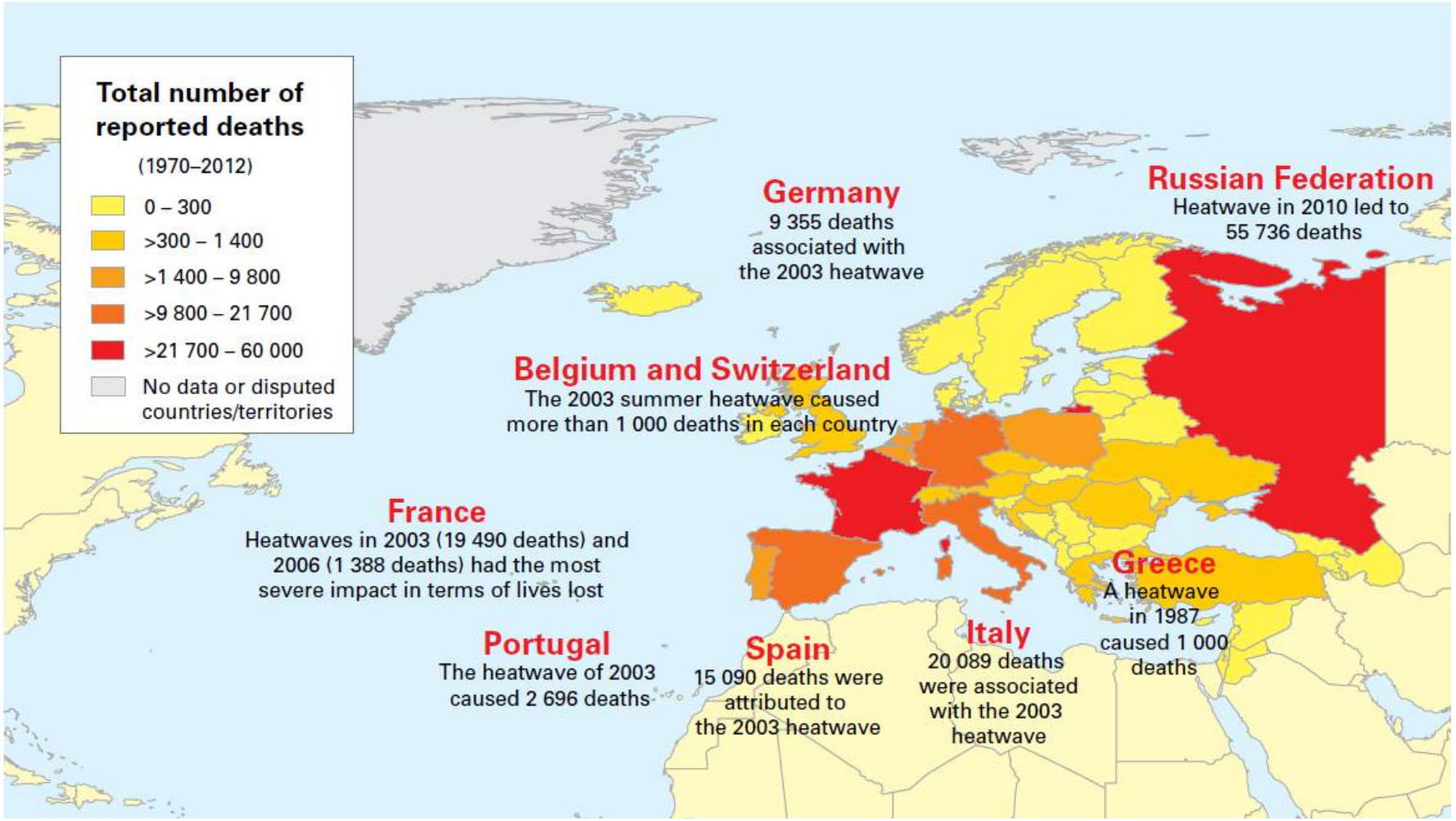
Disaster Risk: Concept, awareness, catastrophes…

Trends: global changes…

Risk Management: Basic concepts

CEDIM forensic disaster analyses…

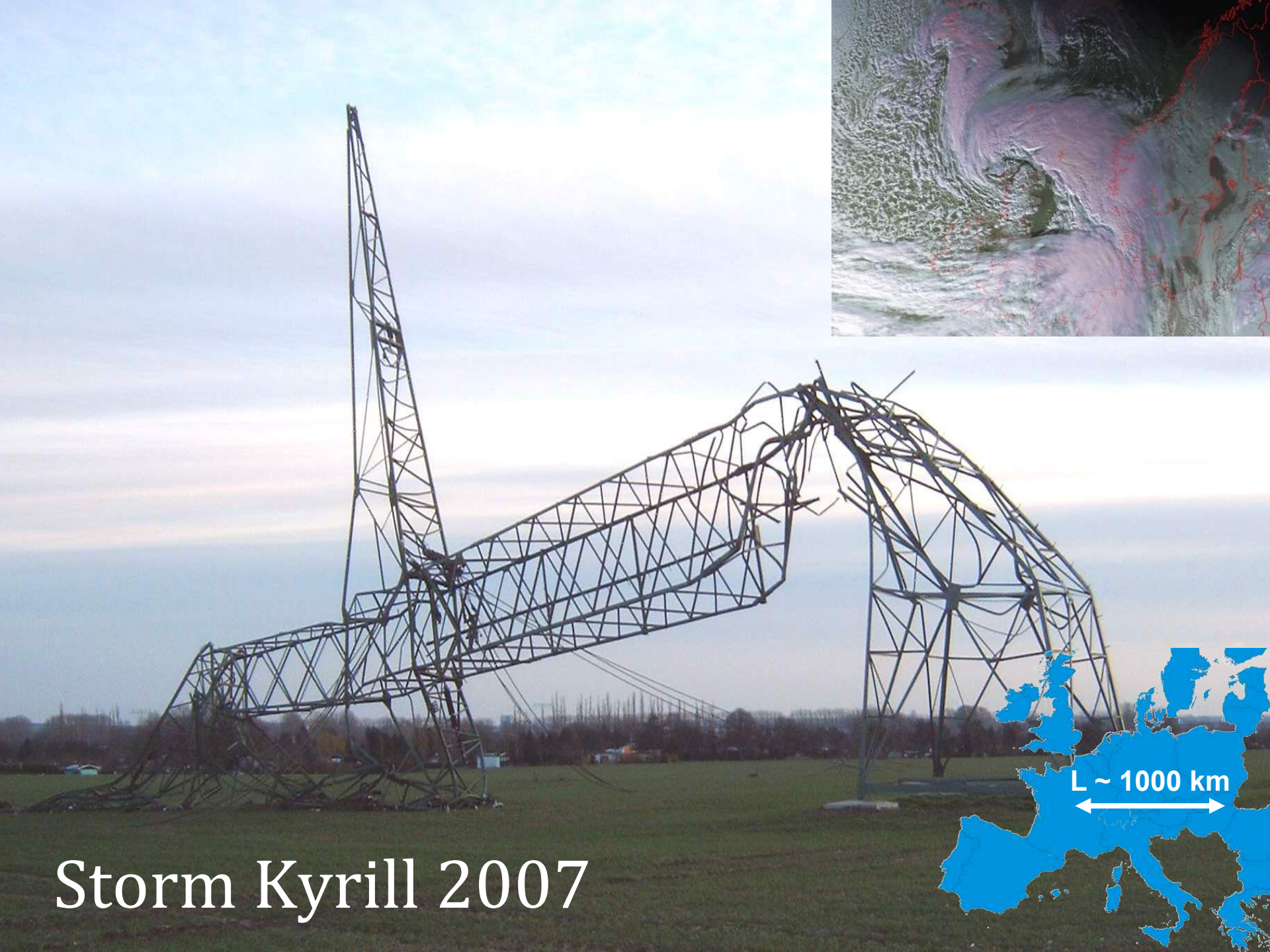
Fatalities by natural hazards (1970-2012)



(WMO, 2014)

Heat wave 2003

River Rhine



Storm Kyrill 2007

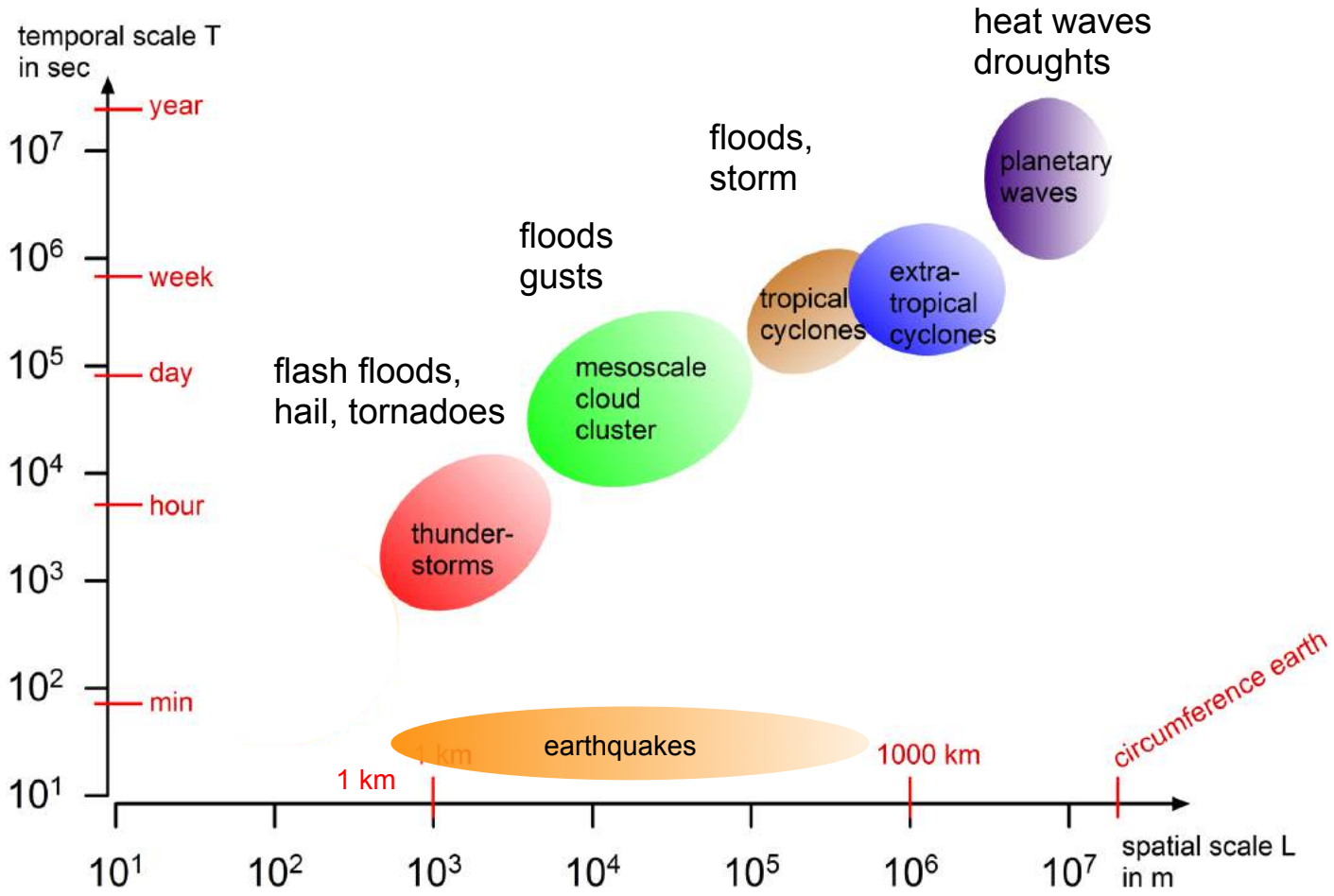
Typhoon Haiyan 2013

Hailstorm Reutlingen 2013

Tornado Bützow 2015

Natural Hazards: Scale Diagram

- Extreme events occur on a wide range of spatial and temporal scales (atmospheric hazards: relation between the two)

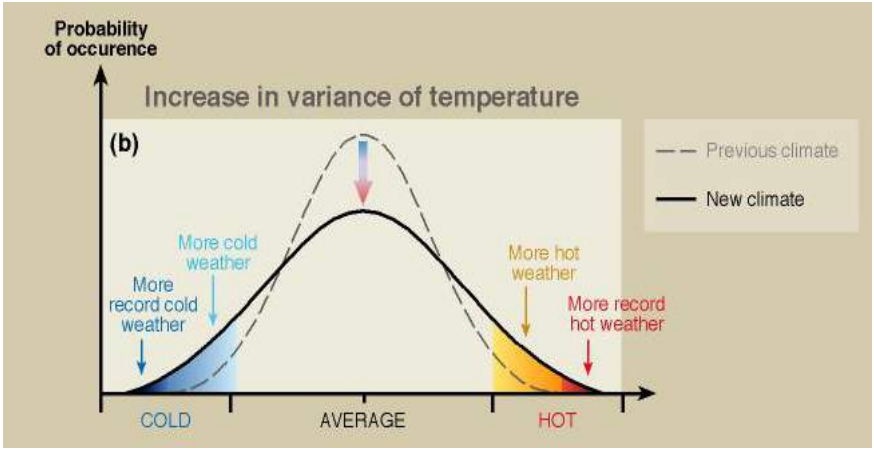


Extreme Events

- Definitions
  - based on Impact (be careful, insurance approach)



  - based on statistics (e.g., thresholds, percentiles, extreme value statistics, …)



Example: Normal distribution

$$f(x) = \frac{1}{\sqrt{2\pi}\cdot\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

