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4th International Symposium on Flood Defence, 6th-8th May, Toronto (CA)

Analyzing and Managing Uncertain Futures of Large-Scale Fluvial Flood Risk Systems

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Members of the Dresden Flood Research Center (D-FRC)

Funding

Project Management

Coordination

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Background

- Drivers of flood risk and therefore flood risks themselves are dynamic in the long term
- Future change and impacts involve considerable uncertainty for analyzing and reducing flood risks
- Aleatory uncertainty results from the systems complexity and according restrictions of anticipating future developments
- Epistemic uncertainty appears due to limitations of models to describe processes and trends even of single factors

Initial assumptions

- Uncertainty could be better understood if the following information could be provided:

  (1) All major factors contributing to the dynamic of flood risk,

  (2) Comprehensive, plausible and consistent alternative future developments (aleatory uncertainty),

  (3) Differences in analysing sectoral process resulting from alternative approaches (epistemic or model uncertainty)

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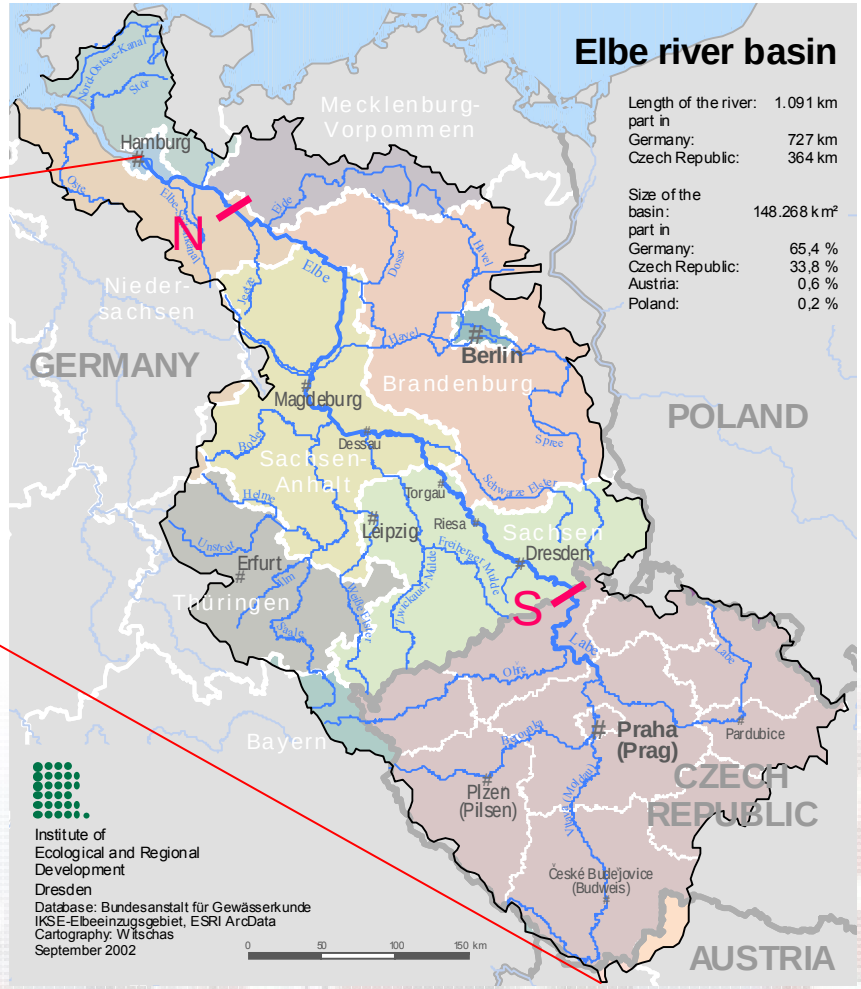
Research area



