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Water-related disaster management

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and

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Contents:

1. **Mechanisms of extreme events**
2. **Odra/Oder and Labe/Elbe floods revisited**
3. **Global change impacts**
4. **Management options**

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Poznań (Poland)

Mean June precipitation:	61 mm
June 1992:	3 mm
7 July 1997:	60 mm

Water management has to cope with three problems related to water:

- **too little**
- **too much**
- **too dirty**

All these problems, in acute form, may lead to disasters.

Other disasters related to freshwater, which will not be considered here:

Landslide

Mudflow

Snow avalanche

Accidental pollution

Droughts

Driving forces

Atmospheric circulation patterns

Rainfall deficiency

Temperature

Catchment storage

Socio-economics – water extraction and use

Drought:

meteorological (precipitation)

agricultural (soil moisture)

hydrological (surface waters: streamflow droughts – river stage, stream flow; lake level; groundwater – groundwater level)

economic (losses)

Hydrological drought

possibly exacerbated by Man

(over-abstraction, mis-management)

A combination of meteorological drought and human activities (such as overcultivation, overgrazing, deforestation) has led to **desertification** of vulnerable areas, where soil and bio-productive resources become permanently **degraded**

Droughts

Water supply problems (agriculture, industry, municipal water) - damages

Malnutrition, famine

Ecological consequences

Wildfire

Water quality

Floods – causal mechanisms

Intense / long-lasting precipitation

Snowmelt

Sealed land surface (e.g. rain on ice)

Flow obstruction (e.g. ice jam, landslide)

Dam failure

Storm surge

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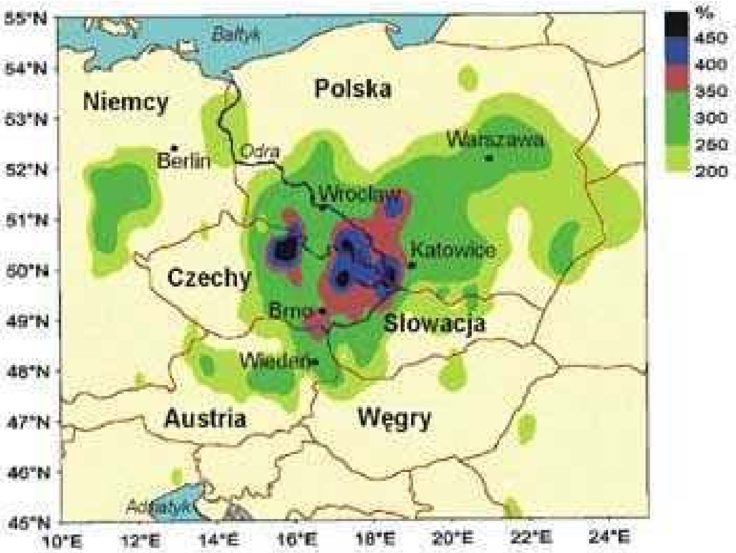

55°N
54°N
53°N
52°N
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49°N
48°N
47°N
46°N
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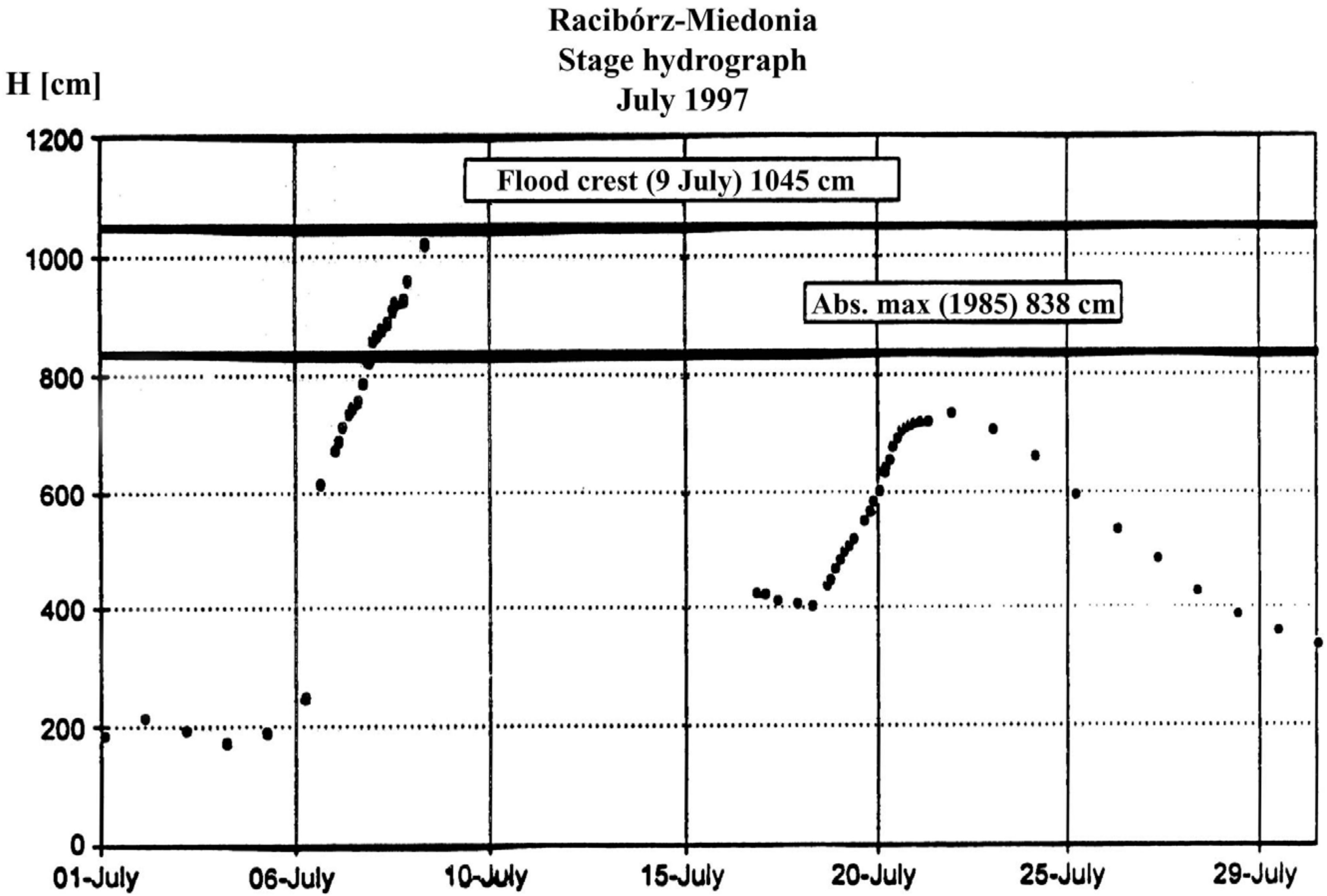
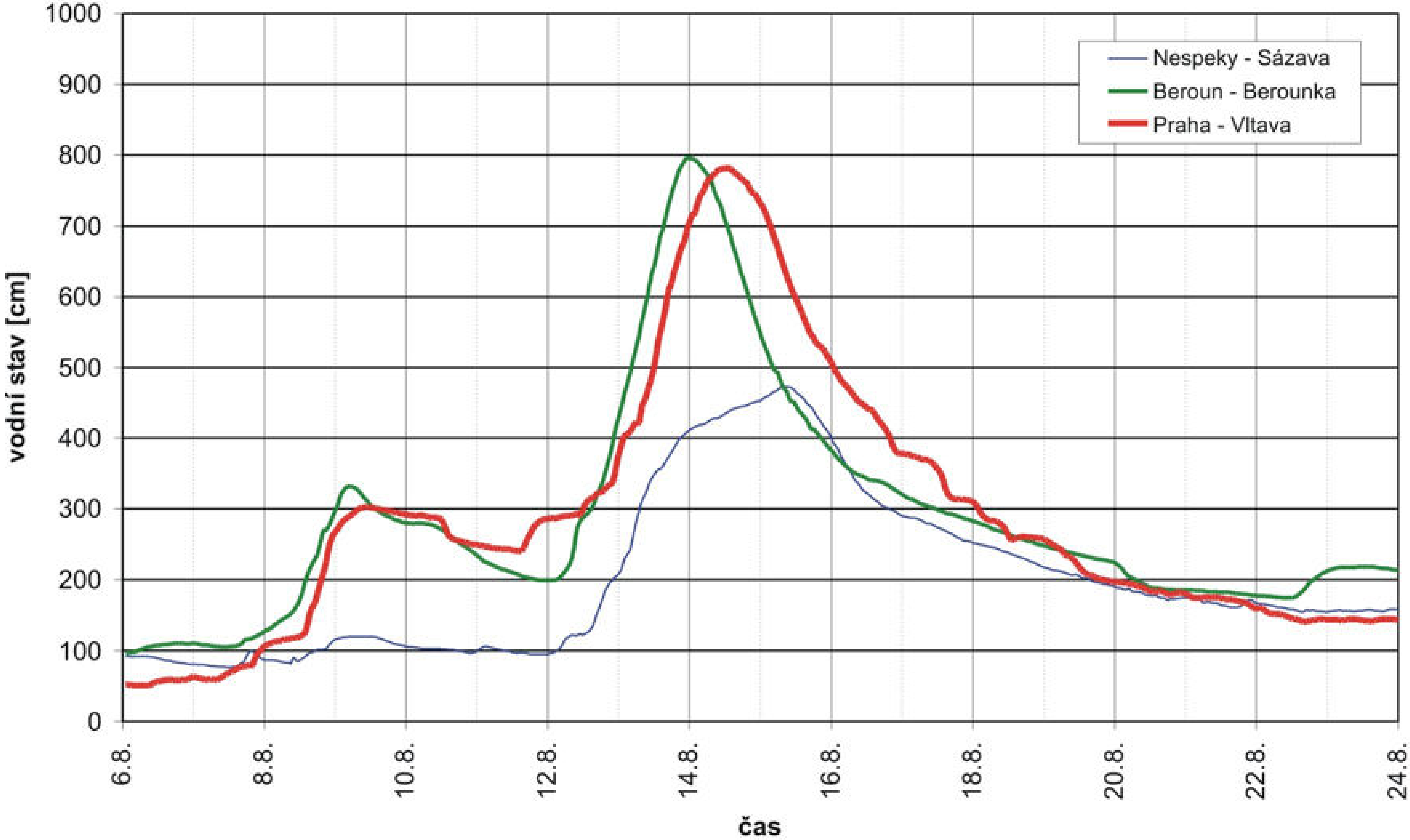
10°E
12°E
14°E
16°E
18°E
20°E
22°E
24°E
%
450
400
350
300
250
200
Bałtyk
Niemcy
Polska
Berlin
Odra
Warszawa
Wrocław
Katowice
Czechy
Brno
Słowacja
Wiedeń
Austria
Węgry
Adriatyk