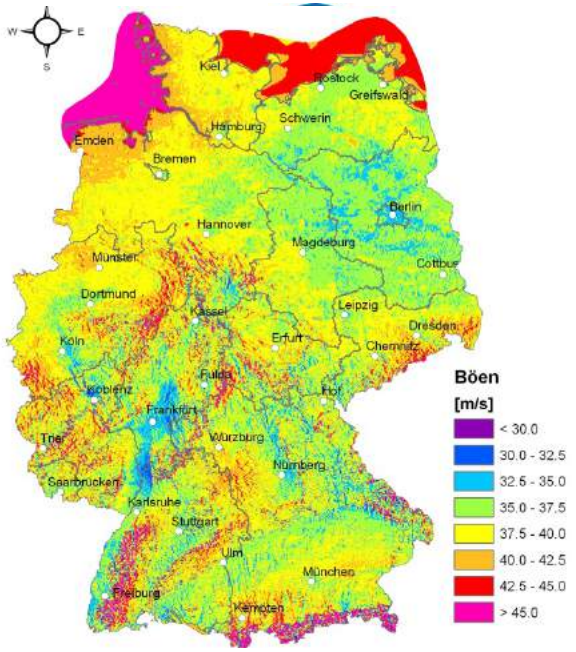
Risk = Hazard x Exposure x Vulnerability

Hazard I

- Intensity of extremes as a function of probability
  - Target figure: wind speed, runoff, water level, rain amount, magnitude, acceleration,… for a certain probability

$$G = p\,(I)$$

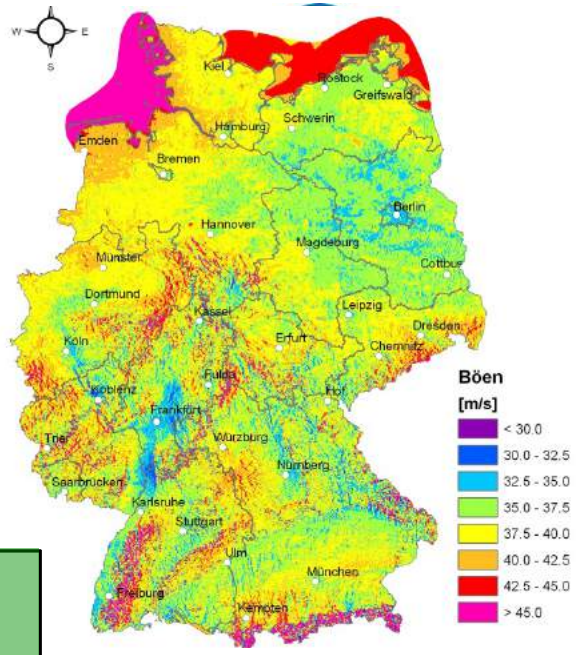
Hazard:
Probability of occurrence for a certain intensity of a certain extreme events in a certain area / location

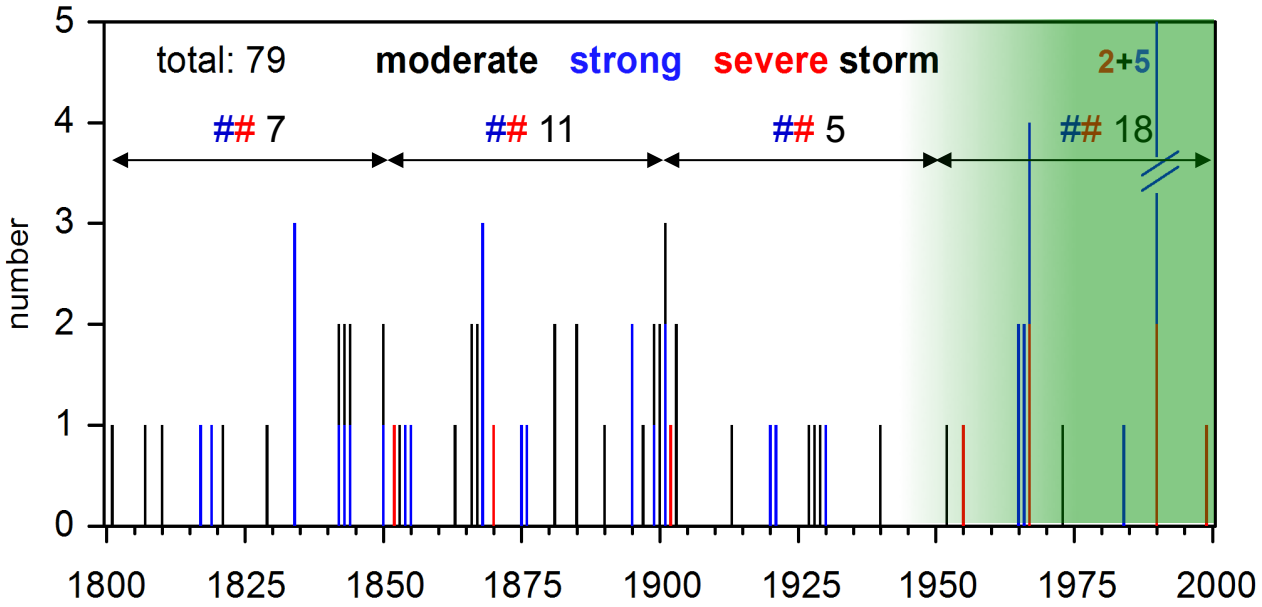


Storm **hazard** per 1 x 1 km²
p = 0.02 (return period 50 yrs)
(Hofherr & Kunz, 2010)

Hazard II

- Characteristics of Extremes
  - High spatial / temporal variability
  - Superposition of long-term variability (i.e., natural climate variability)
  - Low frequency (at a certain point, area, region)





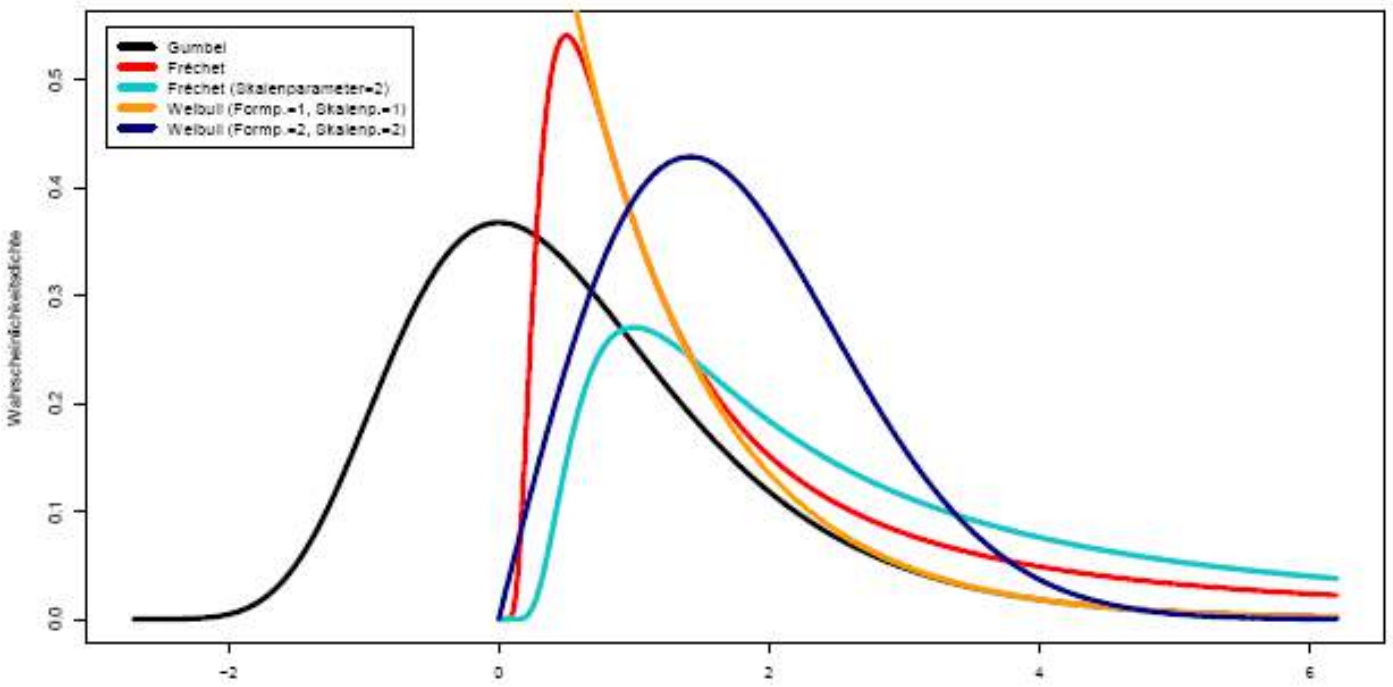
Availability of reliable observations

Damage-related winterstorms over Baden-Württemberg reconstructed from various proxy data (Hofherr und Steller, 2005)

Hazard III

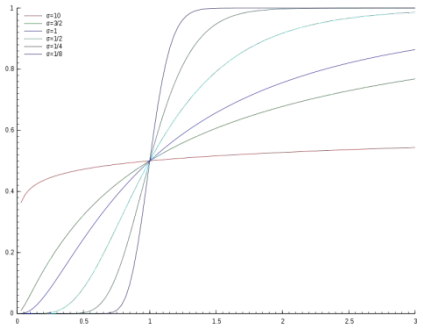
- Objective: Relation between intensity and probability (return period)
- Problem: small sample sizes over a limited period of time; parent distribution not known

  → Estimation of an appropriate cumulative distribution function (cdf)



Hazard IV

- **Sample**: Annual Maxima
- Classical extreme value statistics (Fisher & Tippet, 1928)
- Modelling by **Generalized Extreme Value (GEV)** distribution



$$F(x) = \exp\left[-\left(1 - k\frac{x-\beta}{\alpha}\right)^{1/k}\right] \qquad k \neq 0$$

$$F(x) = \exp\left[-\exp\left(-\frac{x-\beta}{\alpha}\right)\right] \qquad k = 0$$

cdf

k: form parameter
α: scale parameter
β: shape parameter

k > 0: Typ II

Fréchet

$$\Phi_a(x) = \begin{cases} 0 & x \le 0 \\ \exp(-x^{-\alpha}) & x > 0 \end{cases}$$

k < 0: Typ III

Weibull

$$\Psi_\alpha(x) = \begin{cases} \exp(-(-x)^{\alpha}) & x \le 0 \\ 1 & x > 0 \end{cases}$$

k = 0: Typ I

Gumbel

$$\Lambda(x) = \exp(-\exp(-x))$$

Hazard V

- **Sample**: all maxima during a certain period (peaks over threshold, POT)
- Modelling by **Generalized Pareto Distribution (GPD)**

$$F(x) = 1 - \left[1 - \frac{k}{\alpha}(x - \xi)\right]^{1/k} \qquad k \neq 0$$

$$F(x) = 1 - \exp\left[-\frac{(x - \xi)}{\alpha}\right] \qquad k = 0$$

$\lambda = n/M$

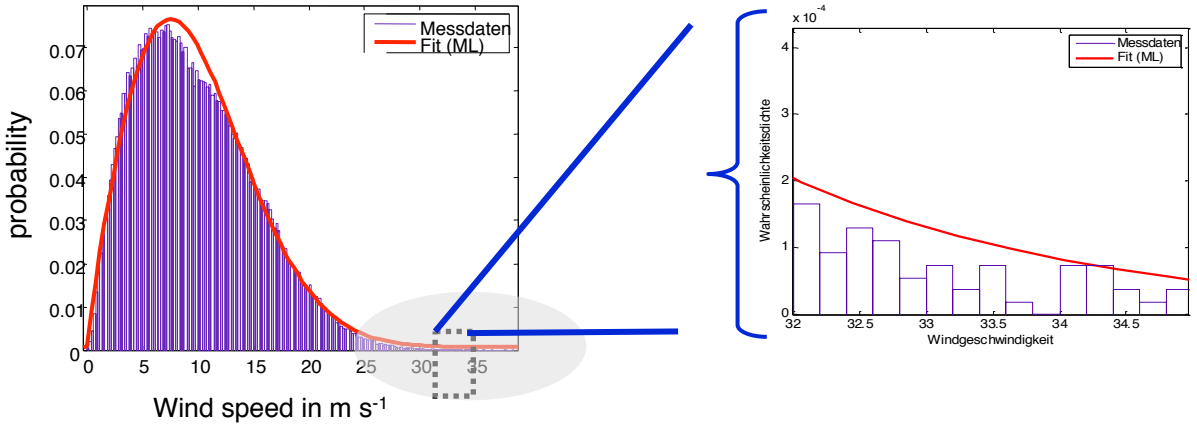
n: number exceed.