Modelling the research area

Whole catchment

- Climate change projections (MPI M, GLOWA-Elbe II+III)
- LISFLOOD

German Elbe river floodplain

- all models
- all projections

River section

— Gauge **N**eu Darchau — Gauge **S**chöna

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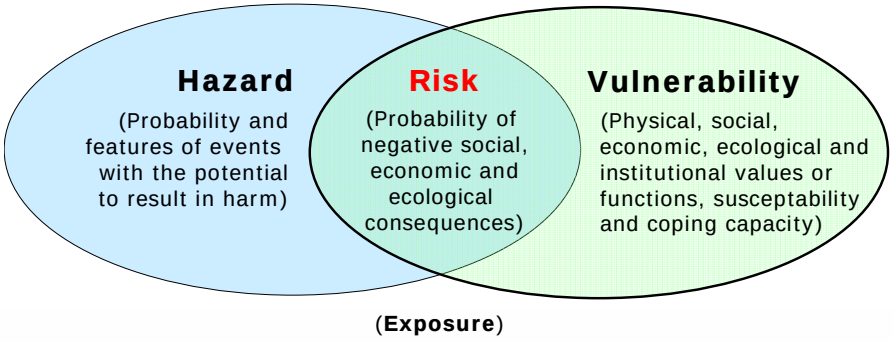
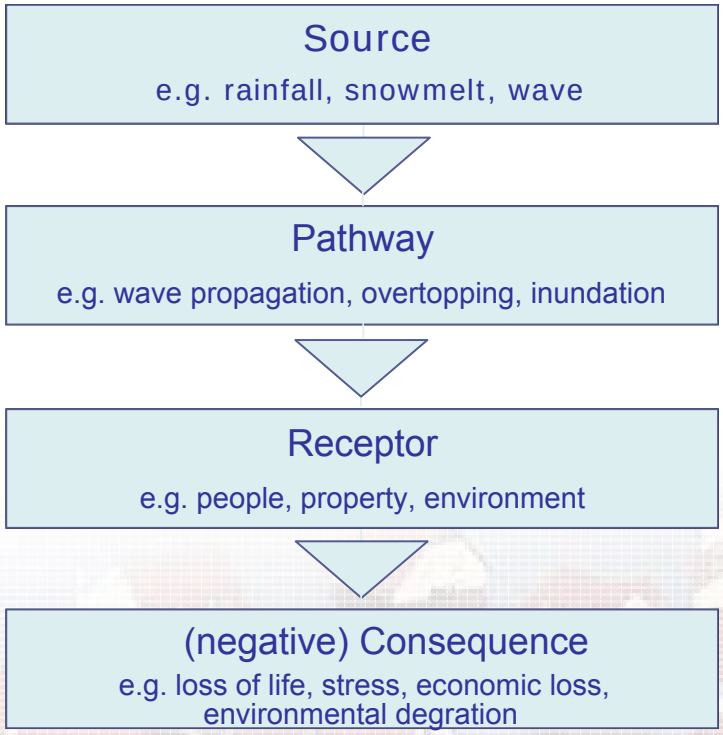
„Risk“ in terms of flood risk

- Overall term: Risk = Probability * (negative) Consequence
- Flood risk = Flood hazard * (exposure) * Flood vulnerability