Summer 1997

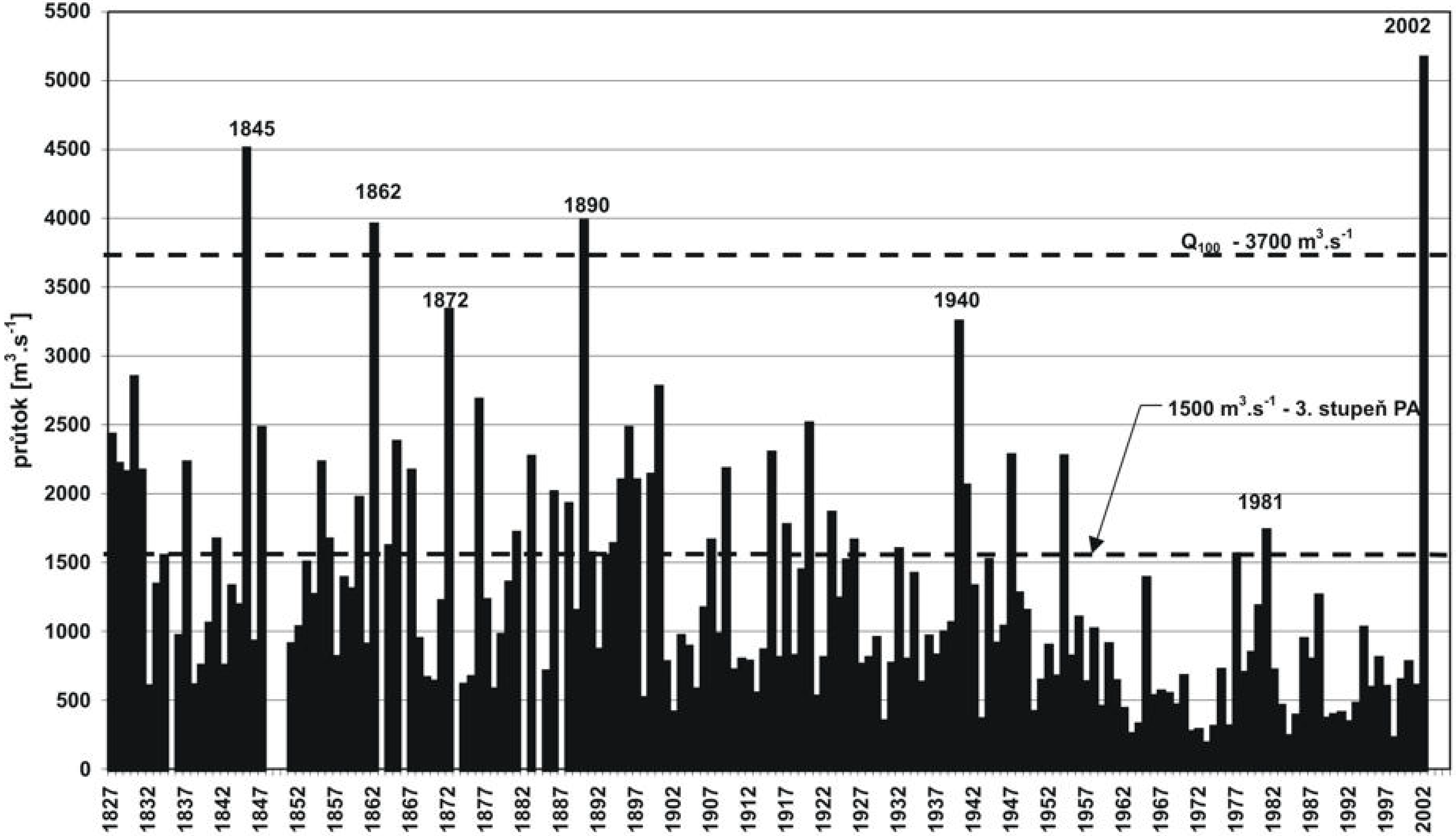
20 lipca 1997
RANKING POLITYKÓW
AMBITNI Z ZAZDROŚCI
NR 29
Cena 2 zł
wprost
KLĘSKA


Racibórz-Miedonia
Stage hydrograph
July 1997
H [cm]
1200
1000
800
600
400
200
0
Flood crest (9 July) 1045 cm
Abs. max (1985) 838 cm
01-July
06-July
10-July
15-July
20-July
25-July
29-July

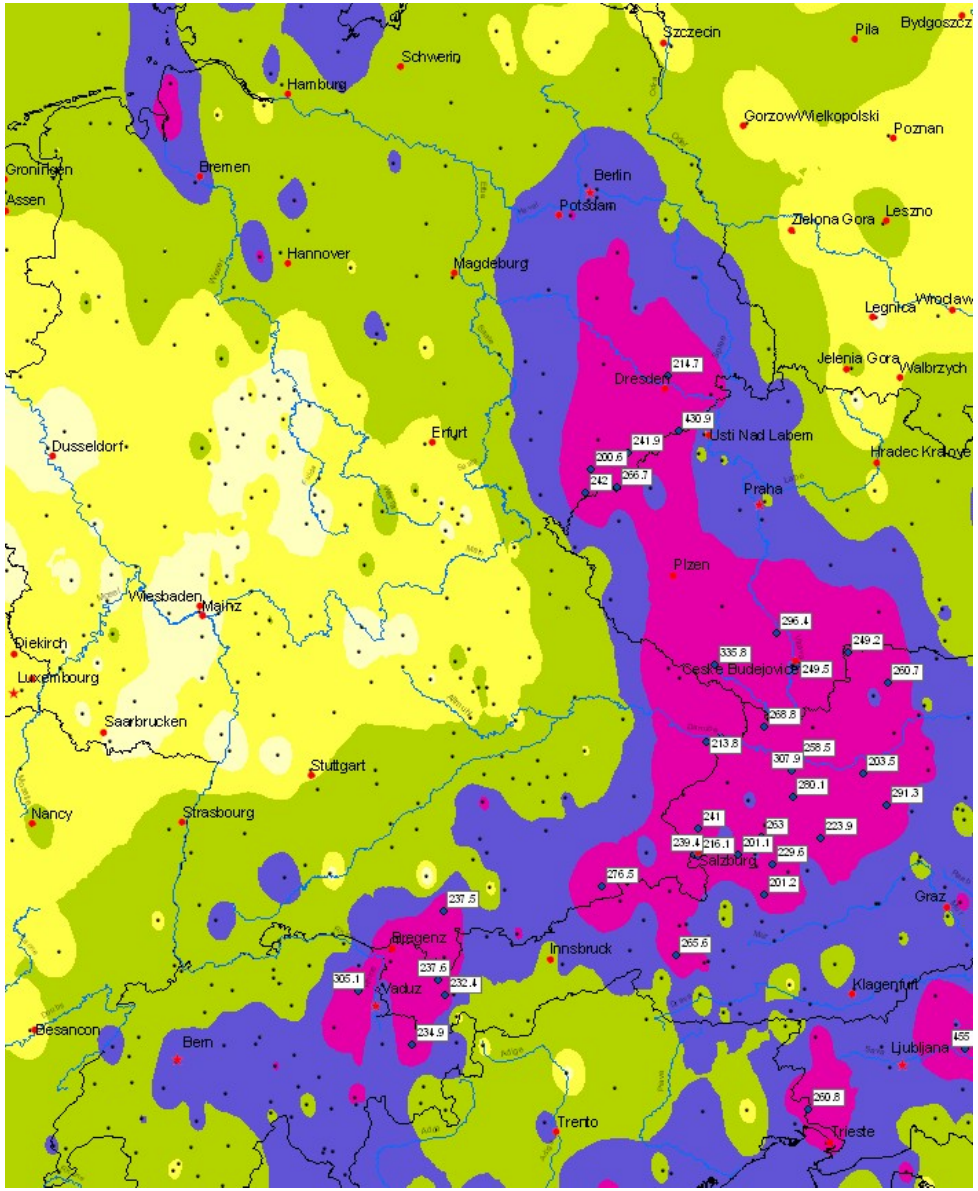
Water stages of three rivers in Czech Republic. Source: CHMU.



Maximum discharge at Vltava (Moldau) in Prague. Source: CHMU.



Accumulated precipitation, 1-13 August 2002

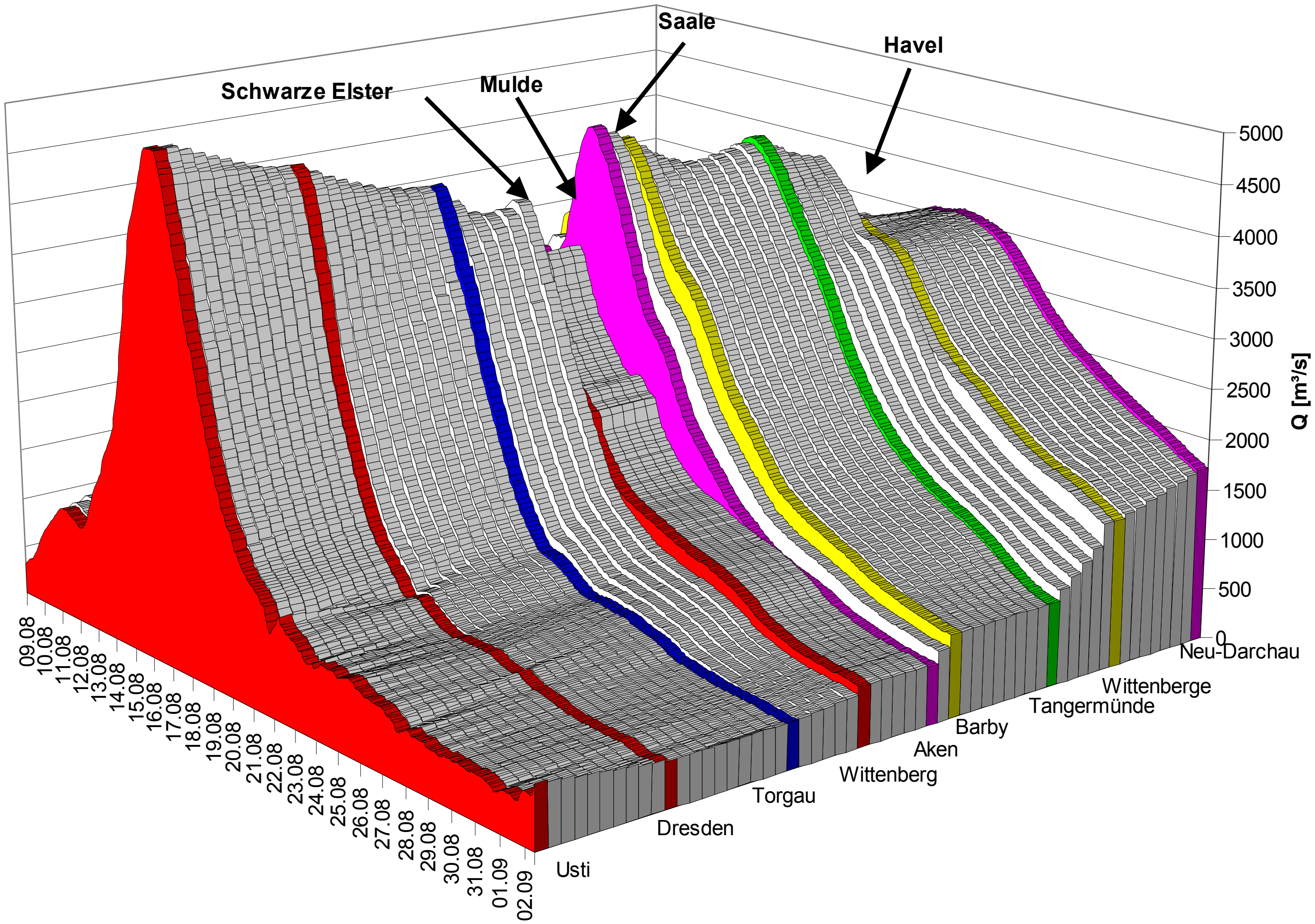


German daily precipitation record of all times:

312 mm

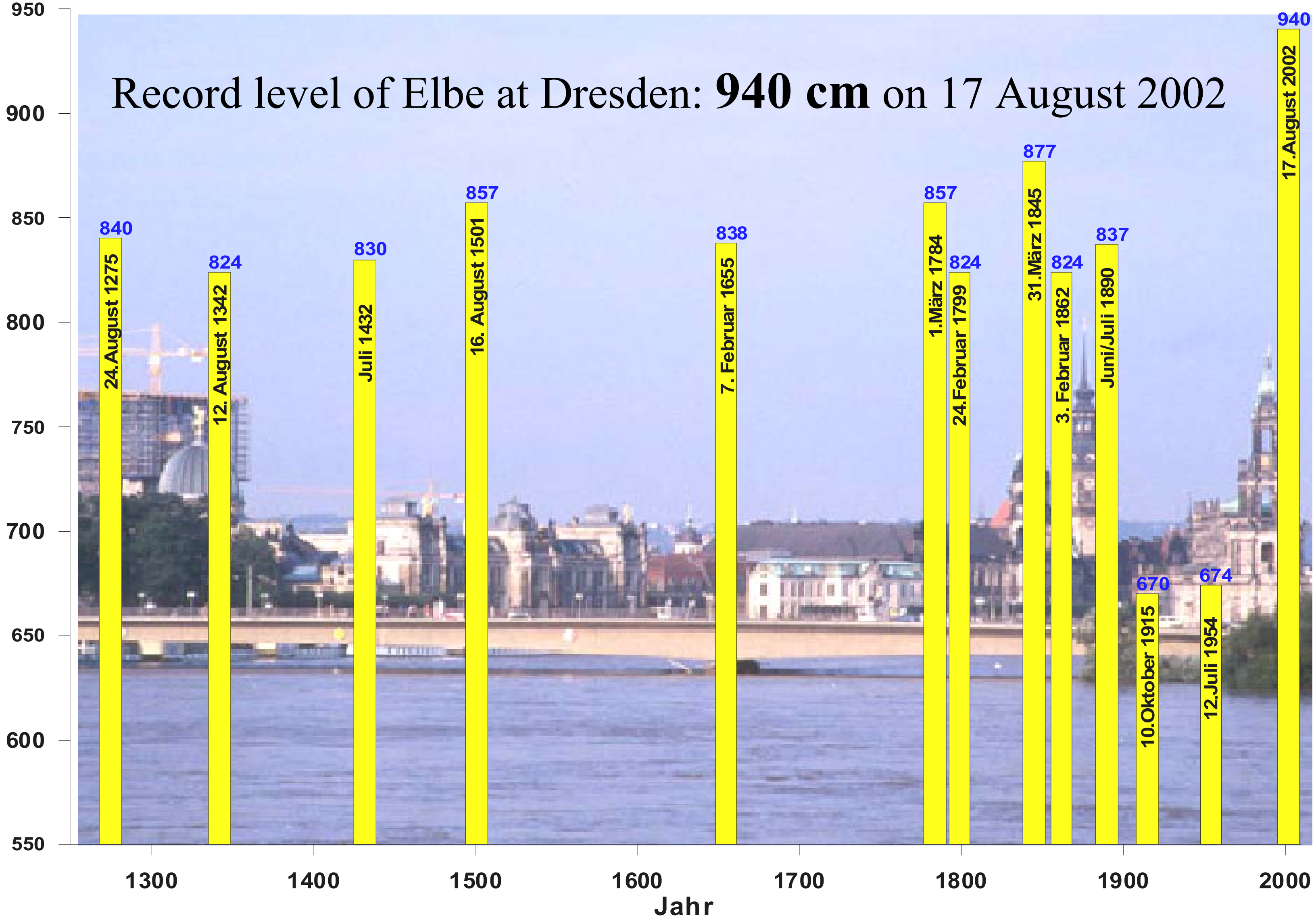
Quelle: DWD, 2002

Propagation of a flood wave on the Elbe, August 2002. Source: BfG.



Primary importance: Mulde (high inflow) and Havel (polder inundation).

Maximum water levels, Elbe at Dresden. Source: Grünewald



Quelle: LfUG, 2002

Contents:

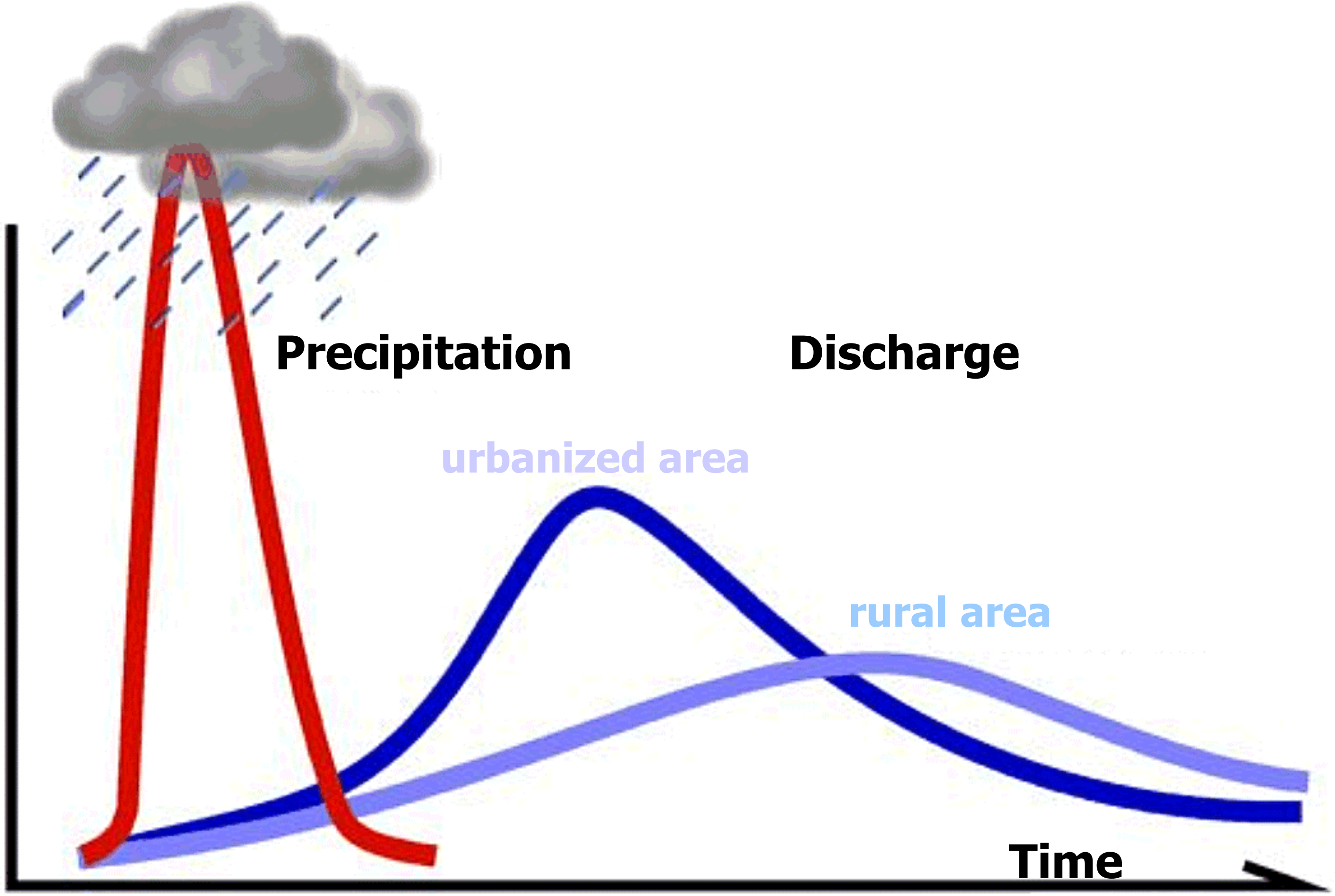
Reasons for changes in flood risk and vulnerability

- **Changes in terrestrial systems** (hydrological systems and ecosystems; land-cover and land-use change - urbanization, deforestation, elimination of natural inundation areas (wetlands, floodplains), river regulation – channel straightening, embankments), changes of conditions of transformation of precipitation into runoff (higher peak, shorter time-to-peak).
- **Changes in socio-economic systems** (increasing exposure and damage potential – floodplain development, growing wealth in flood-prone areas, changing risk perception).
- **Changes in climate** (holding capacity of the atmosphere, intense precipitation, seasonality, circulation patterns).