M: number years

k: form parameter

α: scale parameter

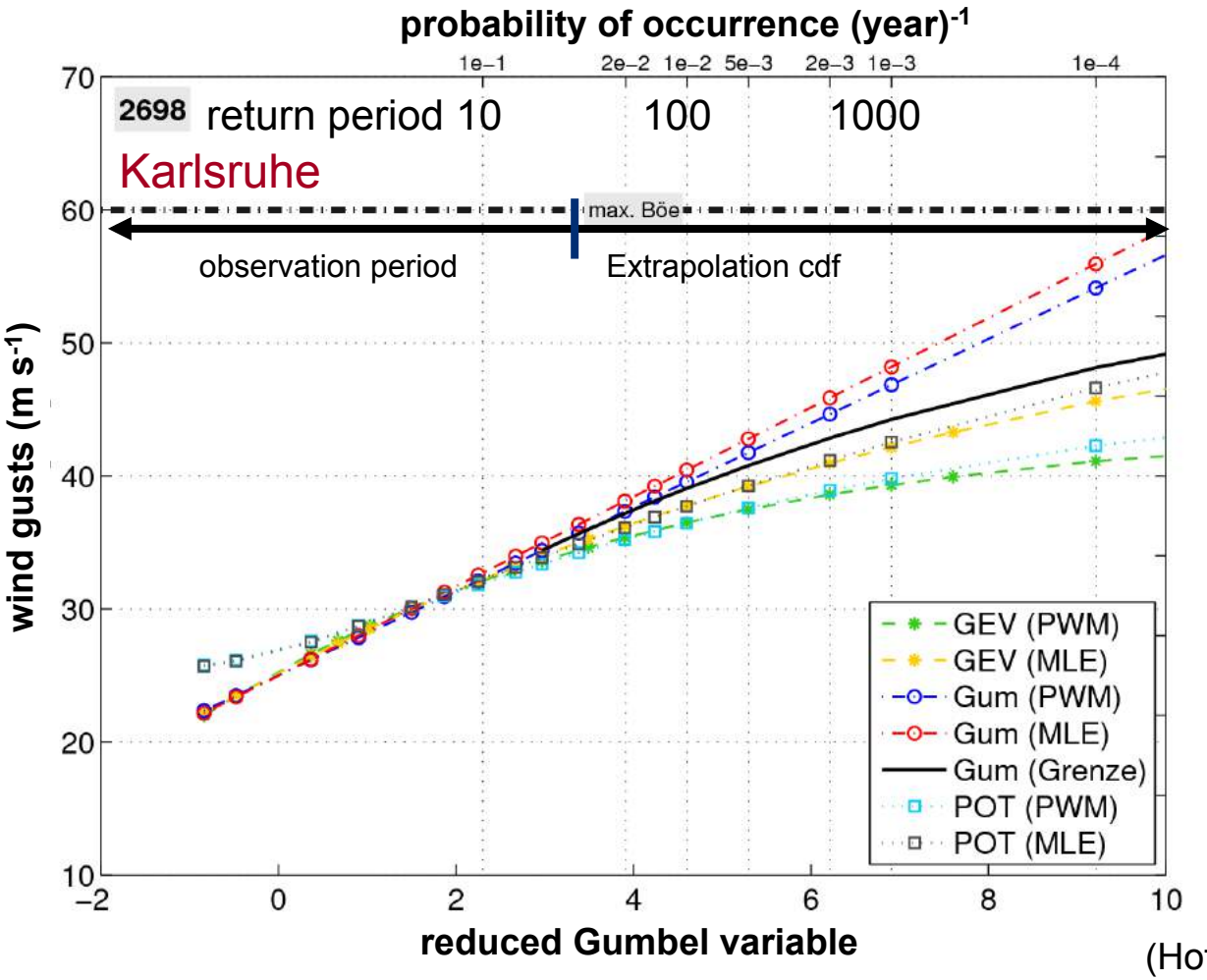
ξ: threshold



Hazard VI

- **Example:** Estimation gust wind speed vs probability using different methods (cdf and parameter estimator)

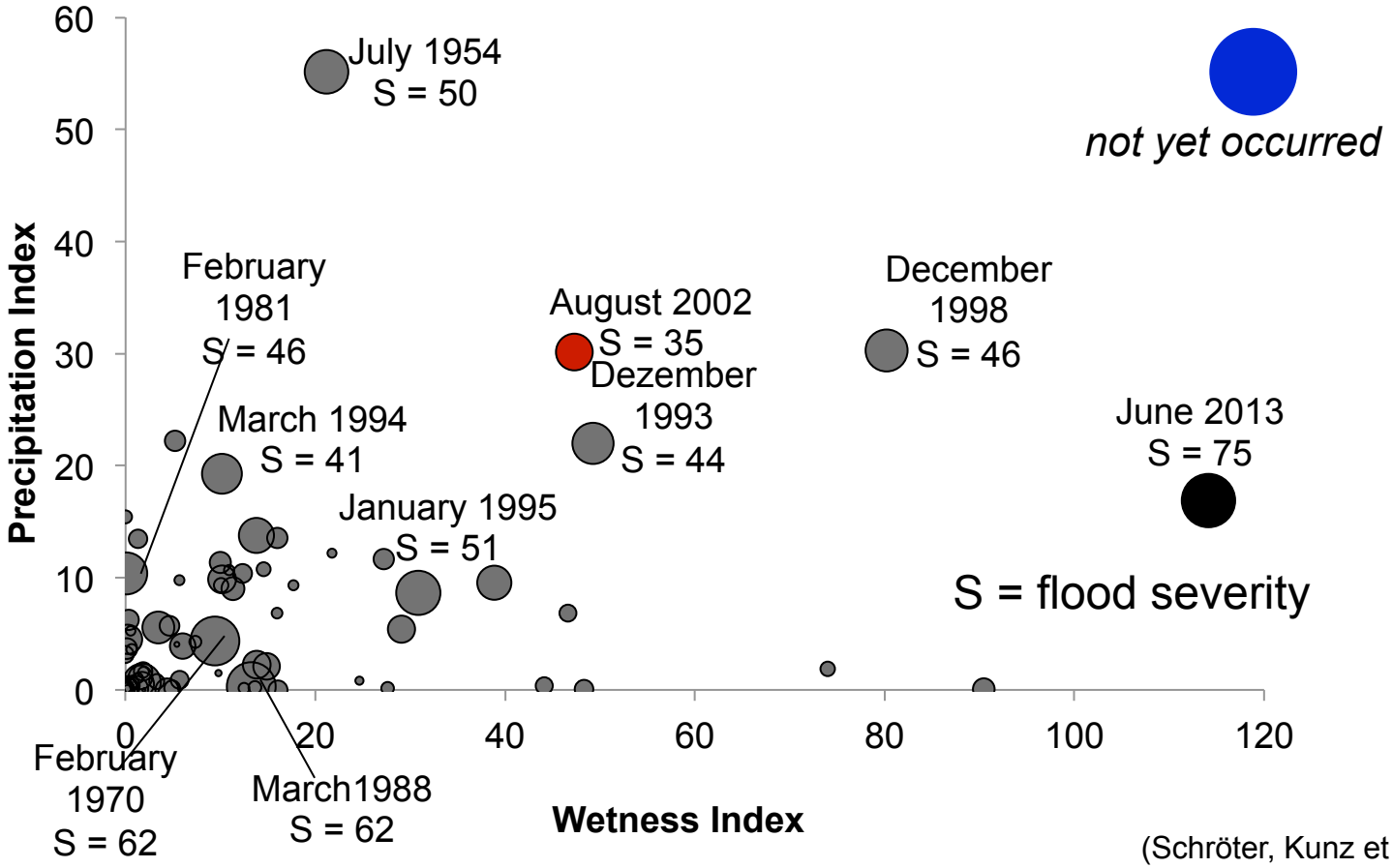
Example: Gusts at Karlsruhe



(Hofherr, 2010)

Hazard VII

- **Application Example**: Flood Hazard in Germany, 1961-2010
- Severity Indices: Accumulation grid points $S_X^k = \frac{1}{\Gamma}\sum_{i,j}\left\{\frac{X_{i,j}^k}{X_{i,j}^{5\text{ yr RP}}}\right\}\left| X_{i,j}^k \geq X_{i,j}^{5\text{ yr RP}}\right.$



(Schröter, Kunz et al., 2015)

Vulnerability I

Vulnerability

"The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." (UN ISDR)

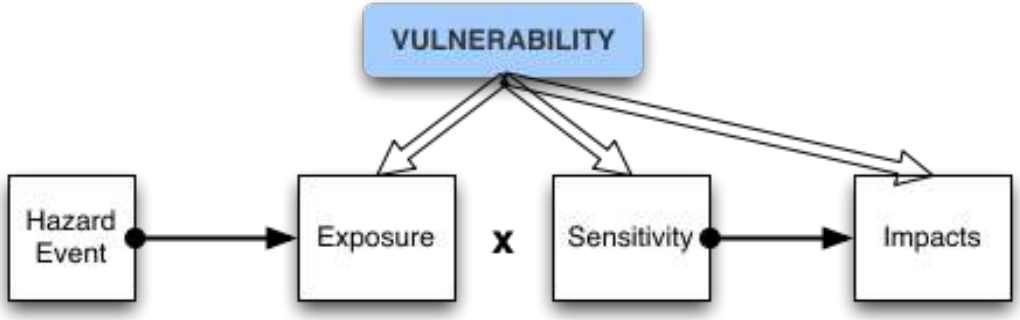
Many concepts of vulnerability and its causes!

Resilience

"The ability of a system, community or society exposed to hazards

- to resist, absorb, accommodate to and recover from the effects of a hazard
- in a timely and efficient manner,
- including through the preservation and restoration of its essential basic structures and functions." (UN ISDR)

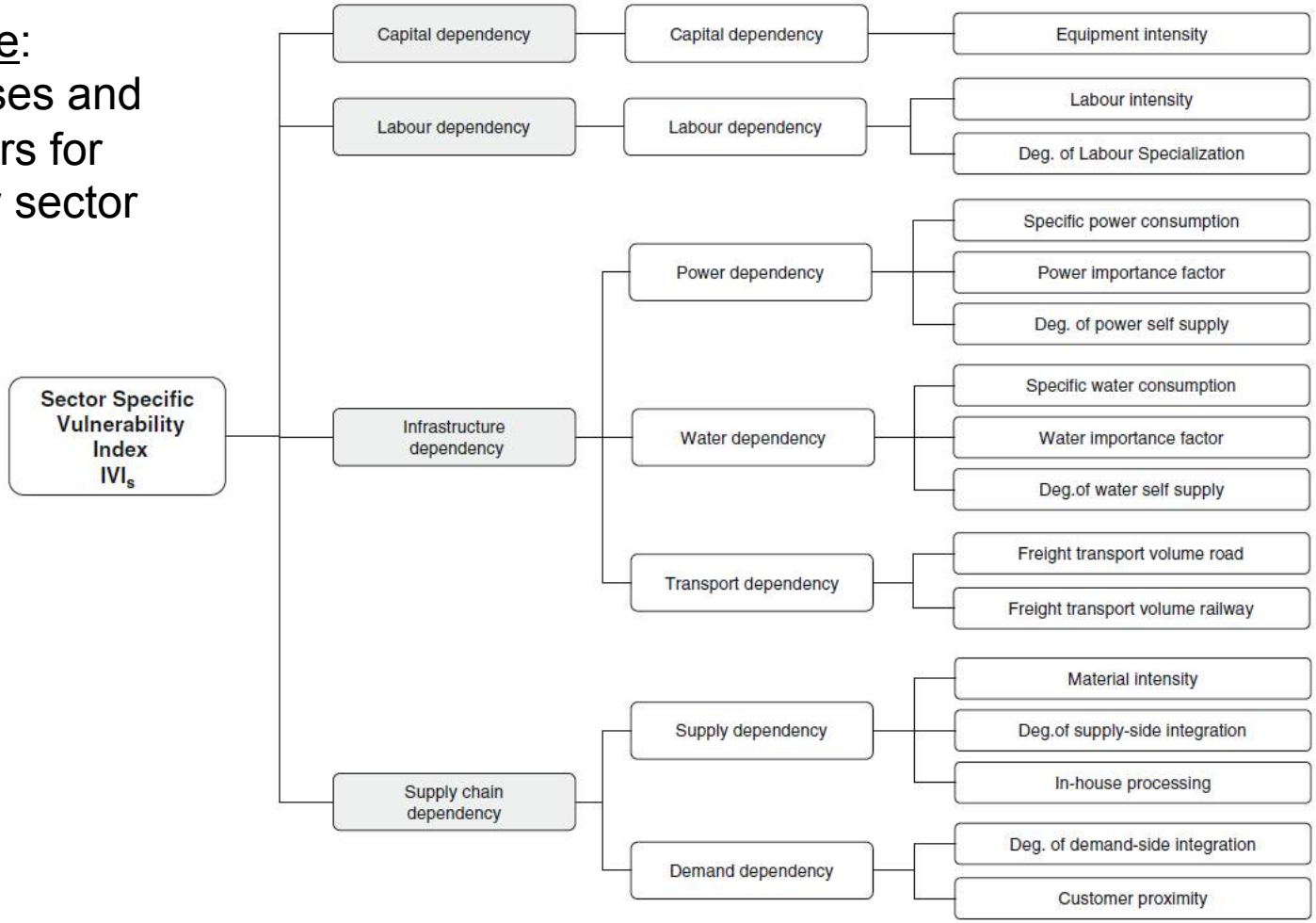
Risk-Hazard (RH) model, Turner et al. 2003