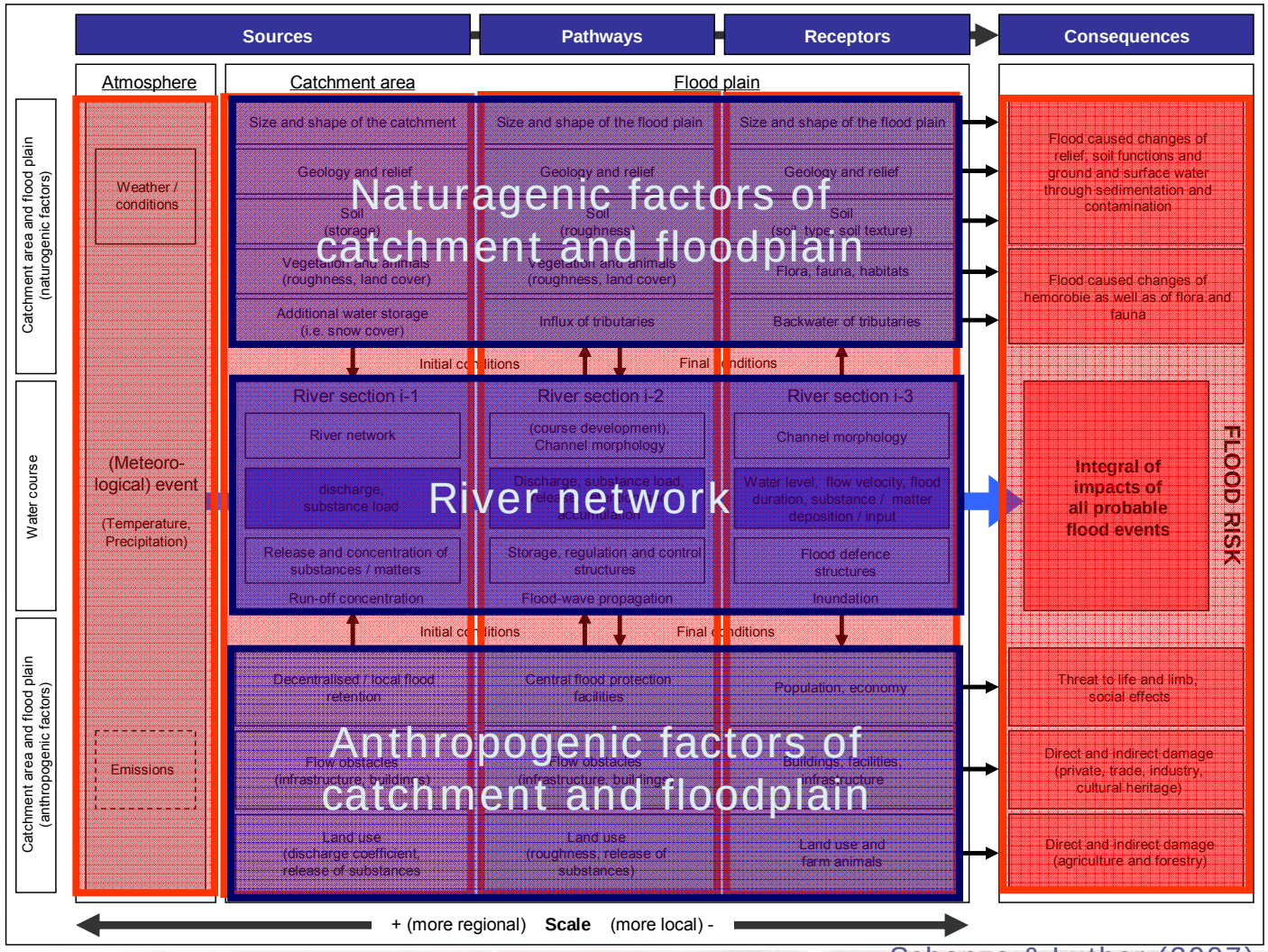




Source-Pathway-Receptor-Consequence Concept

cf. Schanze (2006)

Concept of a fluvial “flood risk system”



Schanze & Luther (2007)

Variable factor groups of fluvial flood risk systems (overview)

	Sources (atmosphere *and* catchment)	Pathways (floodplain)	Receptors (floodplain)	Consequences
Autonomous change (trends through specific drivers)	▪ ***Climate change*** ▪ Land use change/demand	▪ Land use change/demand ▪ Technological-economic development (defences)	▪ ***Land use change/demand*** ▪ ***Demographic change*** ▪ Technological-economic development ▪ ***Buildings***	▪ Technological-economic development ▪ ***Values and attitudes*** ▪ ***Damage***
Controllable alterations (physical measures and policy instruments)	▪ On-site flood retention ▪ Spatial planning ▪ Land management	▪ Reservoirs ▪ ***Flood polder*** ▪ River training ▪ ***Flood defences/ dikes*** ▪ ***Spatial planning***	▪ Flood defences, Dikes ▪ ***Construction provisions*** ▪ ***Spatial planning and provisions*** ▪ Warnings, evacuations	▪ Insurances ▪ Other compensations
Random change		▪ ***Dike breaches***		▪ Overlap with other risks