The role of land-use changes

- Among non-climatic factors exacerbating flood hazard are **land-use changes**, leading to
  - **growth in amplitude** and
  - **reduction of the time-to-peak** of a flood triggered by a given precipitation
- Deforestation, urbanization, reduction of wetlands and river regulation reduce the available **water storage capacity**
- Result: Water runs off faster to the sea

Impacts of land-use change on floods



The mistake of feeling safe

- There is an unjustified reliance on the **absolute safety** provided by flood control works, such as levees, reservoirs etc.
- In reality, even an over-dimensioned and perfectly maintained dike does not guarantee complete protection, as it can be overtopped or even break when an **extreme flood** occurs
- Then, losses in a levee-protected landscape can be higher than they would have been in a levee-free case
- The reason is a **false feeling of security** of the riparians, who have accumulated considerable wealth in endangered areas

Changes in:

Atmosphere's holding capacity

Precipitation

Intense precipitation

Snowmelt / ice jams

Circulation patterns (wet Wz, Genoa cyclone - Vb)

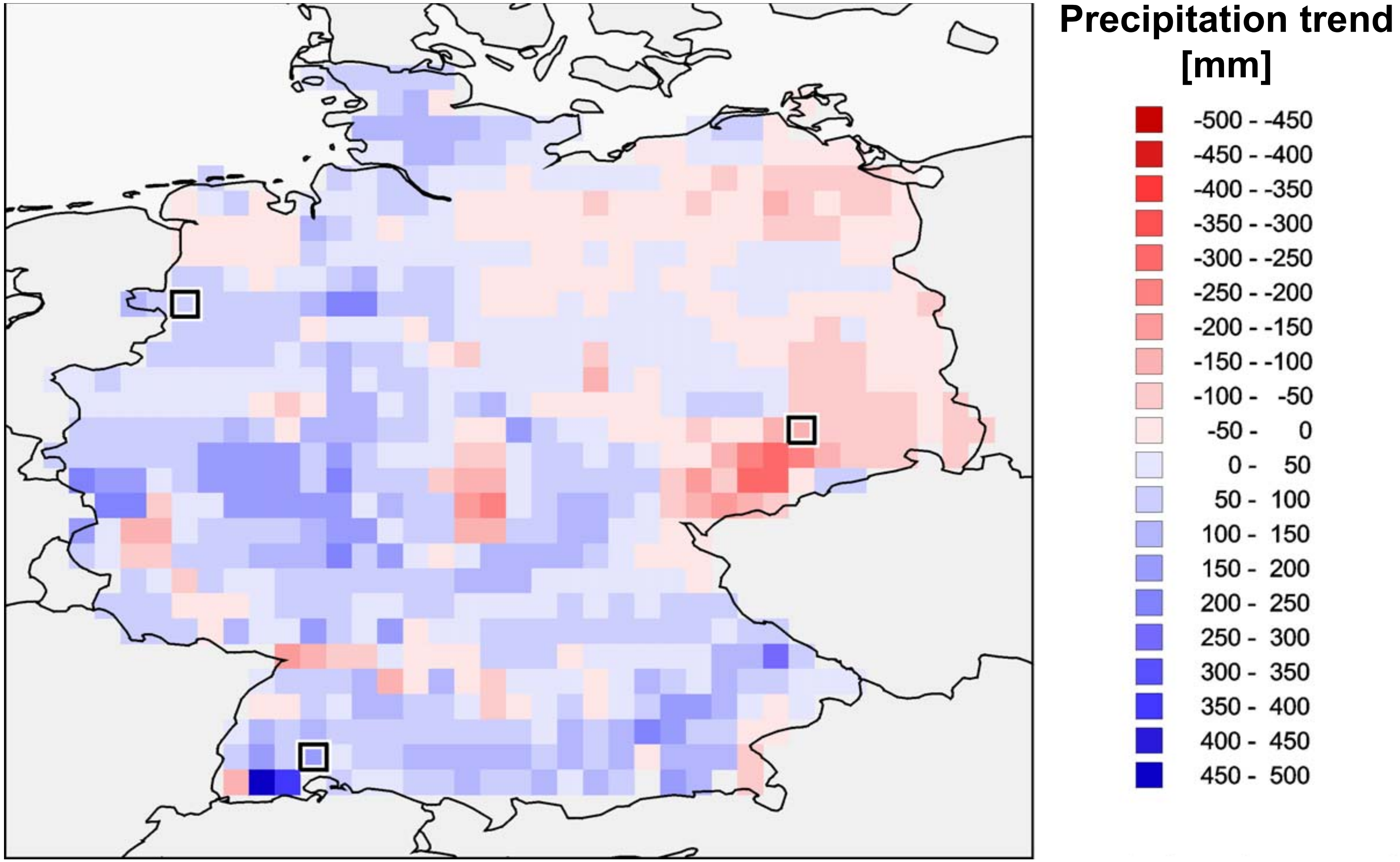
El Niño

Coastal flooding

Risk of singular events

Impacts

Precipitation trend in Germany, 1901 - 1998



Gerstengarbe & Werner (2001)

As the water-holding capacity of the atmosphere grows with temperature, the potential for intensive precipitation also increases. Higher and more intense precipitation has been already observed and this trend is expected to increase in the future, warmer world. This is a sufficient condition for flood hazard to increase.

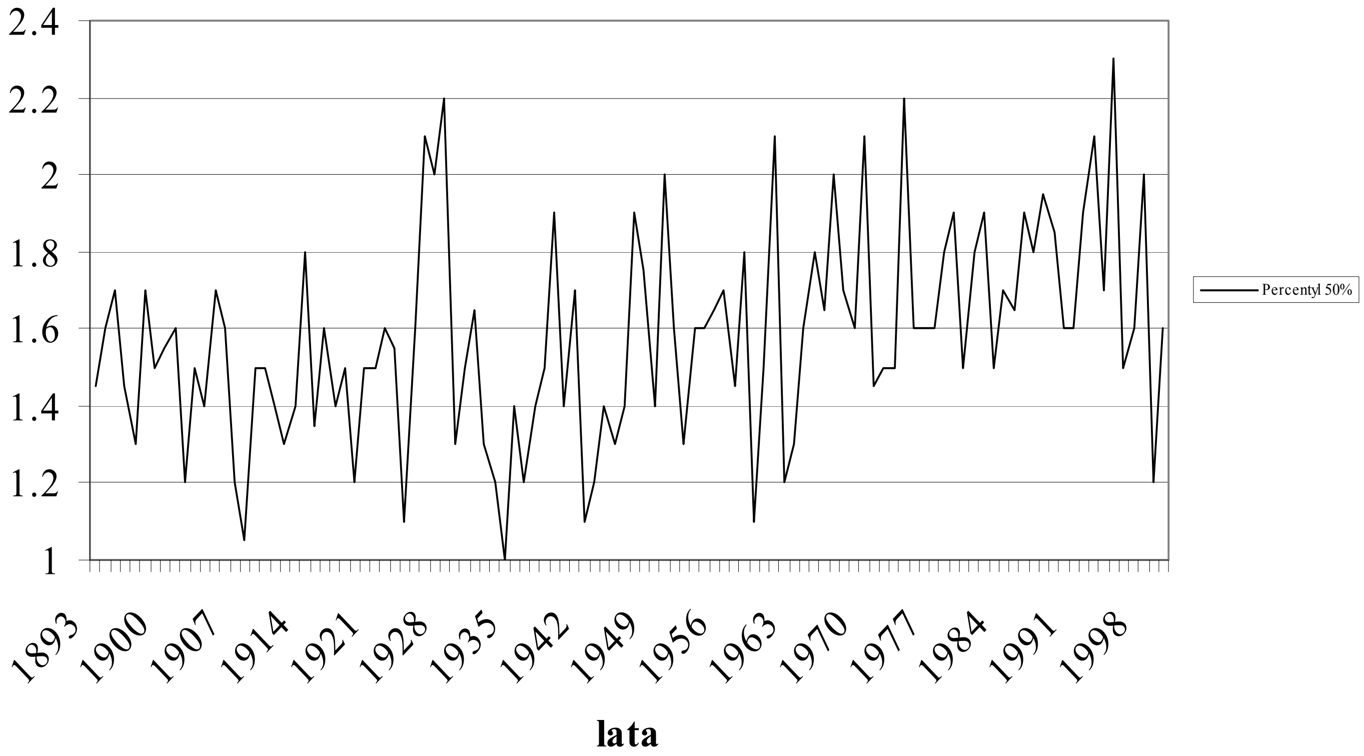
It is very likely “that in regions where total precipitation has increased … there have been even more pronounced increases in heavy and extreme precipitation events. The converse is also true.” Moreover, increases in “heavy and extreme precipitation” have also been documented in some regions where the total precipitation has decreased or remained constant.

[Source: IPCC]

Observed changes in intense precipitation

IPCC (2001)

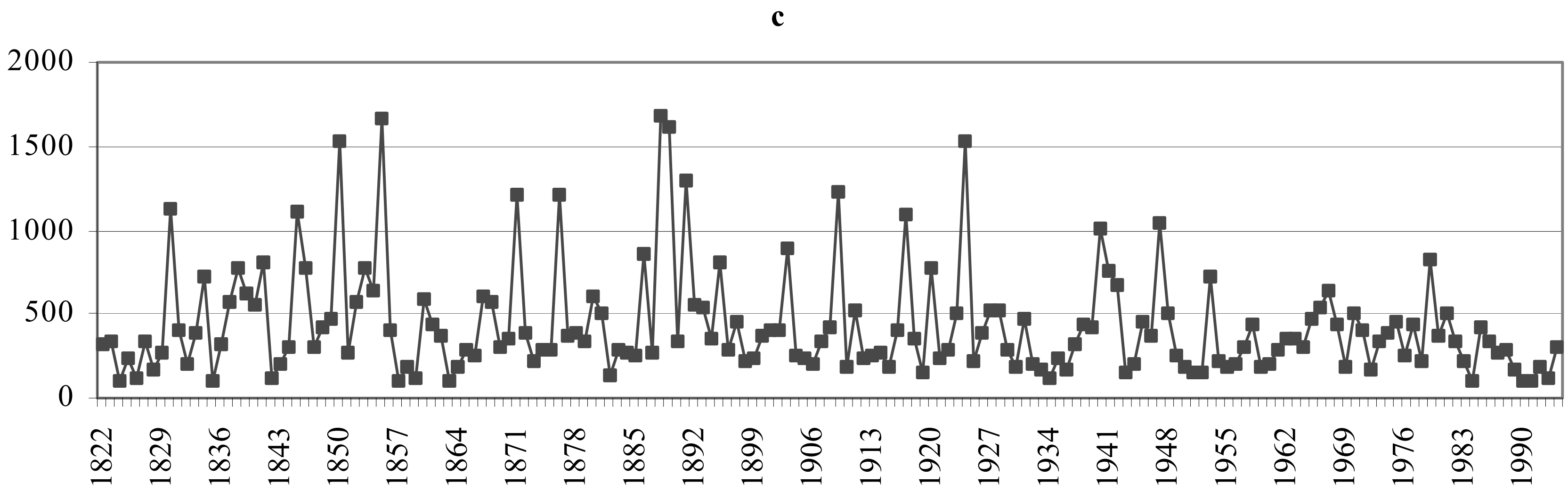
Where?	**When?**	**What?**
Mid- and high latitudes of the Northern Hemisphere	Latter half of the 20th century	A 2 to 4 % increase in the frequency of heavy precipitation events reported by the available observing stations
Globally	1961-1990	A 4 % increase in the annual maximum five-day precipitation total
Many regions of Australia	1910-1995	A 10 to 45 % increase in heavy rainfall, as defined by the 99th percentile of daily totals
Siberia	Summer season, 1936-1994	Statistically significant decrease in total precipitation of 1.3 % per decade, but the number of wet days decreased more strongly In total, an increase in the frequency of heavy rainfall (above 25 mm) of 1.9 % per decade



Annual median values of daily precipitation in Potsdam (non-zero values only); logarithmic scale.