Vulnerability II

- Indicator-based CEDIM model for Social and Industrial Vulnerability

Example:
Processes and indicators for industry sector

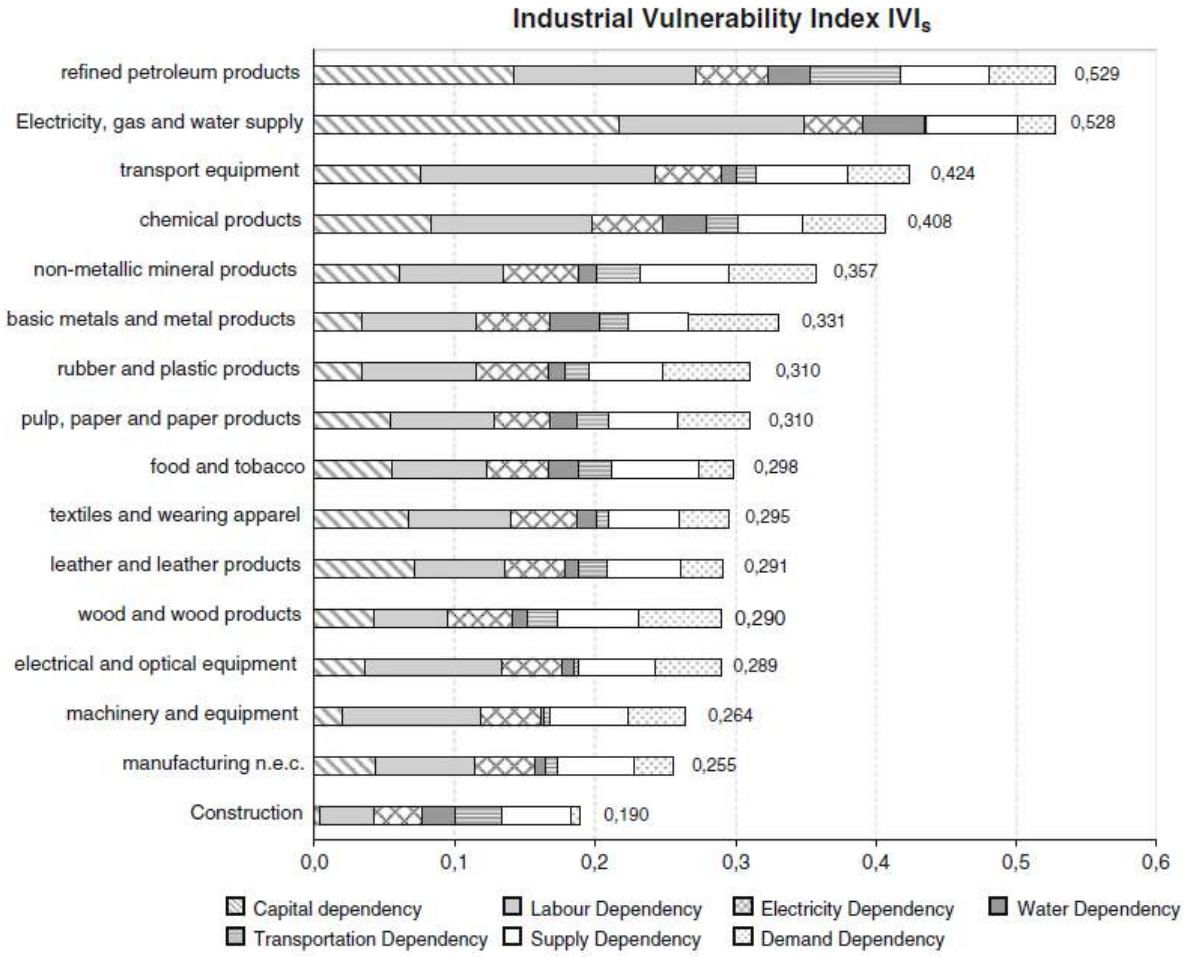


(Khazai et al., 2013)

Vulnerability III

- Indicator-based CEDIM model for Social and Industrial Vulnerability

Example:
Sector-specific industrial vulnerability

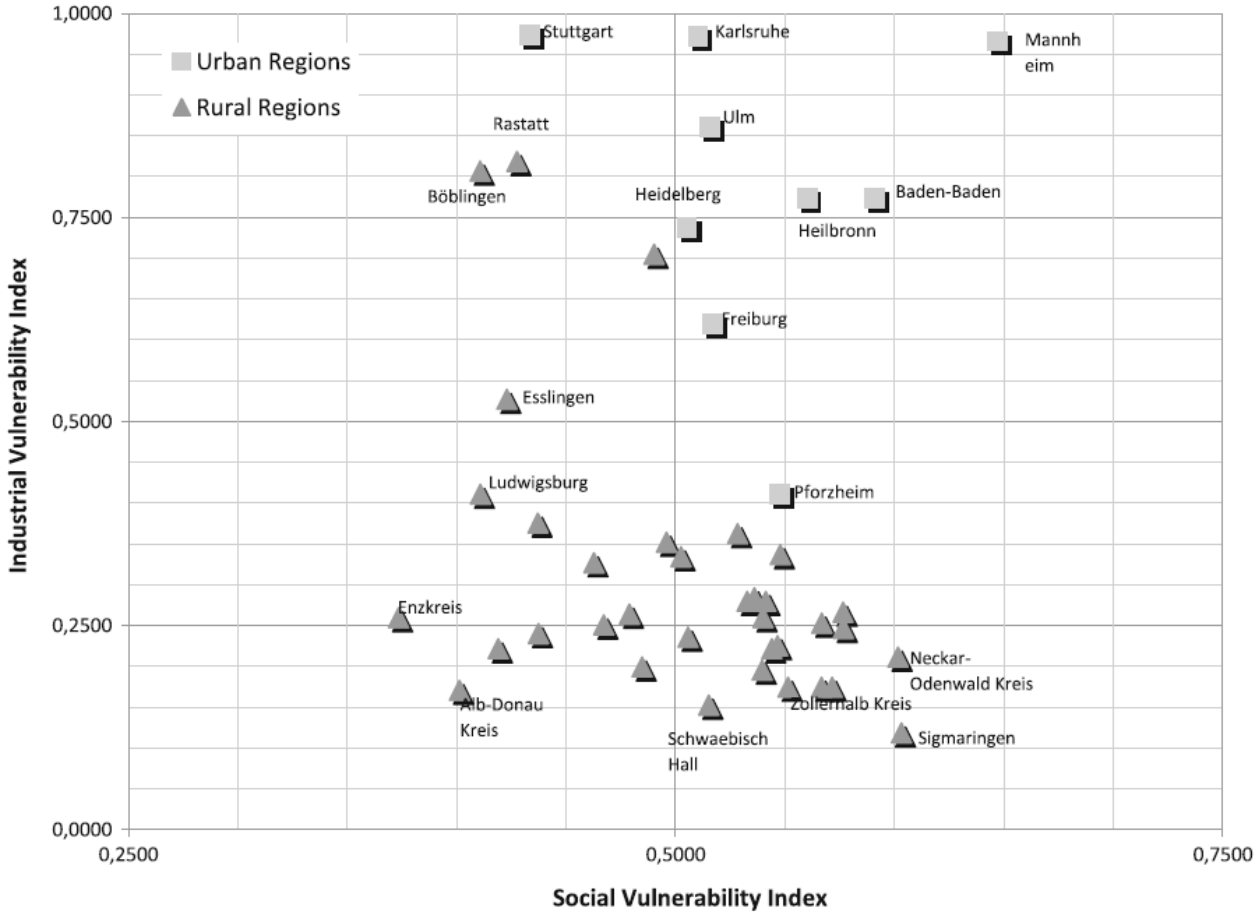


(Khazai et al., 2013)

Vulnerability IV

- Indicator-based CEDIM model for Social and Industrial Vulnerability

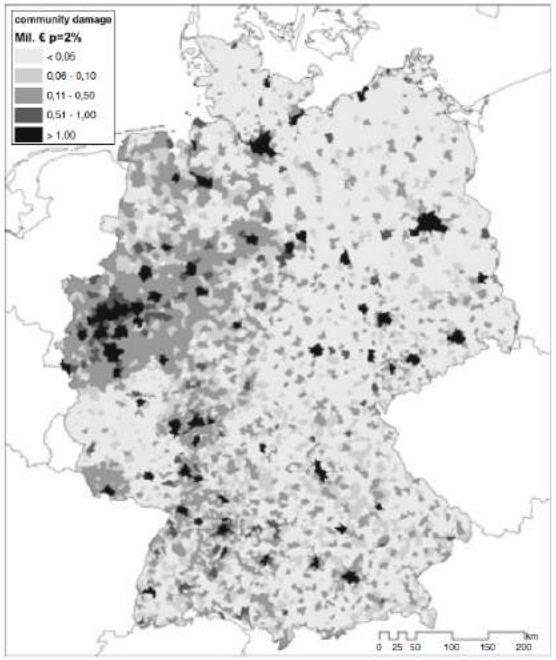
Example:
industrial & social vulnerability Indices BW



(Khazai et al., 2013)

Risk I

- Defined by Risk formula
  - Target figure: assets, money, life,…



Storm **risk** per community
p = 0.02
(Heneka & Hofherr, 2011)

$$R = G * V * E$$

Risk:
expected loss (economic loss, fatalities) caused by a damaging event

Hazard:
Probability of occurrence for a certain intensity of a certain extreme events in a certain area / location

Vulnerability + Exposure:
possible damage, which is related to an event; assets or human life affected; separation between economic and social vulnerability

Risk II

- Statistical quantity: required to
  - estimate **potential loss** for a certain portfolio (insurance business)
  - for **regulation process**: Solvency II requires PML200 (probable loss in 200 years)
  - to assess **precautionary** measures (e.g., development plans, building codes, training, shelters, early warning systems, …)
  - to design **technical protection** measures (e.g., levees, retention systems, supply systems)

- Statistical quantity vs. individual awareness → role of individual & society

Disaster I

What is a disaster?

"A serious **disruption of the functioning** of a community or a society causing widespread **human, material, economic or environmental losses**

which **exceed the ability of the affected** community or society **to cope** using its own resources."

(UNISDR, 2009)

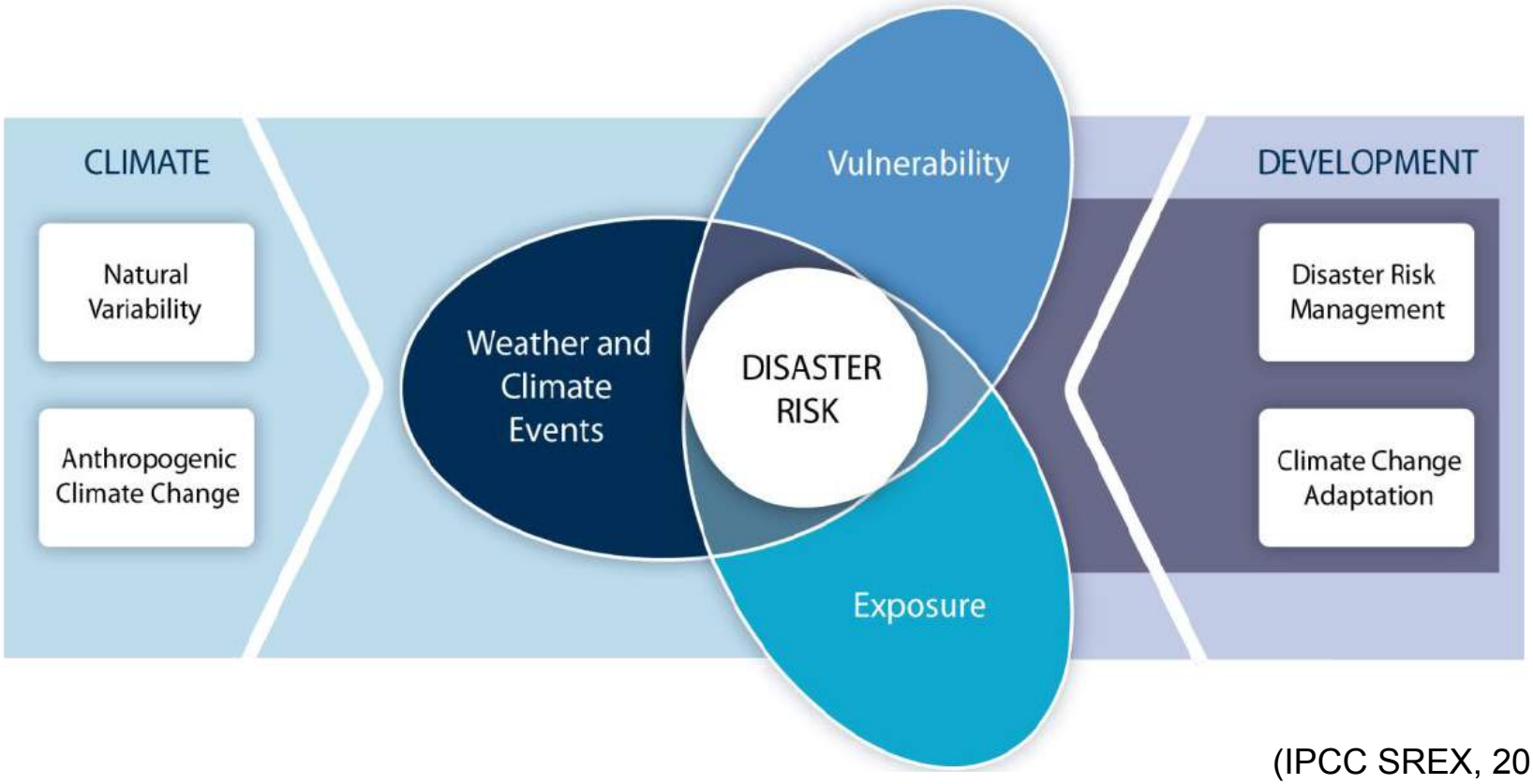
http://www.unisdr.org/we/inform/terminology

UNISDR
The United Nations Office for Disaster Risk Reduction

Other definitions are used, for example: an event killing *x* people.