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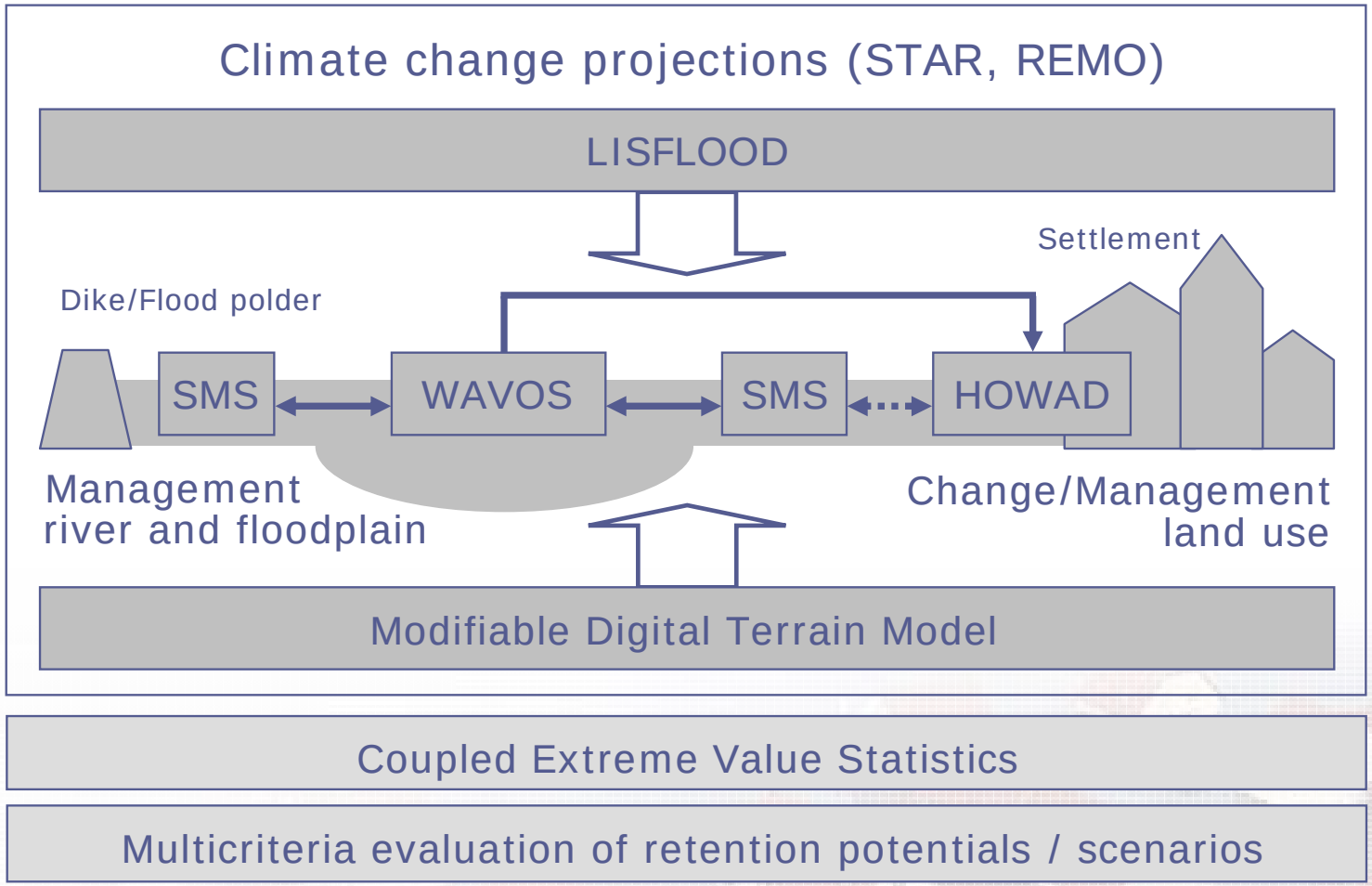
Factors of fluvial flood risk systems (selection)