Flows of the river Warta, gauge Poznań, 1822-1994

Annual maxima



Results of tests for change for varying-length windows in backward-going scheme. (b) Mann-Kendall

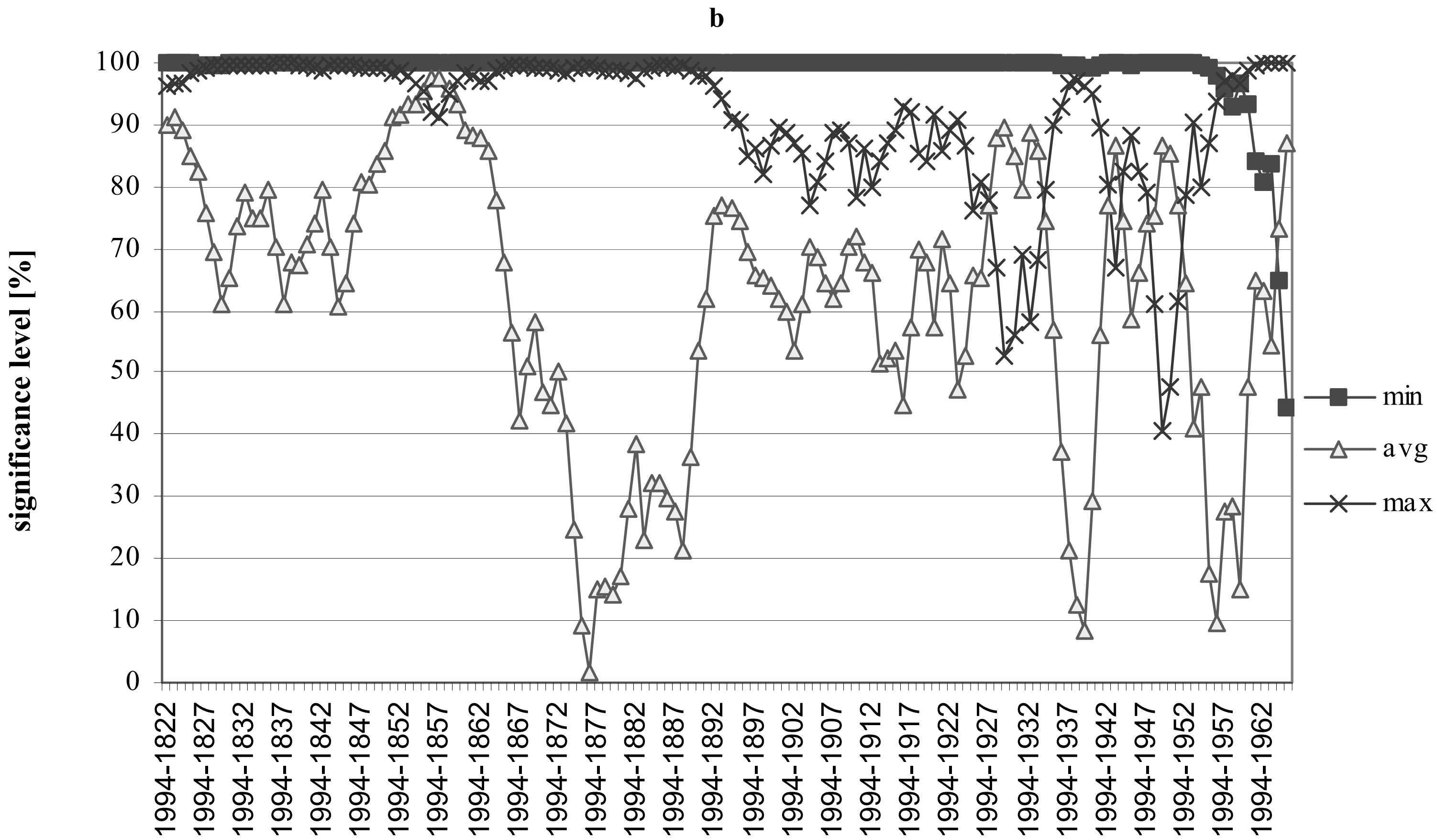
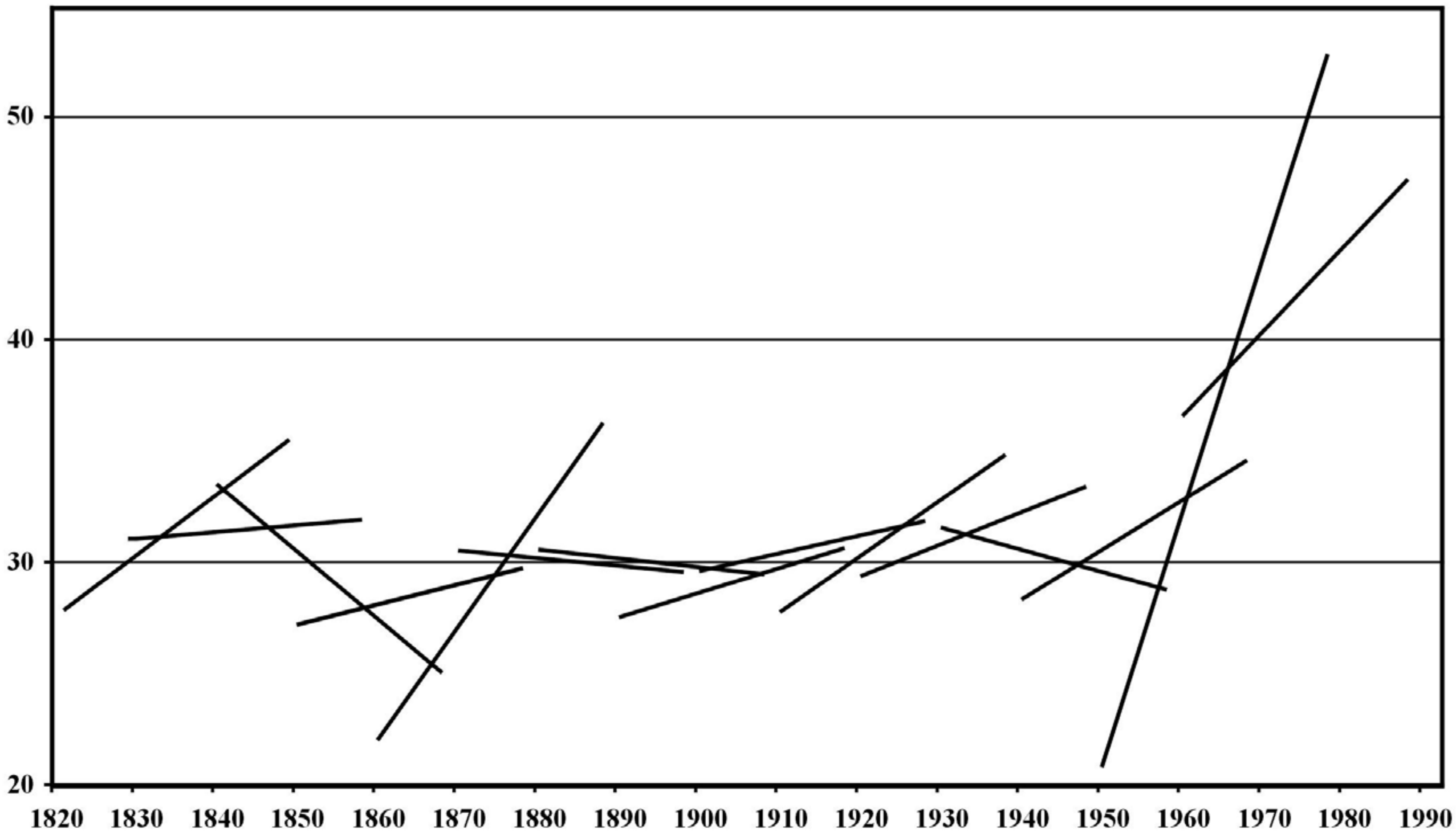


Illustration of historical variability:

linear regression fitted to 15 different 30-year periods

(1822-1851, 1832-1861, ... , 1962-1991)



Past-to-present: no general and universal signal in flow data (e.g., Lins & Slack: wetter but less extreme)

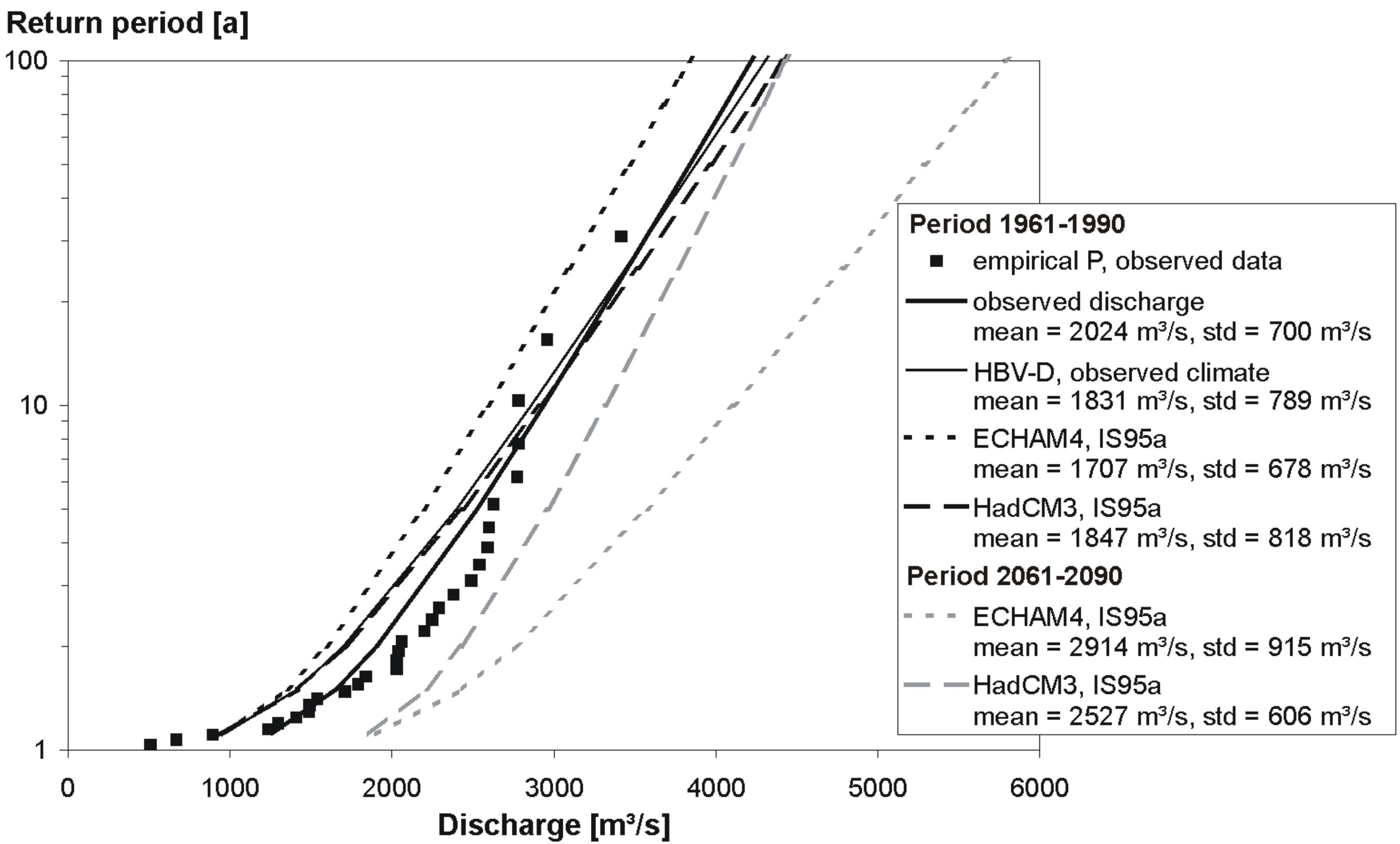
Future: poor accuracy of modelling local, short-lasting, high intensity precip in GCMs. Assumption of similar change in mean and extremes (pro-rating) inappropriate.