Disaster II

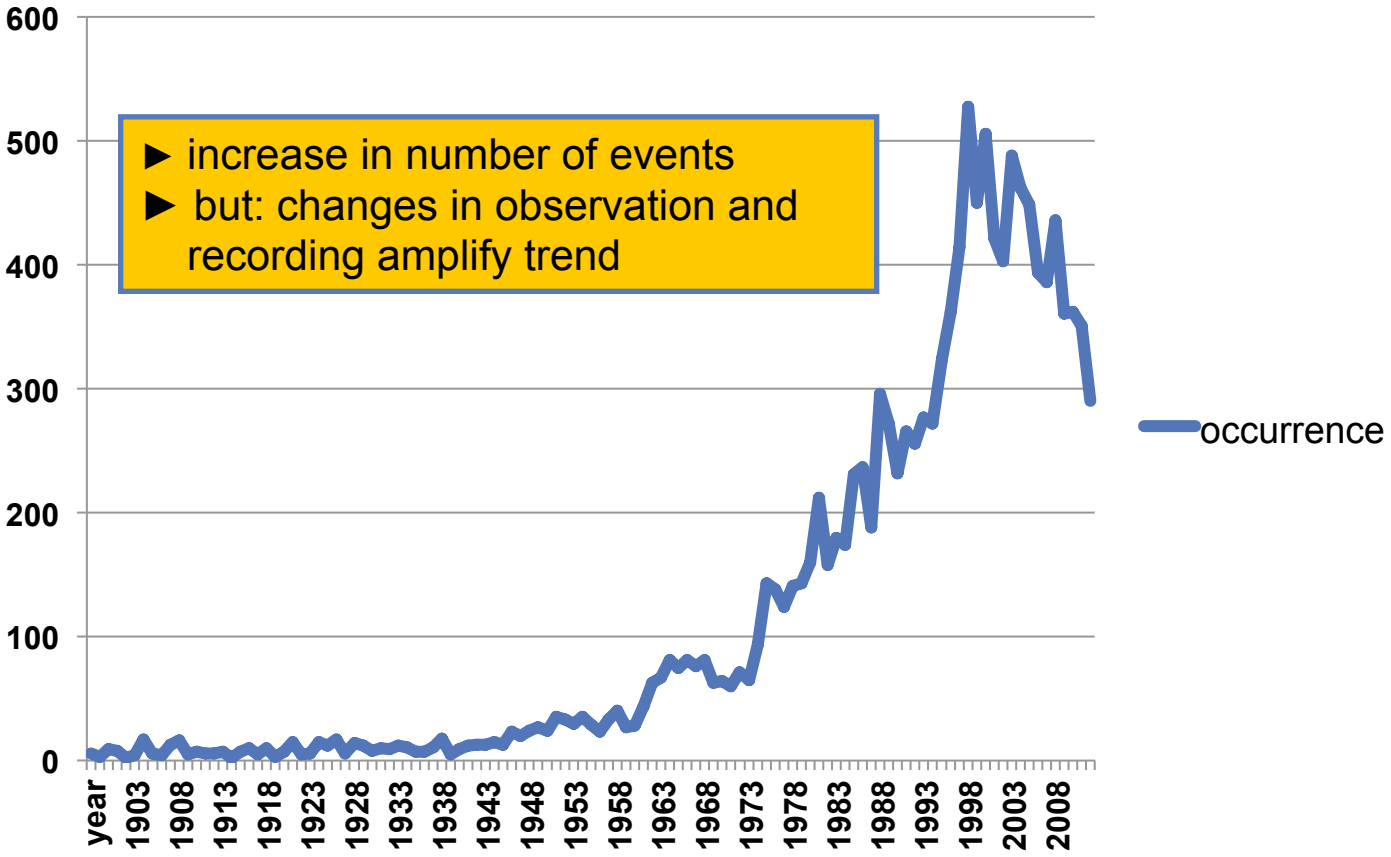
- Extreme event + vulnerability + exposure = **catastrophe** (?)
  - Boundary condition I: Societal reactions, Societal changes
  - Boundary condition II: climate variability (natural, anthropogenic)



(IPCC SREX, 2012)

Disaster III: Statistics 1900 - today

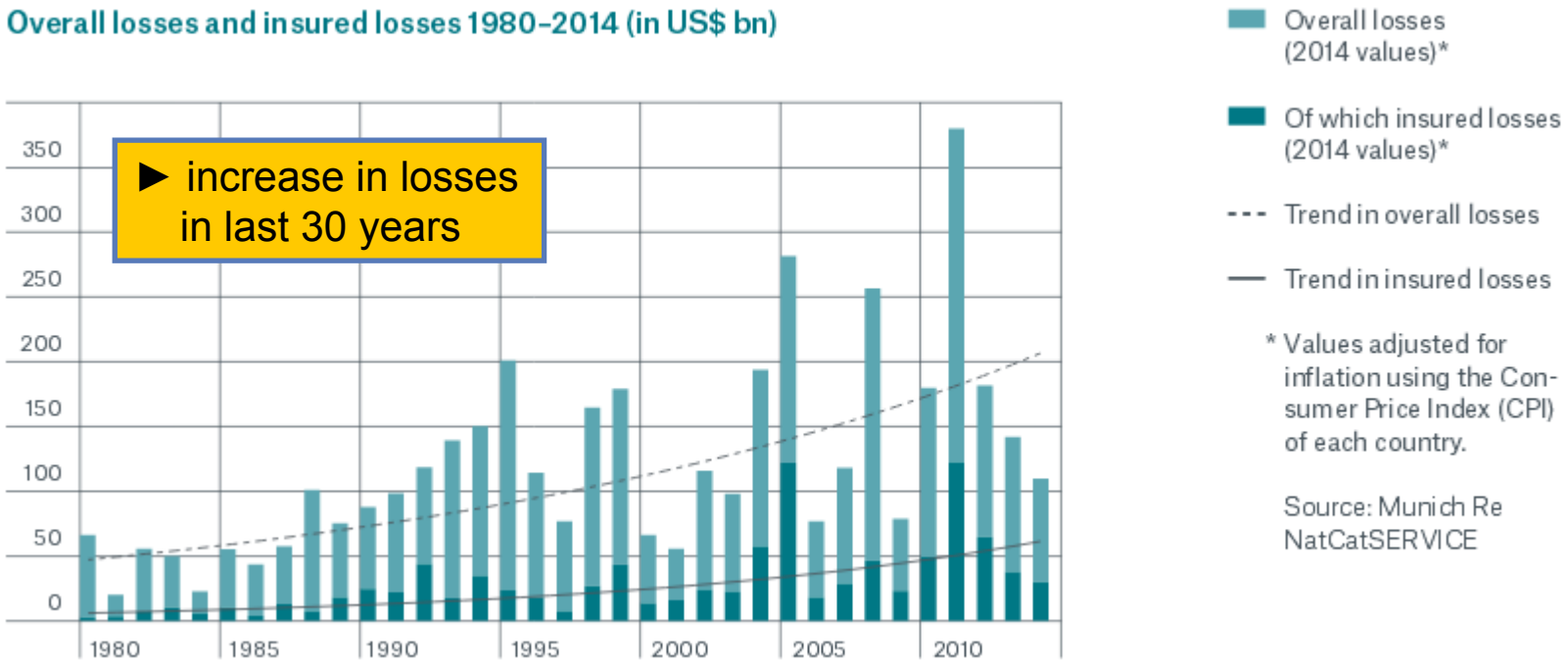
Number of natural disasters reported 1900 - 2014



Source: EM-Dat, the international disaster data base, CRED, Louvain, Belgium, www.emdat.be

Disaster IV: Statistics - last 30 years

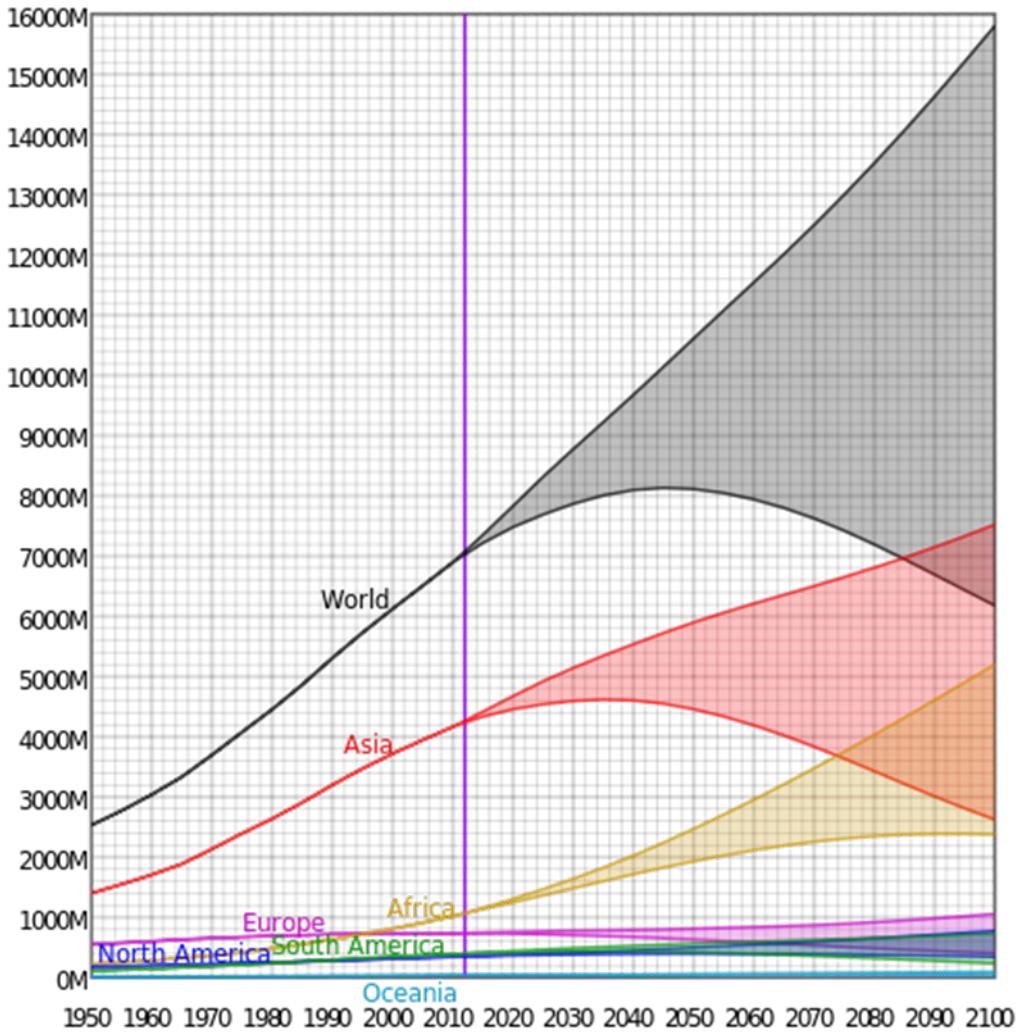
Overall losses (US$ bn) and insured losses 1980 - 2014 absolute values and long term trends



Source: Munich Re NatCatService, Topics GEO 2014

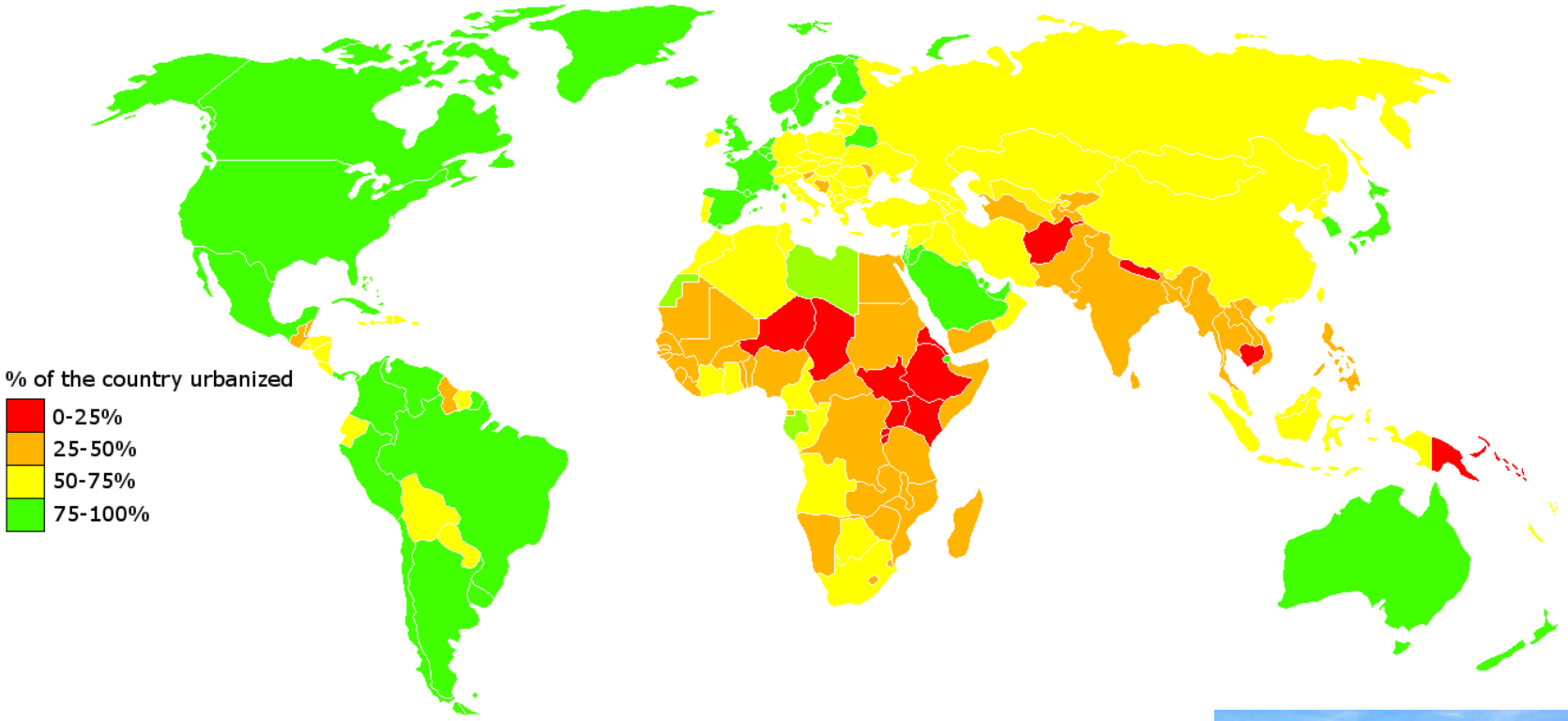
Global change I: Population increase

Estimated and projected populations of the world and its continents (except Antarctica) from 1950 to 2100.