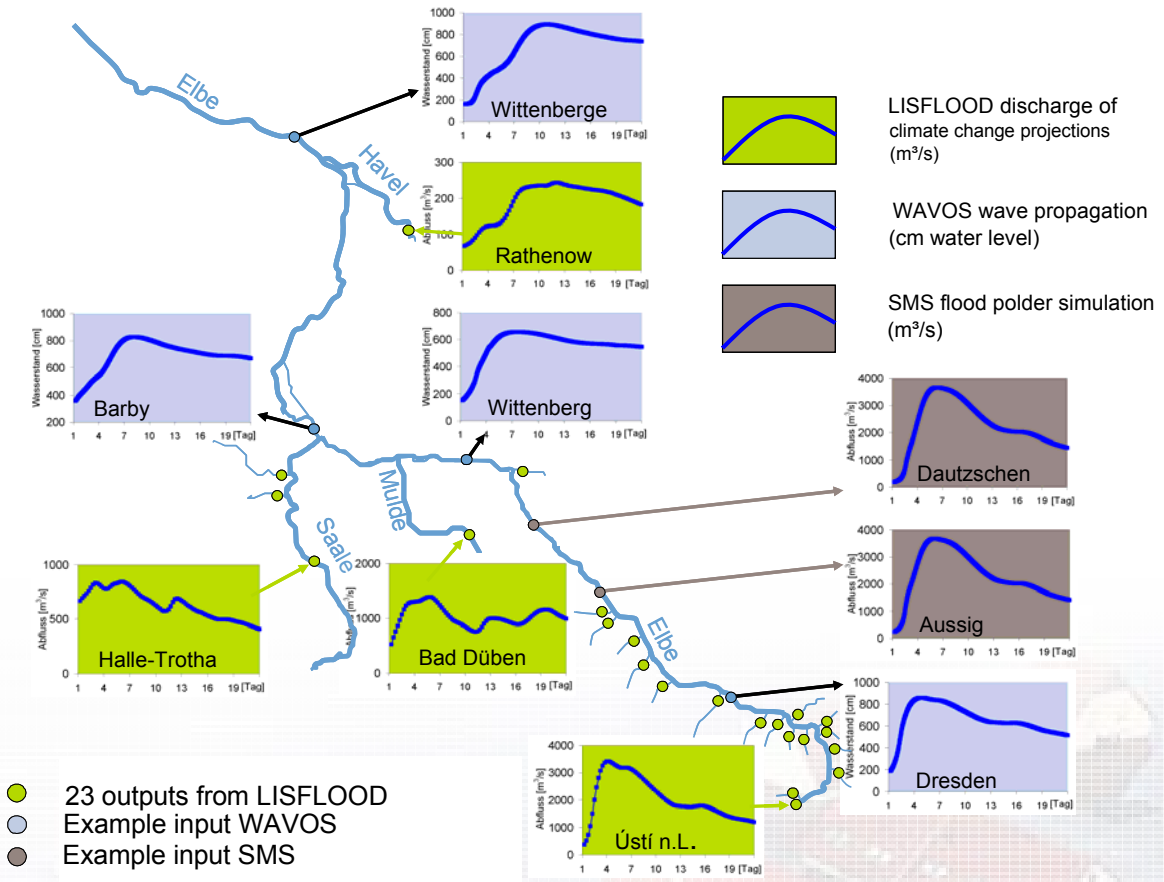
	Factors		Operationalisation	Development framework (scenarios)		Strategic agenatives		Other assumptions		Control	Comments
Classification of factor groups	Factor groups	Single factors	Methods, models	Causes / Drivers	VERIS-Elbe	Measures and instruments	VERIS-Elbe	Boundary conditions	VERIS-Elbe		
Receptors (damage genesis)											
VI watercourse (Ausuferung)											
VIa watercourse properties	**channel morphology**	cross section profile	WAVOS / SMS								
		harshness	WAVOS / SMS								
		capacity channel storage	WAVOS / SMS			river training					
	Central flood defence structures	dikes, embankments				river training		failure			
		mobile defences									
VIb condition of watercourses before runoff event (= initial conditions)	**filling level**	spare channel storage volume	WAVOS / SMS		(P)						water level, flood duration
VIc runoff event	**runoff**	water level	WAVOS / SMS		0						
		flood duration	WAVOS / SMS		0						
		flow velocity	SMS		0						
		substance load									
	backwater of	volume	WAVOS		(P)						
VII floodplain											
VIa naturogenic	**(Hydro-)geology**	substrate									
		capacity groundwater storage		geology, relief, etc.	x	withdrawel	(x)				storage properties
	relief	size / form floodplain	WAVOS / SMS	discharge, regime, etc.	(x)	deepening, broadening	(x)				corrugation
		altitude									
		slope inclination	WAVOS / SMS								
		capacity depression storage	WAVOS / SMS	relief, substrate type, etc.	(x)	deepening, broadening	x				
	soil	soil texture and type		geology, relief, climate and land-use change		(cultivation)					hydraulic conductivity
		thickness									
		sedimentation		load, incline, flow velocity	x	retention	x				
	vegetation (floodplain)	species spectrum		climate and land-use change	x		x				(flora)
		species composition		climate and land-use change	x		x				potential natural vegetation
		vegetation structure		geology, relief, climate	x		x				height of plant cover
	animals	(species composition and spectrum)		land-use change	(x)	mobility	(x)				size of animals, population density, behaviour, sensibility
	biocoenosis	biocoenosis		climate and land-use change							
VIb anthropogenic	**land use at risk**	cultivation	WAVOS / SMS+ DGM + HOWAD	relief, climate, soil, economic and technologic development, legislation (and	(P)	cultivation, legislation (spatial planning)	(P)	fire?	x		proportion of different land uses, crop rotation, ploughed land
		land use type, sealing, (runoffbeiwert)	WAVOS / SMS+ DGM + HOWAD	geology, relief, climate, soil, population development, economic and technologic development, demand, legislation, living demands	P	spatial planning	P	spatial planning, de-sealing	x		including de-sealing, settlement structure types
	buildings at risk	buildings and inventory at risk	WAVOS / SMS+ DGM + HOWAD	technology							types, properties, cultural heritage
	population	number of people at risk		population development		Informationszugang, mobility	x	information access, mobility	x		
	domestic animals	number of animals at risk		species, size, susceptibility	x	suitability, mobility	x	suitability	x		
	infrastructure (flow obstacles)	bridges, hampering built structures, kind, size, length, height, resistance	WAVOS / SMS+ DGM + HOWAD	population development, economic and technologic development, demands, legislation	x	spatial planning	x	spatial planning	x		
	central flood defence structures						x		x		
	passive defence										
	economy			(climate), population, technology							
VIc condition before runoff event		spare storage volume Mulden-, soil- und groundwaterstorage		(meso- / mikrorelief), temperature, precipitation, initial conditions	x	cultivation, (land consolidation)	(x)	cultivation, (land consolidation)	(x)		altered by floods!