Floods – often spatially restricted to vicinity of rivers (except flatlands: in flat Bangladesh, two-thirds of the country area was inundated in 1998), yet contributing catchments may be up to millions km^2.

Projected changes in intense precipitation

IPCC (2001)

Where?	**What?**
Europe	Wetter winters are predicted throughout the continent, especially in the Northeast of the continent and the Northwestern Mediterranean coast In summer, Northern Europe is getting wetter by 2 % per decade, while Southern Europe becomes drier by 5 % per decade However, there are large quantitative differences between scenarios and models
Much of Asia	Enhancement of the hydrological cycle and increase in mean annual rainfall are expected, affecting Boreal Asia most
Parts of India, Nepal and Bangladesh	Possibility of more frequent flash floods is foreseen
Tropical Indian Ocean region	Future seasonal precipitation extremes associated with an ENSO event are likely to be more intense Anomalously wet areas could become even wetter
Australia	In the 21st century drier conditions are anticipated for most of Australia Yet, an increase in heavy rainfall is also projected, even in regions with small decreases in mean rainfall



Flood frequency of the Mosel at Cochem, 1961-1990 *vs* 2061-2090. Return interval vs discharge. Application of the HBV-D model and climate information from the ECHAM4 and HadCM3 models. A specific discharge becomes more frequent under climate change (after: Menzel *et al*., 2003).

Quantification of flood statistics is subject to high uncertainty. It is difficult to disentangle the climatic component from the strong natural variability and direct, man-made, environmental changes. There is a large difference between results obtained by using different scenarios and different models. **It is a robust statement that, in general, today's climate models are not good at producing local climate extremes** due to, *inter alia*, inadequate (coarse) resolution. There is hope that, with improving resolution, models will be able to grasp details of extreme events in a more accurate and reliable way.

MICE

Modelling Impacts of Climate Extremes

Re-analysis
(NCEP)

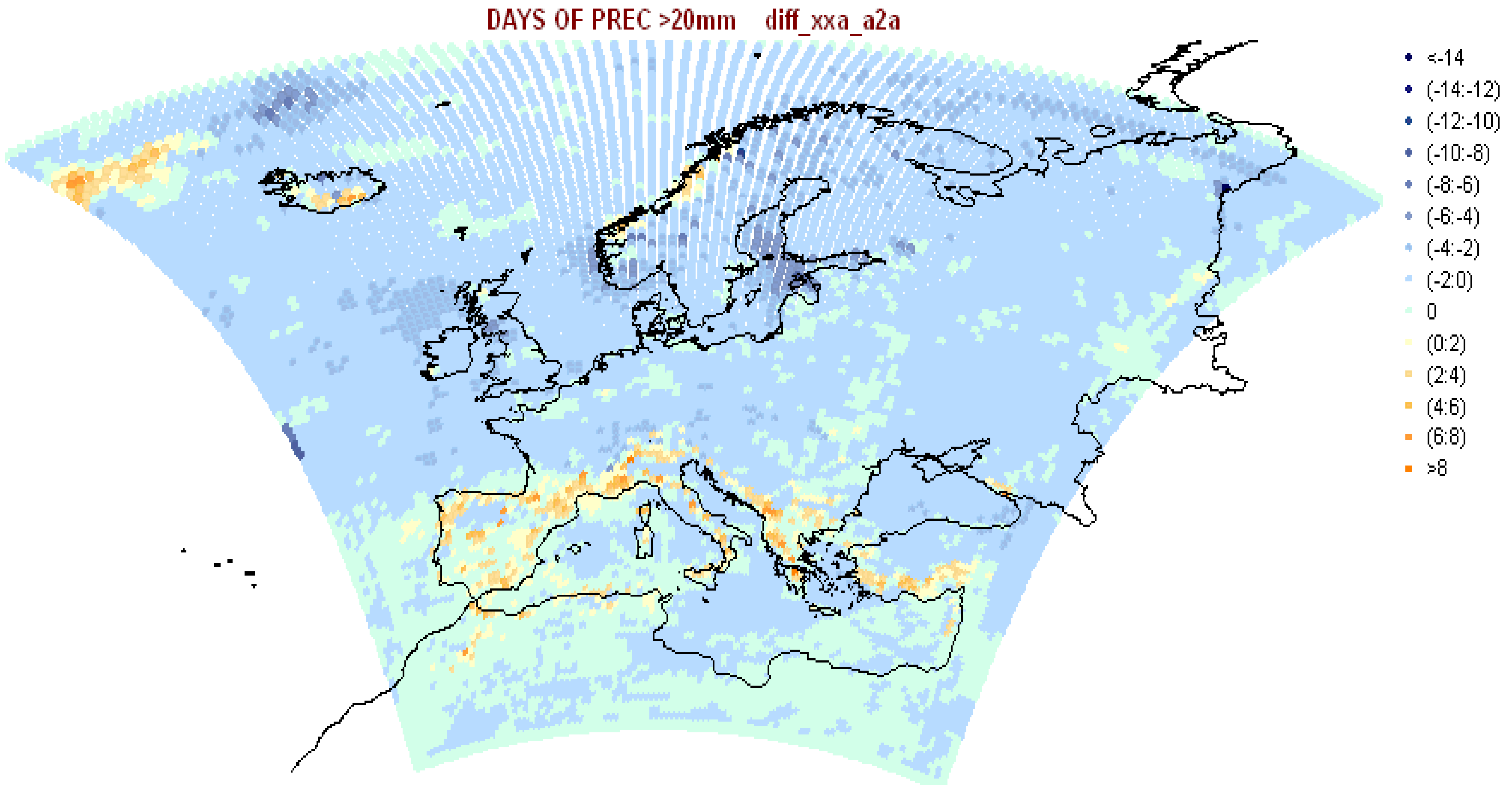
Ground-truth data
(for quasi-verification)

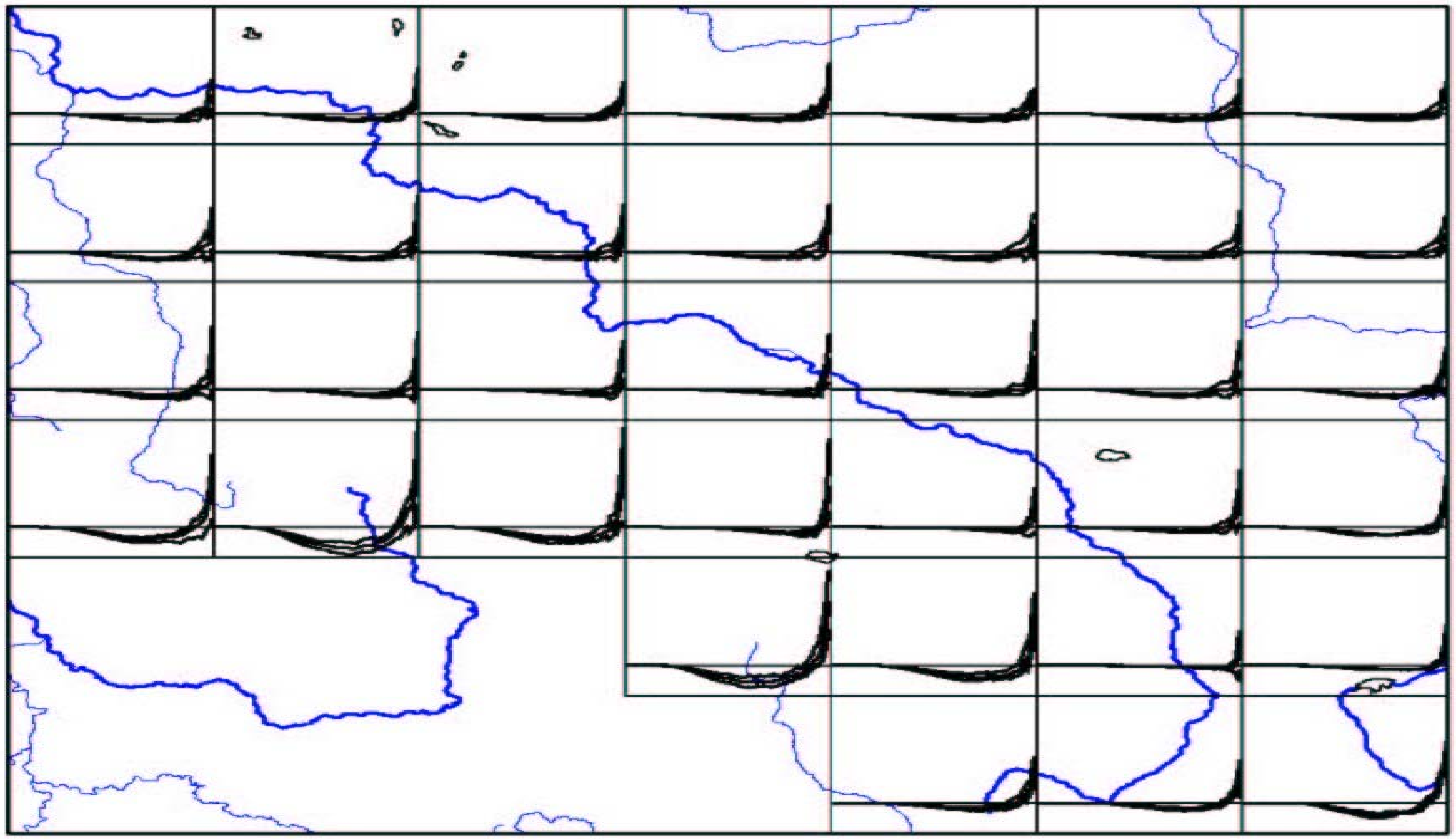
1961-1990

Results from a Global Circulation Model (GCM) of the Hadley Centre (U.K.)