Projections by the United Nations Department of Economic and Social Affairs. Data is from http://esa.un.org/unpd/wpp/unpp/panel_population.htm

Global change II: Urbanisation



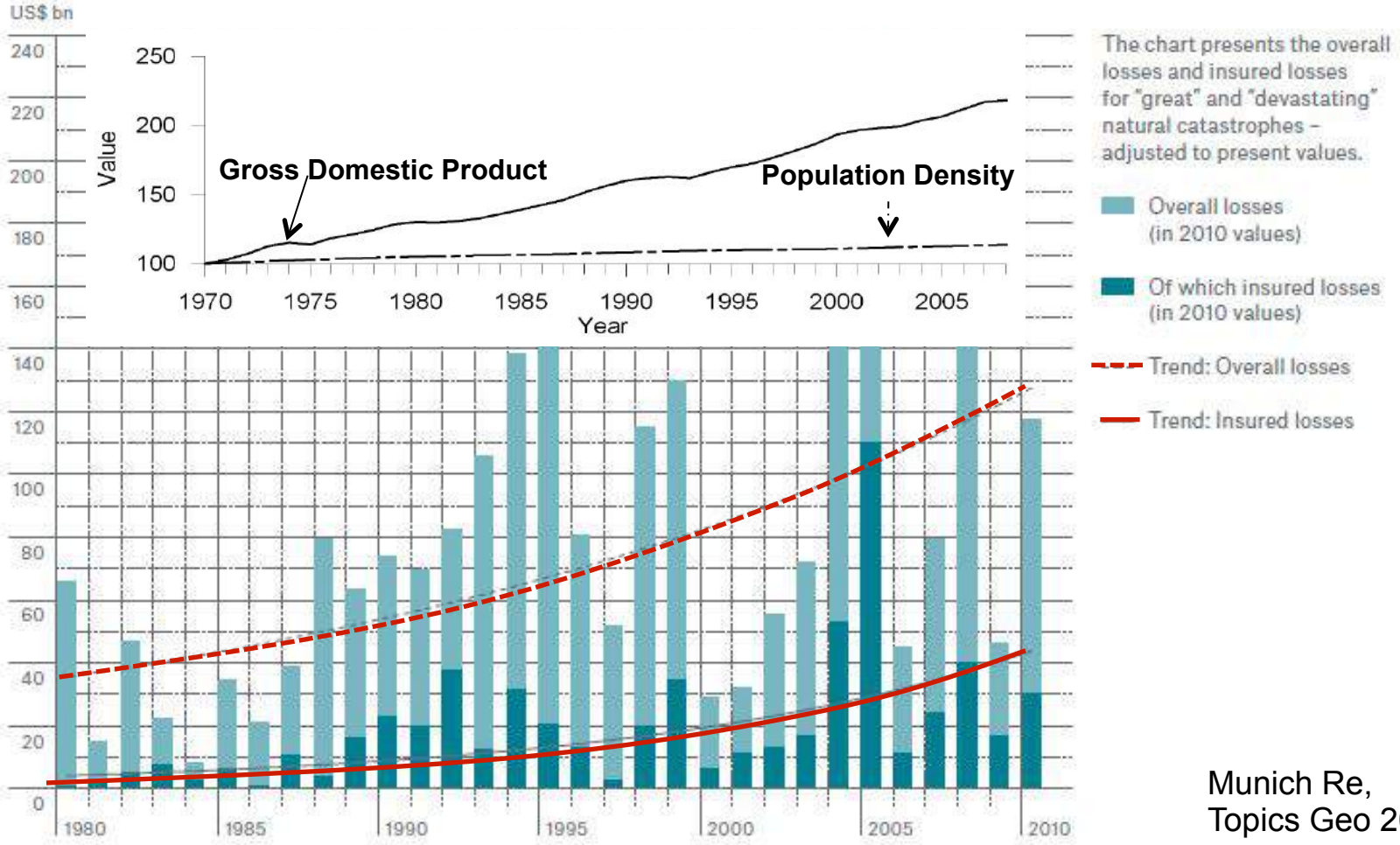
Global change III: Urbanisation

Rank	Name	Countriy	Continent	Million Inhabitants	Annual growth
1	Tokyo	Japan	Asia	35,68	0.60%
2	Jakarta	Indonesia	Asia	28,02	2.20%
3	Seoul	South Korea	Asia	25,60	1.40%
4	Shanghai	China	Asia	25,30	2.20%
5	Karachi	Pakistan	Asia	23,50	4.90%
6	Mexico City	Mexico	North America	23,20	2.00%
7	Delhi	India	Asia	23,00	4.60%
8	New York City	USA	North America	21,50	0.30%
9	São Paulo	Brazil	South America	21,10	1.40%
10	Mumbai	India	Asia	20,80	2.90%
11	Manila	Philippines	Asia	20,70	2.50%
12	Los Angeles	USA	North America	17,60	1.11%
13	Osaka	Japan	Asia	16,80	0.15%
14	Beijing	China	Asia	16,40	2.70%
15	Moscow	Russia	Europe	16,20	0.20%

Several Megacities highly exposed to hazards / disasters!

Global change IV: Economy

Overall losses (US$ bn) and insured losses 1980 – 2010

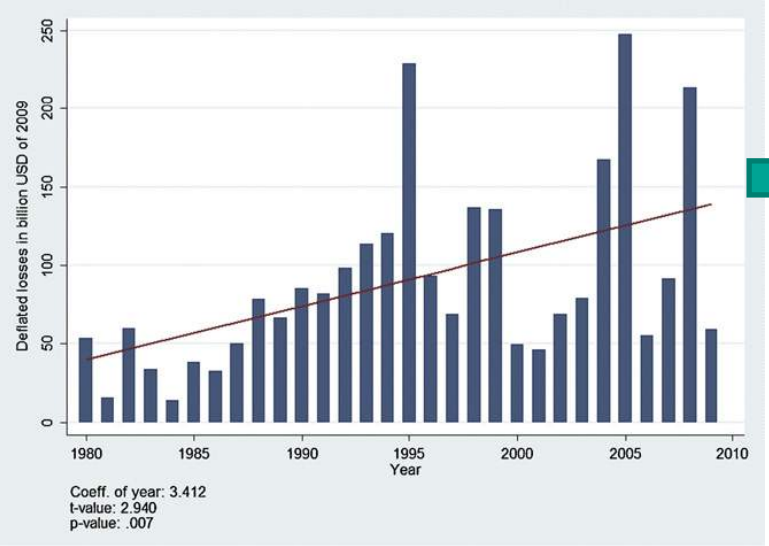


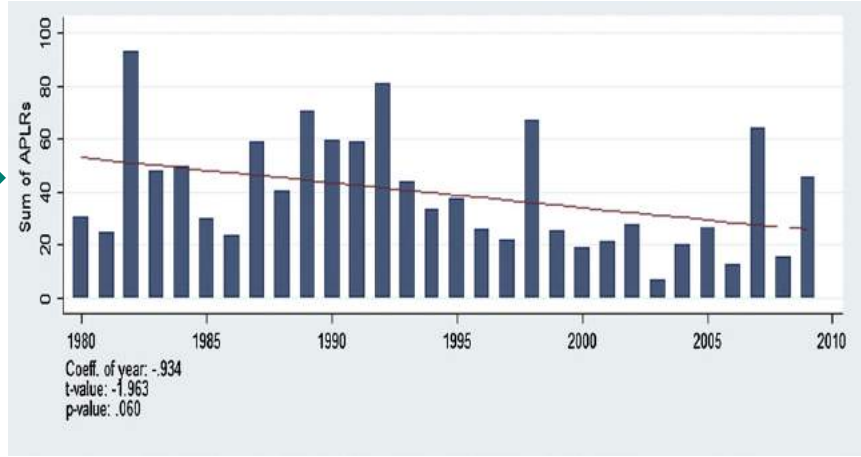
Munich Re,
Topics Geo 2010

Global change vs Risk

- Trend losses by natural hazards (global) and after normalization considering regional differences in development

$$ND_t = D_t \times (\text{Wealth}_t)^{-1}$$





(Neumayer and Barthel, 2010)

Global change vs Risk

- Trend losses by natural hazards (global) and after normalization considering regional differences in development

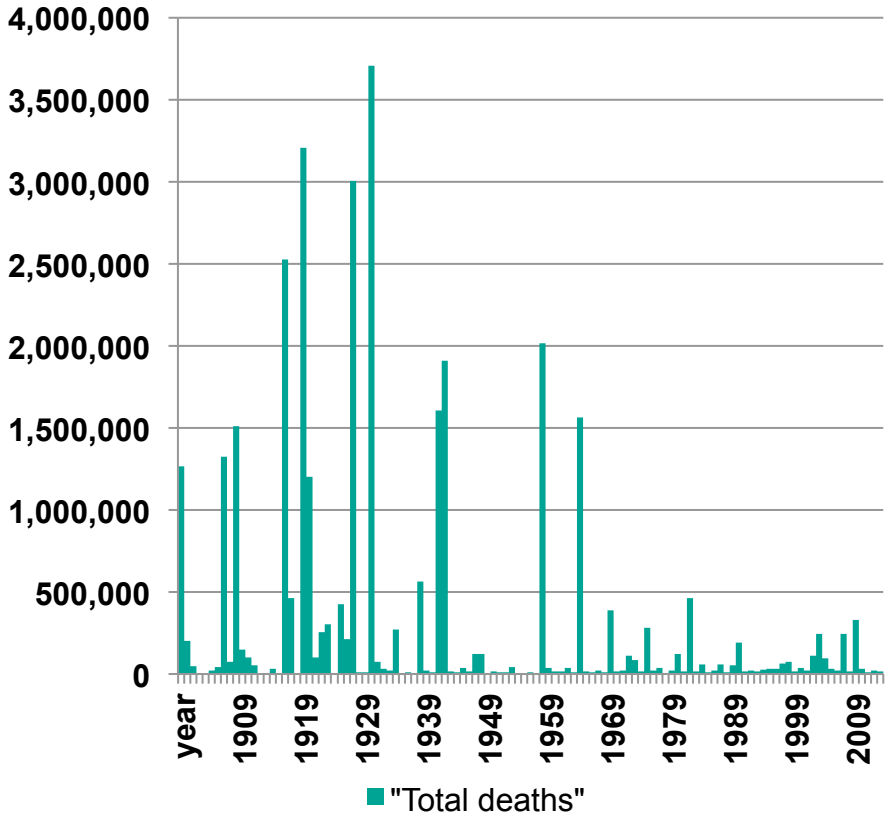
$$ND_t = D_t \times (\text{Wealth}_t)^{-1}$$

Contributing factors for increasing disaster losses

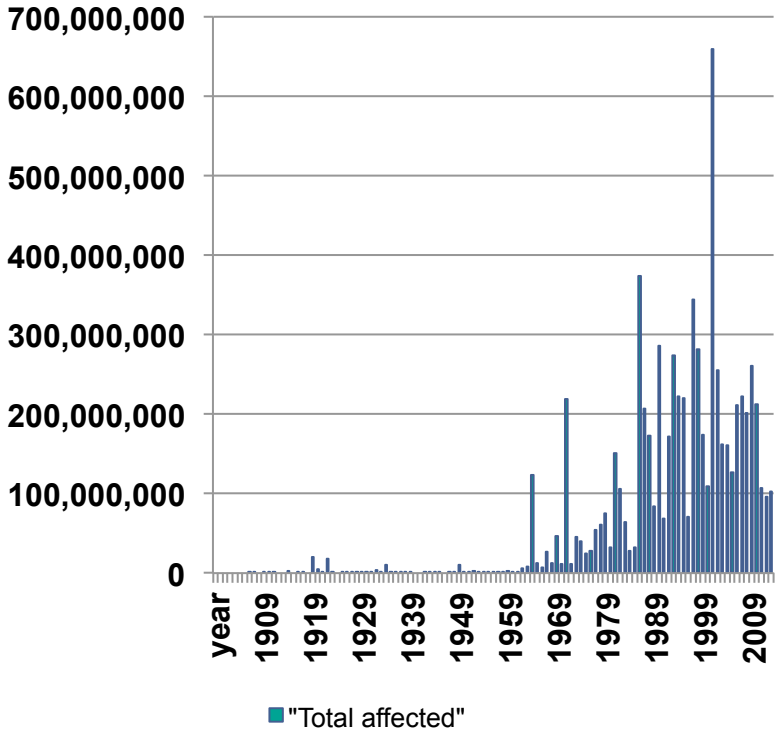
- ✓ population growth
- ✓ rising living standards
- ✓ spatial concentration of population and values in urban agglomerations / megacities
- ✓ settlement, land-use, industrialization of sensitive regions
- ✓ complexity of modern societies relying on technical infrastructures: growing interdependencies
- ✓ increase of extreme events due to climate change