Coupled models for analysing the FRS of the Elbe River



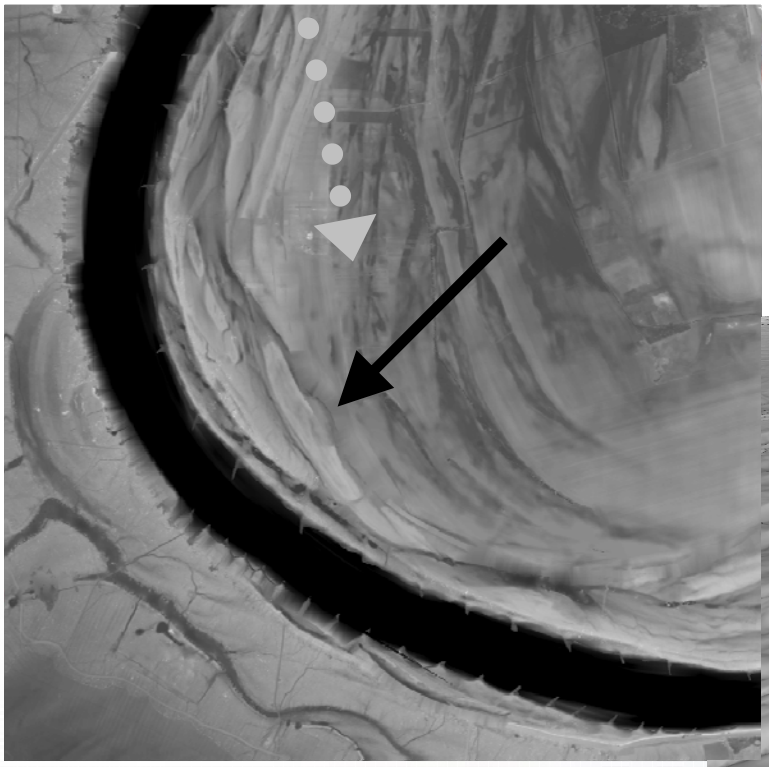
Schanze et al. (2005)