1961-2100

Research Centre for Agricultural and Forest Environment
Polish Academy of Sciences, Poznan, Poland





Changes in percentiles of precipitation, Upper Odra (Oder) grids, HadRCM3 (2070-2099 vs 1961-1990).

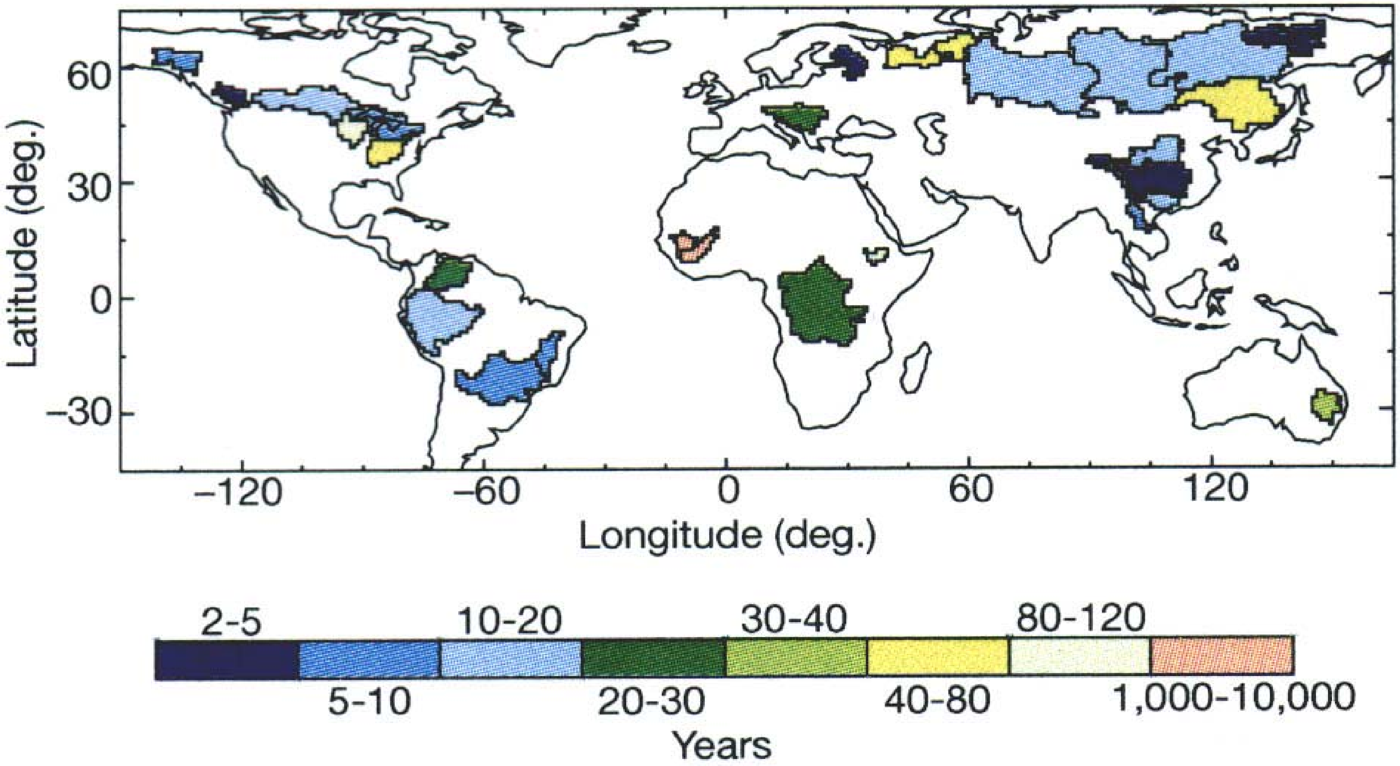


Figure 2 Map showing the gauged drainage areas and flood-risk sensitivities of the 29 river basins in this study. Colour indicates the modelled return period, under idealized quadrupling of atmospheric CO_2 concentrations, of the flood magnitude associated with a 100-yr return period in the control experiment. Although results for low-latitude basins are provided, the poor performance of the model in low latitudes should be kept in mind.

Source: Milly *et al*. (*Nature*, 2002).

Water resources, climate change, and sustainable development

- Water abuse (excessive withdrawals)
- Maladaptation (some reservoirs, levees, transfers)
- Extreme hydrological events destroy human heritage
- Right to water as essential human right (some for all forever)
- Environmental refugees?

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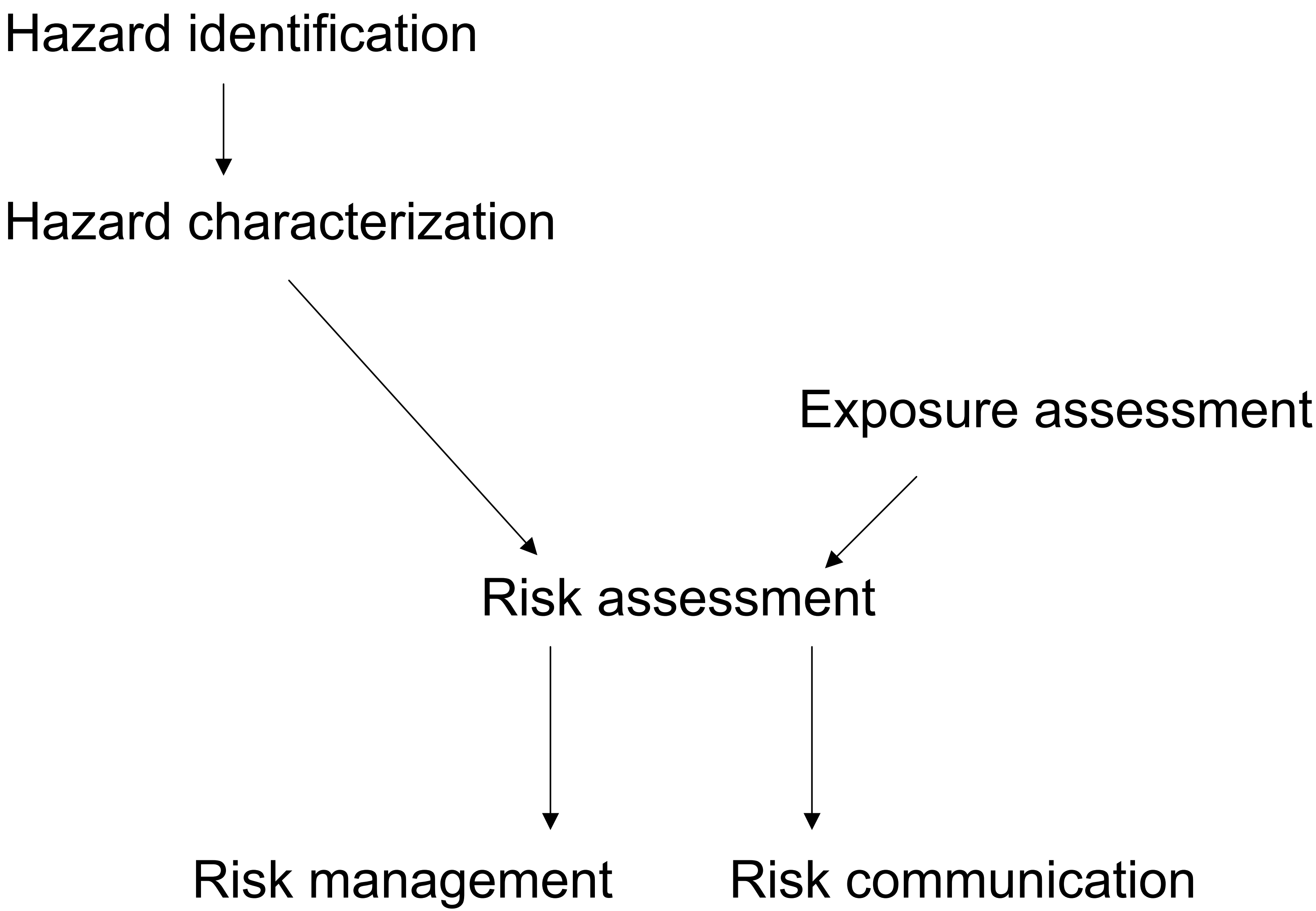

Hazard identification
Hazard characterization
Exposure assessment
Risk assessment
Risk management
Risk communication

Vulnerability:

Hazard

Exposure (Sensitivity)

Adaptive capacity

Water storage against floods and droughts

- **Enhancing water storage** (though not necessarily in large reservoirs) is a remedy for both classes of hydrological extremes: floods and droughts
- Catching water when abundant and storing it for the times of need can be realized in **reservoirs**, including **underground retention** (e. g. by enhancing infiltration), **rainwater harvesting**

KEEP WATER WHERE IT FALLS

- The construction of **big dams** is questionable, due to unforeseen side effects
- An optimal **combination of storages** of different size might be more appropriate to maximize water availability at minimum cost

Problems:

Inundation of living places, ecosystems, and historic / cultural monuments

Erosion and sedimentation

Large-scale resettlement

Barrier for fish migration

Risk and reliability

Reality vs expectations

Preparedness to floods and droughts

- An immediate challenge is to **improve flood and drought forecasting** at a whole range of time horizons:
  - from **short-term** weather forecasting and quantitative precipitation forecasts needed for flood preparedness
  - to **long-term** forecasting, based on climatic variability and sea surface temperature (important tool of drought preparedness)

Preparations to drought in the Yakima river basin (USA)

issuing permits to drill new wells;

- leasing rights to water, aimed at saving irrigated multi-season crops (e.g., peppermint);

- transplanting cultivated multi-season vegetation to other locations;

- subsidies for farmers of one-season crops: payment for „do nothing“;

- preparation to water supply by trucks;

- promotion of water saving;

- launching a subsidized bank of virtual water, buying rights to water from farmers of one-season crops and selling to farmers of multi-season crops;

- *ad hoc* feasibility studies of pumping dead storages in reservoirs, cloud seeding...

[Source: Glantz]

Glantz (1977) gave a gloomy, yet realistic statement on the situation in the West African Sahel:

"Even if a six month forecast of weather were available few of the areas could have responded in any different way to that which actually happened".

Demand management:

- Improving efficiency of water use: Factor Four;
- Pricing;
- Regulations (standards);
- Awareness raising
- Subsidies
- Change of water allocation;
- Virtual water vs. food self-sufficiency doctrine

Changes of water prices in Japan – mechanism of demand management

1961:	
User below 22 m^3/month	22 ¥/m^3
User above 22 m^3/month	26 ¥/m^3
1990:	
User below 22 m^3/month	195 ¥/m^3
22-200 m^3/miesiąc:	404 ¥/m^3
200-1000 m^3/miesiąc:	545 ¥/m^3
User above 1000 m^3/month	667 ¥/m^3

Achieve more with less resource use – receipt for the era of water scarcity

Dramatic improvement of effectivity of water use is urgently necessary!