Disasters: statistics and trends 1900 - today

Number of people killed in natural disasters 1900 - 2014

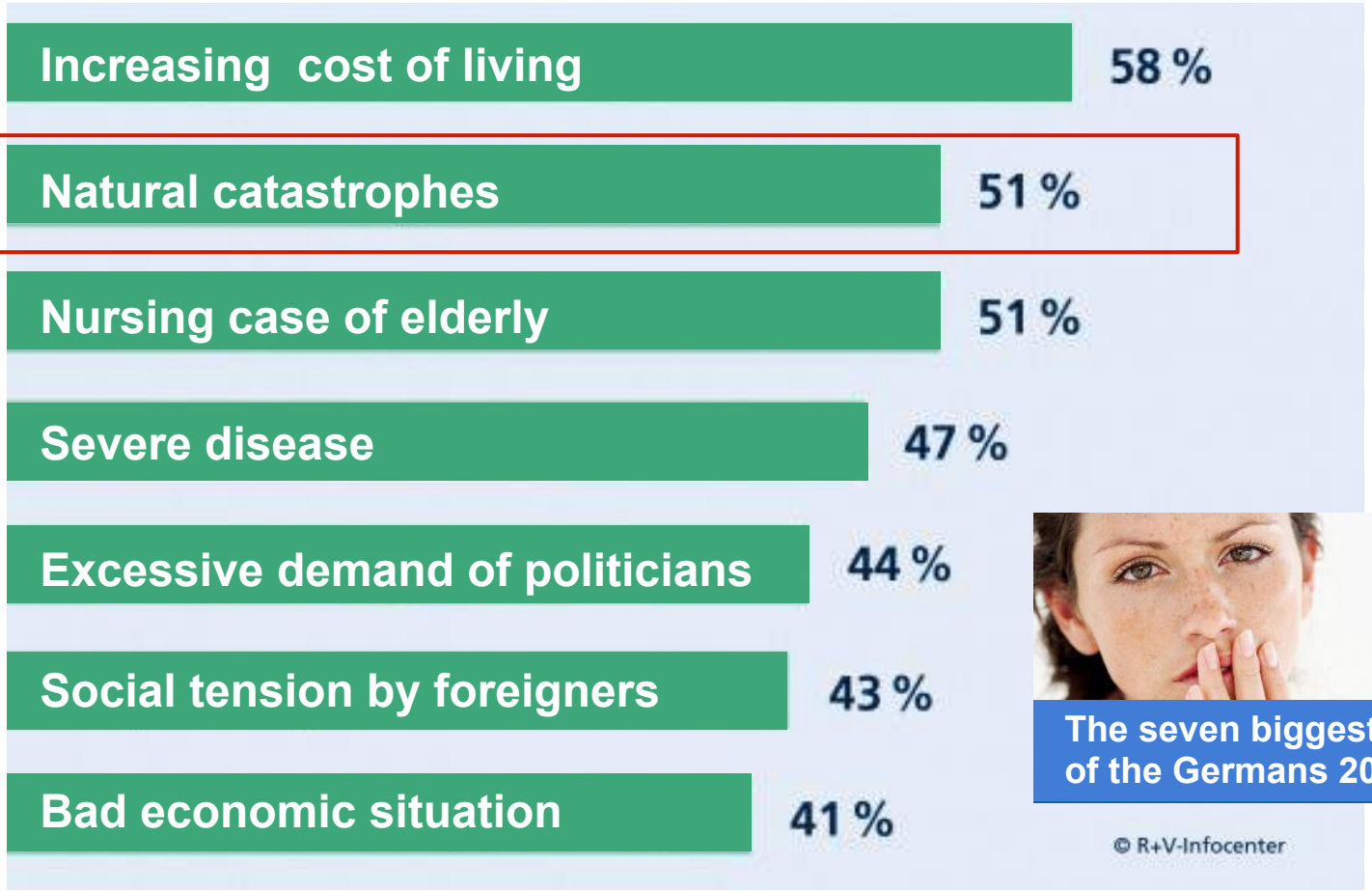


Number of people affected by natural disasters 1900 - 2014



Source: EM-Dat, the international disaster data base, CRED, Louvain, Belgium, www.emdat.be

Fears of Germans 2014…



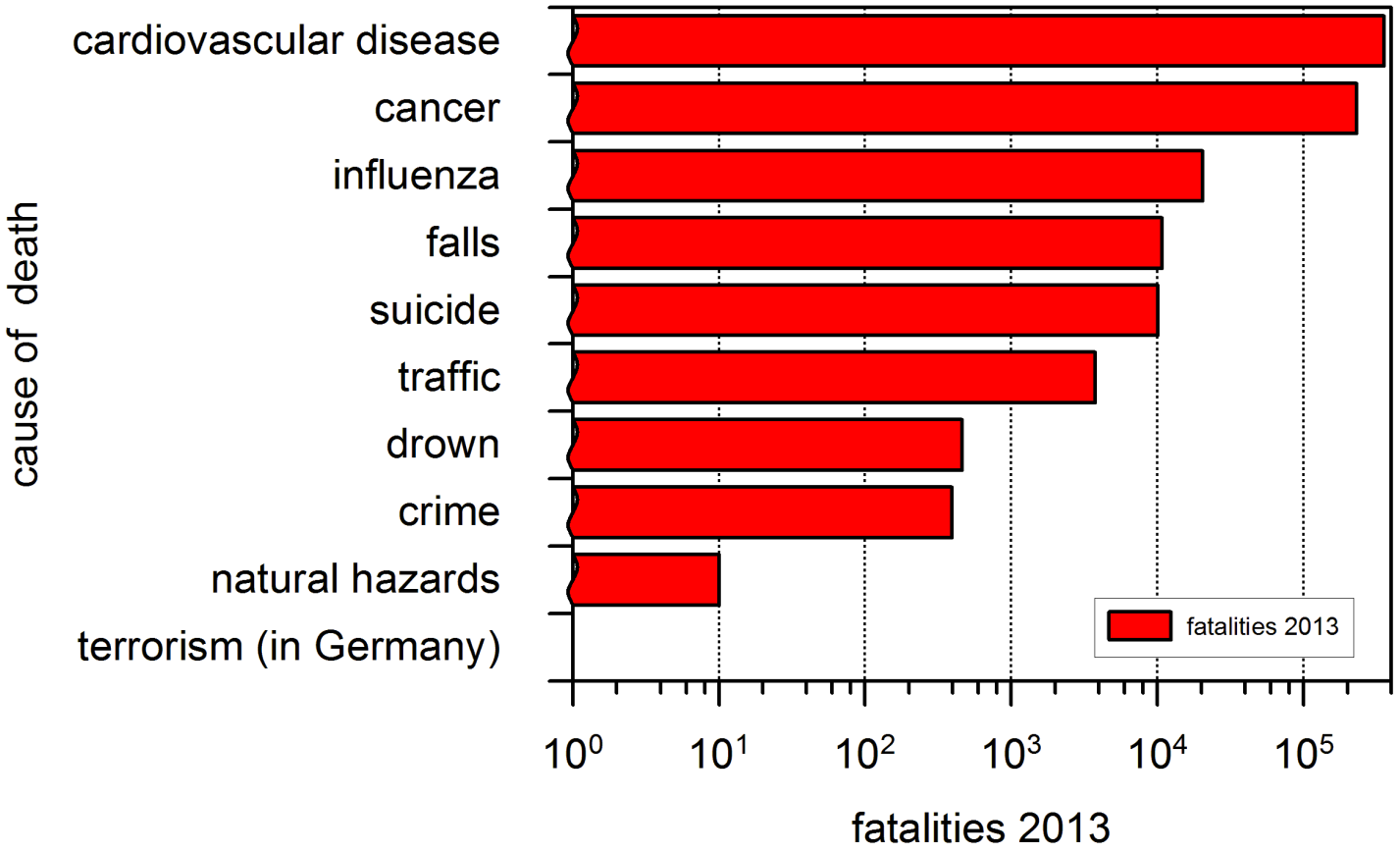
The seven biggest fears of the Germans 2014

Fears Baden-Württemberg 2014…

The seven biggest fears 2014 Baden-Württemberg

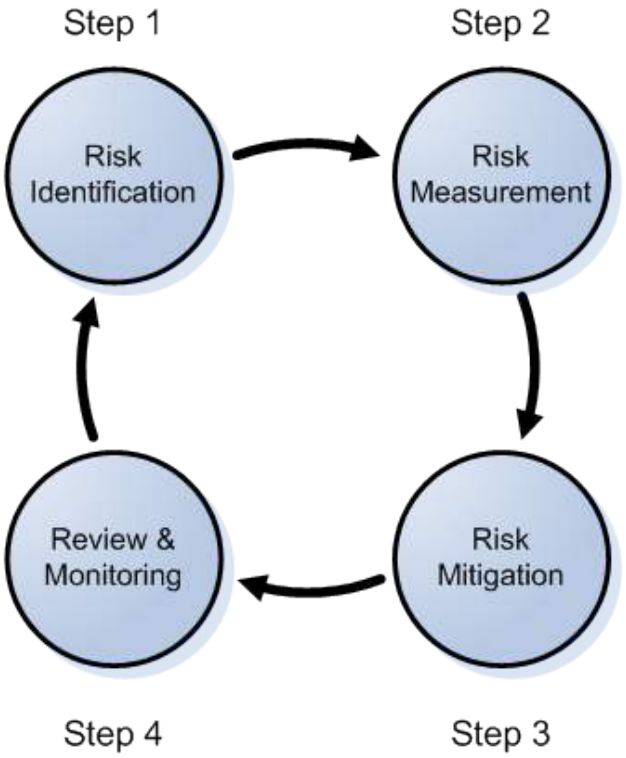
…and the Reality (fatalities)

- Causes of death in Germany 2013 (note the logarithmic scale on the x-axis!)



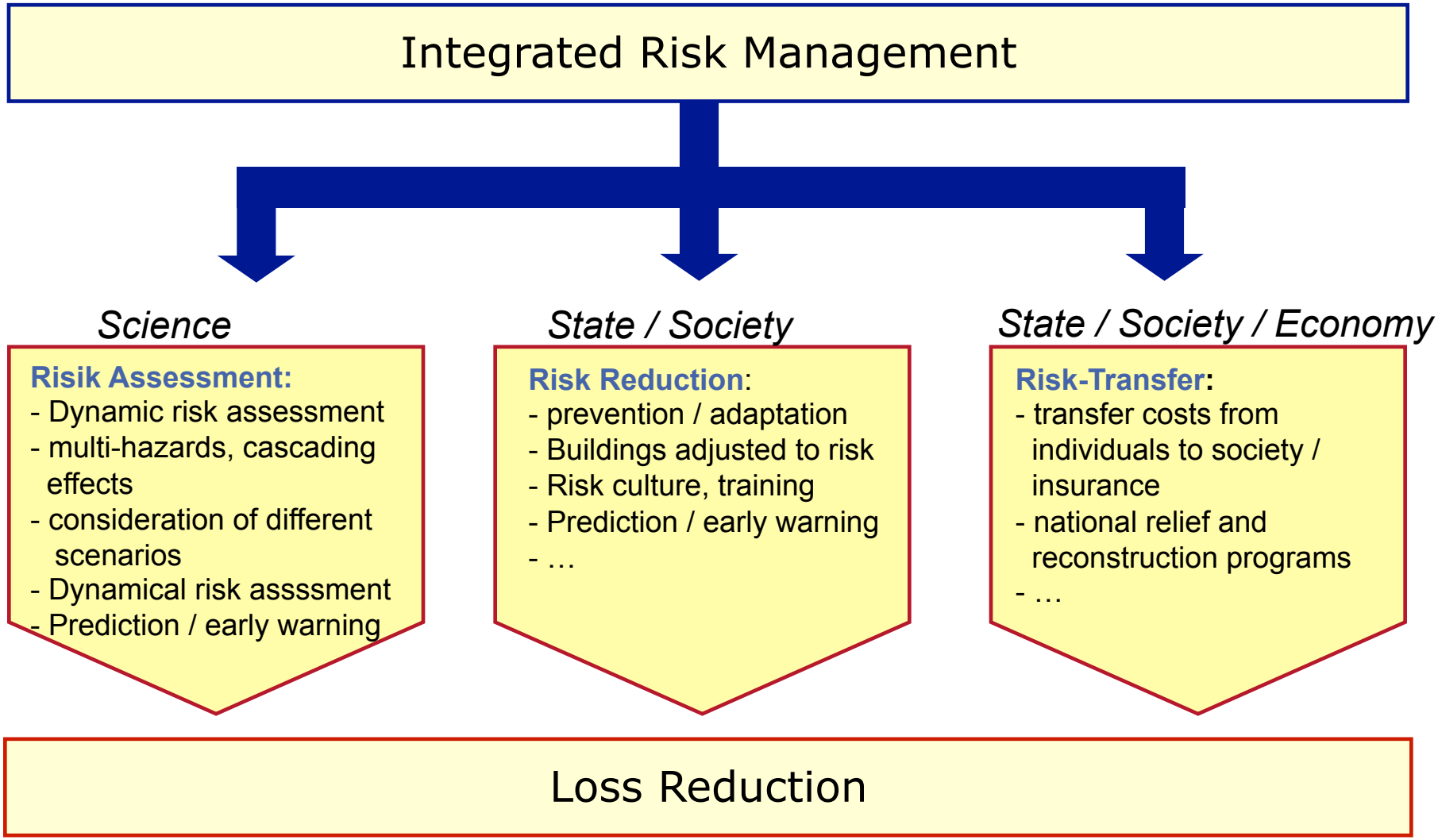
(source: Statistisches Bundesamt 2015)

Disaster Risk Management Cycle



► **idea of cycle vs. long-term development ?!**

Integrated Risk Management



Disaster Risk Management Research

- Requires interdisciplinary research
- Combination of
  - basic research for better understanding of natural events
  - applied research to develop technologies and / or tools that can be used in disaster risk reduction

… how can research in CEDIM contribute?

Main objectives of CEDIM:

- to advance the scientific understanding of natural and man-made hazards assessment,
- to develop disaster management solutions for the early detection and reduction of risk,
- to develop technologies and tools in the areas of risk communication, risk assessment and risk management
- To use the interdisciplinary competence / synergies and cooperate with emergency management institutions at various levels.

CEDIM – Center for Disaster Management and Risk Reduction Technology

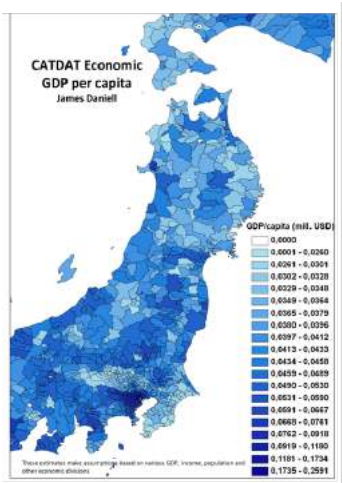
- A joint interdisciplinary research center by **KIT** and **German Research Centre of Geosciences GFZ** (until end of 2015)
- Founded in 2002
- **Staff:** appr. 30 scientists in 2015
- Consideration of whole process from natural disasters to engineering to impact on society

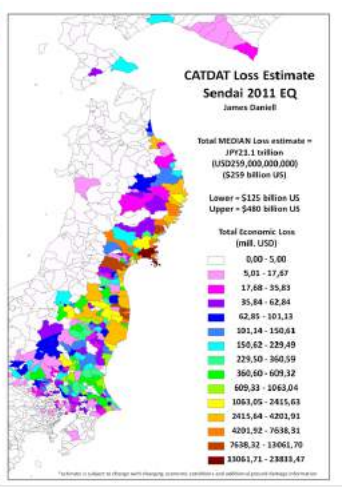
CEDIM Forensic Disaster Analysis (FDA)

- **Objectives**
  - Identifying relevant drivers for loss and risk, „event → disaster“
  - Analyzing interaction between systems and evolution of disaster over time
  - infer implications for disaster mitigation
- **Strategy**
  - Collecting available information and knowledge
  - Developing and applying methods and tools for rapid assessments
- **Research Mode**
  - Event-based and near-real time
  - Interdisciplinary in a team

CEDIM FDA: Scientific Questions

- Methodology according to Integrated Research on Disaster Risk (IRDR),
- CEDIM Near-Real Time Component





Critical **factors for losses** (life, socio-economic, infrastructure / facilities)**?**

Were **preventive measures** in place / sufficient?

Critical **interactions** of natural hazard event, social system – technical systems**?**

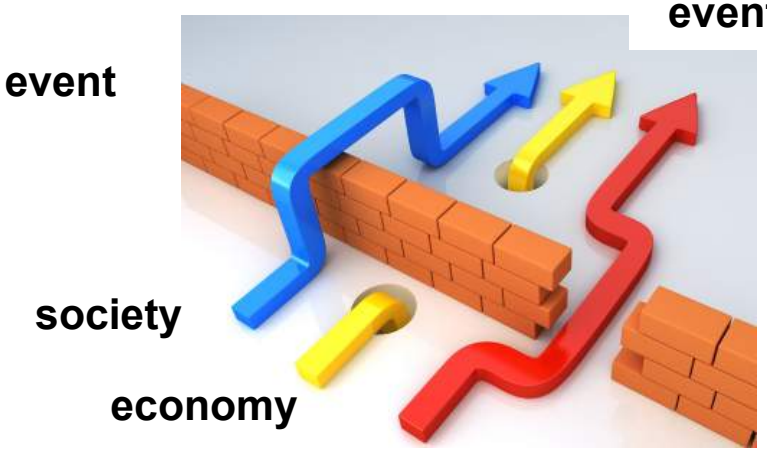
What can be **learnt** from past disasters**?**

Role of multi-hazards or cascading processes**?**

CEDIM Forensic Disaster Analysis (FDA)

- …**forensic**: scrutinize an event by combining methods from various disciplines
- …deep **event analysis**: interaction technique – human – society
- …CEDIM focus: **near real-time FDA**

Loss estimation, shelter needs, information gaps, comparison to historic events, lessons learned…



CEDIM Forensic Disaster Analysis (FDA)

Task Force *event-based*

R&D *development of models & methodologies*

Phase 1 (near real time event analysis):

Science based facts, application of own models and methodologies, data bases, expert knowledge

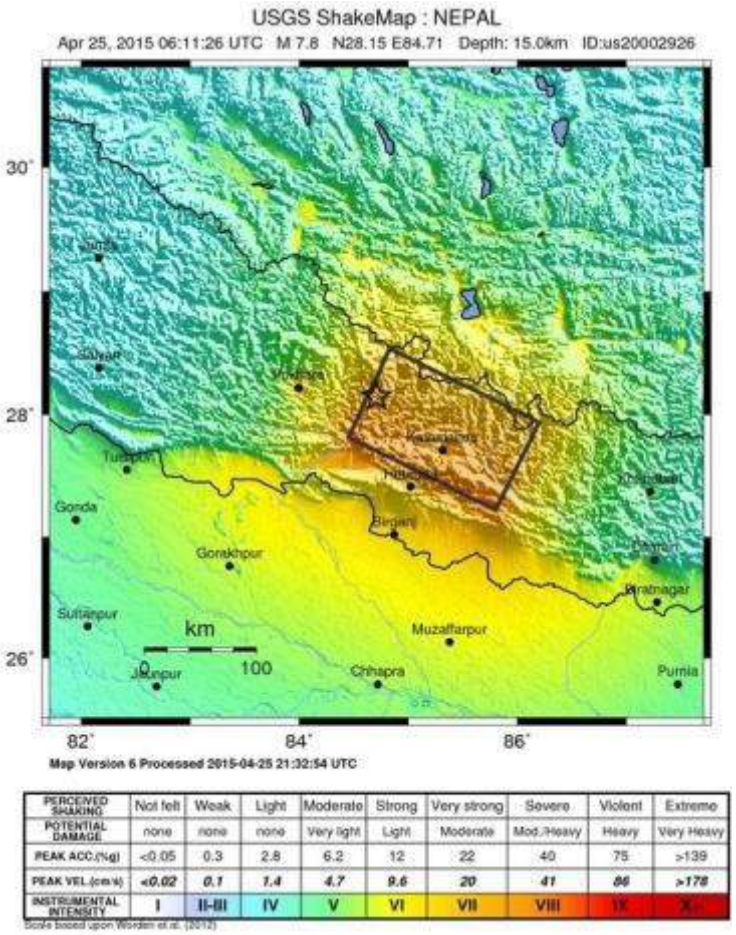
EQ (24 Apr.)	Report 1 27 Apr. 20:00	Report 2 5 May	Report 3 12 May	Field Mission 6-20 June	Report 4 17 July

Example: PDF process during Nepal earthquake

Phase 2 (in-depth analysis):

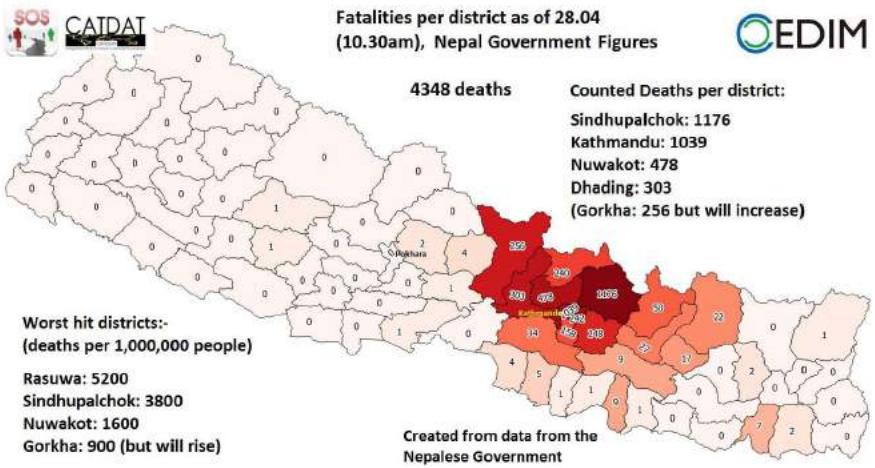
Event peculiarities (formation, development)
Key factors for impacts
Methodological developments
Field Experiment

CEDIM FDA Nepal Earthquake



USGS

- Earthquake: Sat, 25.4.15
- First impact report by CEDIM online Monday, 27.4. evening
- >5,000 Fatalities, > 10,000 Injured
- Many government, religious and private buildings destroyed.



http://reliefweb.int/sites/reliefweb.int/files/resources/Nepal%20Worst%20hit%20districts.pdf

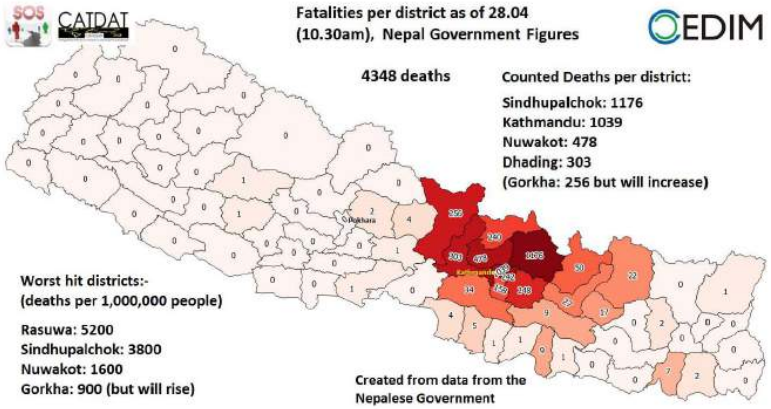
CEDIM FDA Nepal Earthquake

First rapid (!) estimation of economic loss (as of 27 April 2015):

- Damage 3-3.5 bn USD (CATDAT, James Daniell)
- Replacement cost totaling over 25% of the GDP

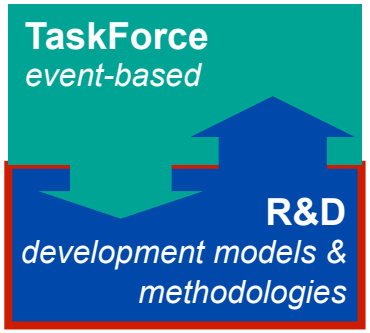
Focus of 2nd / 3rd reports

- Impact: social, general, economy, indirect damage
- Remote mountain areas: information, accessibility
- Landslides (destabilized slopes, upcoming monsoon season)
- Displacement and shelter

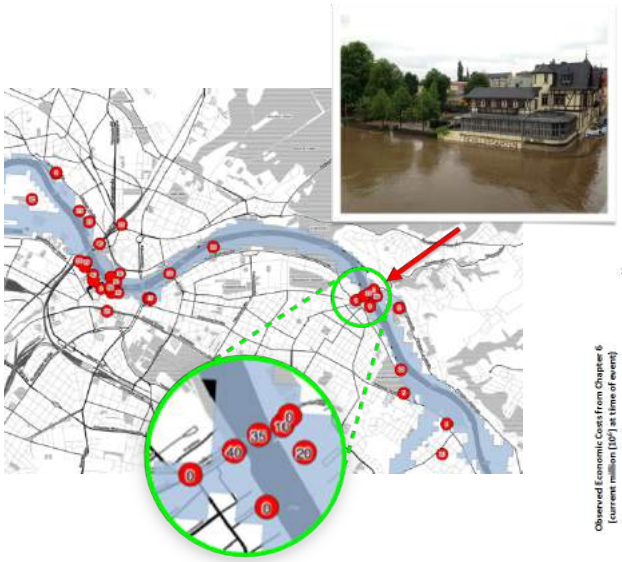


CEDIM Forensic Disaster Analysis

- Development of models and methodologies for rapid assessment of ongoing catastrophes (direct & economic losses, fatalities, shelter models, early warning systems, information gap analysis, causal loss analysis,…)
- New: International Center of Excellence (ICoE) IRDR



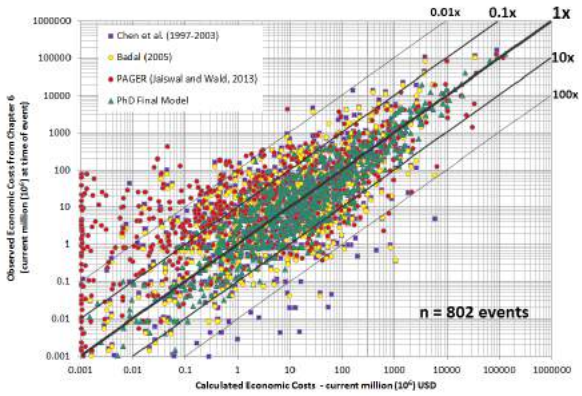
Examples of CEDIM projects

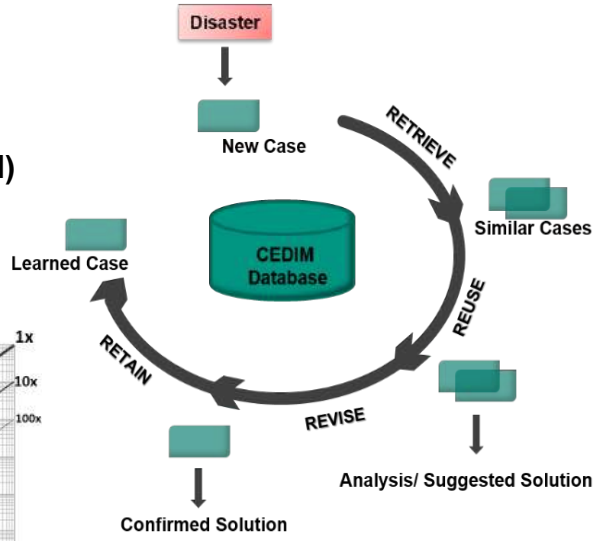


Crowd sourcing: estimation intensity (A. Dittrich, IPF)

Impact model, based on
> 10.000 hist. events
+ economic data (J. Daniell, GPI)

CATDAT
Integrated Historical Global Catastrophe Database





Case-based reasoning: impact assessment using attributes (S. Möhrle, IKET)

Conclusions

- Large range of temporal & spatial **scales/variability** of extreme events; relevant for impact, but also protection measures
- **Risk** = Hazard x Vulnerability x Exposition; Statistical quantities
- **Disaster** (Risk): Societal & Individual Components, Risk awareness
- Almost every year disasters triggered by extreme natural events cost many lives (not in Germany!) and lead to high economic losses
- Disasters tend to **increase** in terms of: Numbers & Losses
- Contributing factors of **global change**:
  - socio-economic changes, technical development, climate change
- **Integrated Risk Management** necessary, will become even more important for the future

More about CEDIM: www.cedim.de

Thank you for your attention!