Von Weizsäcker, Lovins & Lovins (1997) - Factor 4: Search of **negaliters and negawatts** rather than **megaliters and megawatts**. IWMI: in 25 years: 40% growth of food production – with 10-20% reduction of water use!

Save water! Avoid wastage! Change water allocation! Virtual water!!! Cotton in desert?!

Right to water: an essential human right (Water Conference of United Nations, 1977)

Some (water) for all forever

Inter-generational equity - Intra-generational equity

One of Millennium development goals (in implementation plan of World Summit on Sustainable Development, Johannesburg, 2002):

to halve, before 2015, …the proportion of people without access to safe drinkwater

(now: ca 1.2 – 1.3 billion!)

Flood preparedness

- There is **no single universal remedy** against floods
- A **site-specific mix of measures** is necessary, depending on geographic factors and human dimension (socio-economic development and awareness)

Preparedness systems should be built on the appropriate selection of one of the following options:

Protect or accommodate or retreat

- **Protect** as far as technically possible and affordable
- **Accommodate**, i. e. prepare to "living with water-related extremes"
- **Retreat**, if a necessary level of protection cannot be provided and accommodation is not possible

Classification of measures for flood protection and management

(1) Modify flood waters

Flood defence infrastructure: dams and flood control reservoirs, flood dikes, diversions, floodways, improvement of channel capacity to convey a flood wave, enhancing source control via watershed management, enhancing storage - floodplains and wetlands, polders and washlands, enhancing infiltration, vegetation management (afforestation, cropping pattern avoiding bare soil during precipitation season), terracing, etc.

(2) Modify susceptibility to flood damage

Legislation, land-use planning and management, zoning, development control of flood hazard areas leaving floodplains with low-value infrastructure, e. g. riparian forests which are subject to frequent flooding, buy-out of land and property located in floodplains – stimulating relocation, flood proofing (by elevation, barriers, or sealing), disaster contingency planning, preparation of flood forecasting and warning systems, flood insurance schemes, awareness raising: improving information and education on floods and on actions in emergency, community self-protection teams

(3) Modify impact of flooding

Detection of the likelihood of flood formation, forecasting of future conditions, warning issued to the appropriate authorities and the public on the extent, severity and timing of the flood, dissemination of warning, response by the public and the authorities, evacuation, financial aid (insurance claims, loans, tax deduction, debt reduction), relief for those affected, post-flood recovery and regeneration of the environment and the economic activities in the flooded area, review of the flood management activities to improve the process and planning for future events.

Flood preparedness measures

Flood preparedness measures can be **structural** (dams and flood control reservoirs, dykes, bypass channels) or **non-structural**, such as:

- **zoning**, i.e. regulations for flood hazard areas leaving floodplains with low-value infrastructure
- flood mitigation systems of **forecasting**, **warning** (issue and distribution), **evacuation**, relief and post-flood recovery
- flood **insurance**, i.e. division of risks and losses among a higher number of people over a long time
- **capacity building** (improving flood awareness, understanding and preparedness) and enhancement of participatory approach

A change of flood protection paradigms is needed. The traditional strategy of pursuit of "satisfactory protection" is not likely to lead to an acceptable solution. Adequate protection can be prohibitively costly, while absolute protection is not possible. Hence, it is necessary to live with the risk of floods. Taking an anticipatory, rather than reactive stance, one may perceive the time after the flood as the time before the (next) flood.

Once upon the time, floodplain and wetlands used to provide much storage space for the abundant water. Now, many floodplains have been separated from rivers by levees. Worldwide, 50% of wetlands are estimated to be lost, while in Europe and the USA this percentage is even higher (e.g. California and Iowa lost 99% of their wetlands). Many wetlands have been developed, drained, converted to agriculture and settlements. Hence, their highly valuable habitat was degraded.

Value of global ecosystem services of freshwater wetlands (swamps and floodplains) in the area of disturbance (flood) regulation, in 1994 US$ (Costanza et al.)

Area	165 mln ha
Value of services per ha per year	19 580 US$
Total global value of services	3.231 trillion US$

Specification of value of ecosystem services provided by global freshwater wetlands, in 1994 US$

Service	**Value in US$ per ha per year**
Gas regulation	265
Disturbance regulation	7240
Water regulation	30
Water supply	7600
Water treatment	1659
Habitat/refugia	439
Food production	47
Raw materials	49
Recreation	491
Cultural	1781

Along the Rhine in F, D, and NL, more than 85 % of natural floodplains have been removed within the last two centuries.

After the 1993 and 1995 floods - “Flood Action Plan” has been launched, whose implementation of the Plan is monitored by the International Commission for the Protection of the Rhine (IKSR).

Beside traditional technical measures, the main emphasis is on non-structural, natural flood reduction measures.

The Plan aims to reduce risks of flood damage by 10 % until 2005 and by 25 % until 2020 and flood water levels by 30 cm until 2005 and by 70 cm until 2020 downstream of the regulated Upper Rhine.

Until the year 2020, the programme intends:

to restore 11,000 km of river sections into natural conditions,

to reactivate 1,000 km² of floodplains, to promote extensive agricultural use on 3,900 km²,

to remove sealed surfaces in the range of 2,500 km², and

to allow natural successions and aforestations on a total of 3,500 km².

Further activities aim at enhancing risk mapping, flood forecasting and alert systems.

Flood protection in the sustainability context:

- Catastrophic floods destroy continuity of human material growth and worsen the quality of human life.

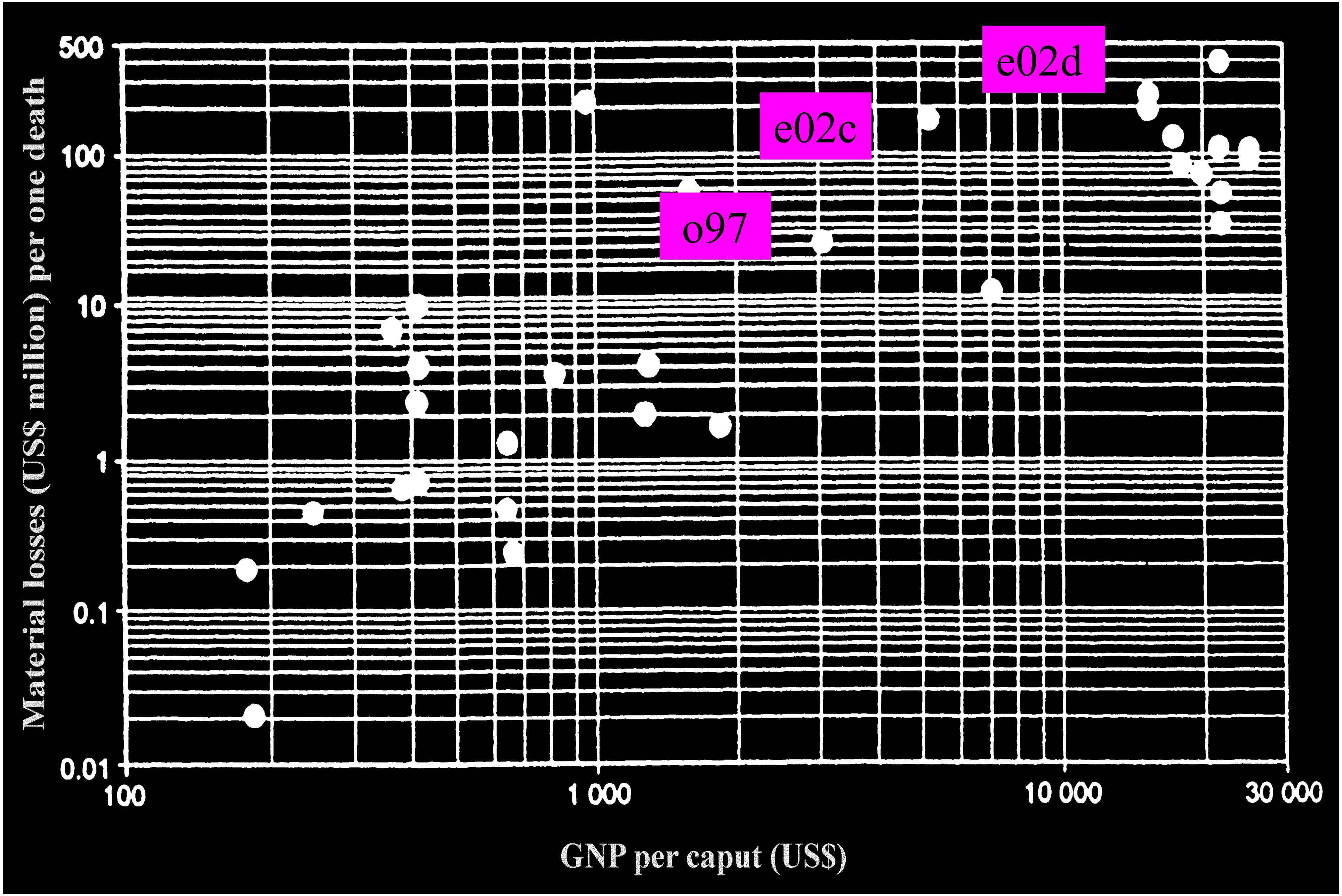
- One should not choose policies, which could be rated by future generations as inappropriate options of flood defense.

More sustainable is to **keep water where it falls** (i. e. by increasing storage capacity of the catchment) and, if there is no way to stop abundant water masses, to (re-) create the possibility of **benign inundation**.

Flood protection should be **integrated into more general development strategies, including spatial development, river management, agriculture and economic policies**. The appropriate choice of flood defense options should result in the optimal use of resources while meeting necessary protection standards.

TABLE 1 - Compliance of components of pre-flood preparedness with the spirit of sustainability.

Flood preparedness measures	**Compliance with sustainability**
Construction of large physical flood defence infrastructure	L to M
Zoning, development control within the floodplains	M to H
Source control, land-use planning and watershed management	M to H
Flood forecasting and warning system	H
Flood proofing	L to H
Disaster contingency planning and maintenance of preparedness of community self-protection activities	H
Installation of insurance scheme	L to H
Capacity building, improving flood awareness, understanding and preparedness	H


e02d
e02c
o97
500
100
10
1
0.1
0.01
100
1 000
10 000
30 000
Material losses (US$ million) per one death
GNP per caput (US$)

Hydro-illogical cycle – Short memory syndrome

It is important to break the traditional rule of **hydro-illogical** cycle, which means that only occurrence of a catastrophic flood mobilizes support, and triggers strengthening flood protection systems. Yet, in a flood-free period, the risk is **quickly forgotten**, and the willingness-to-pay decreases, so flood preparedness activities are slowed down, or even suspended. The occurrence of the next flood serves as a reminder!