RR modeling and wave propagation (LISFLOOD-WAVOS-SMS)



Burek, Rademacher (2007)

Simulating DTM including dike detection and extraction

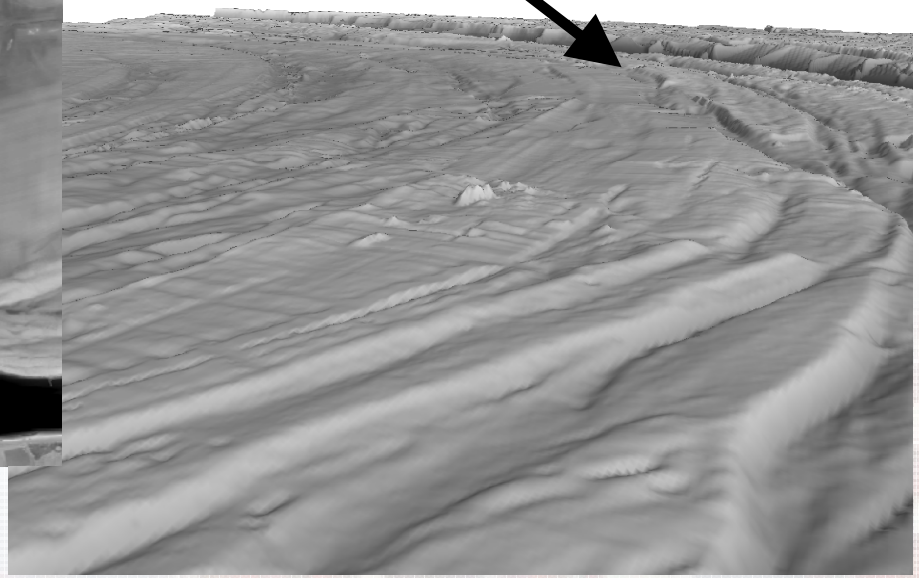


DTM cutout

Krüger (2006)

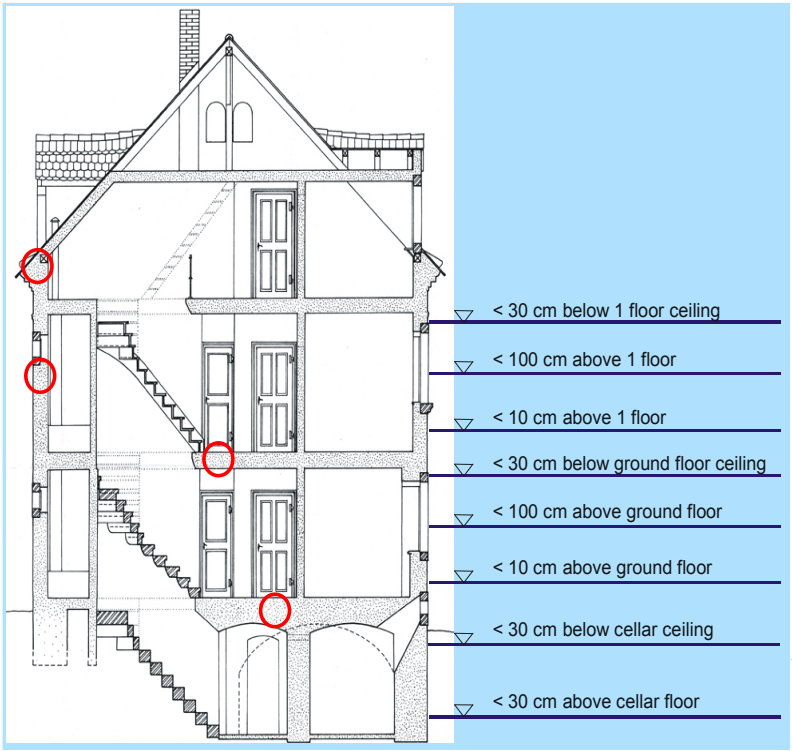
Software module for analysing and editing DTM

- Dike detection, dike extraction, dike raising / dike moving
- DTM intersection of water levels
- Identification of potential retention areas

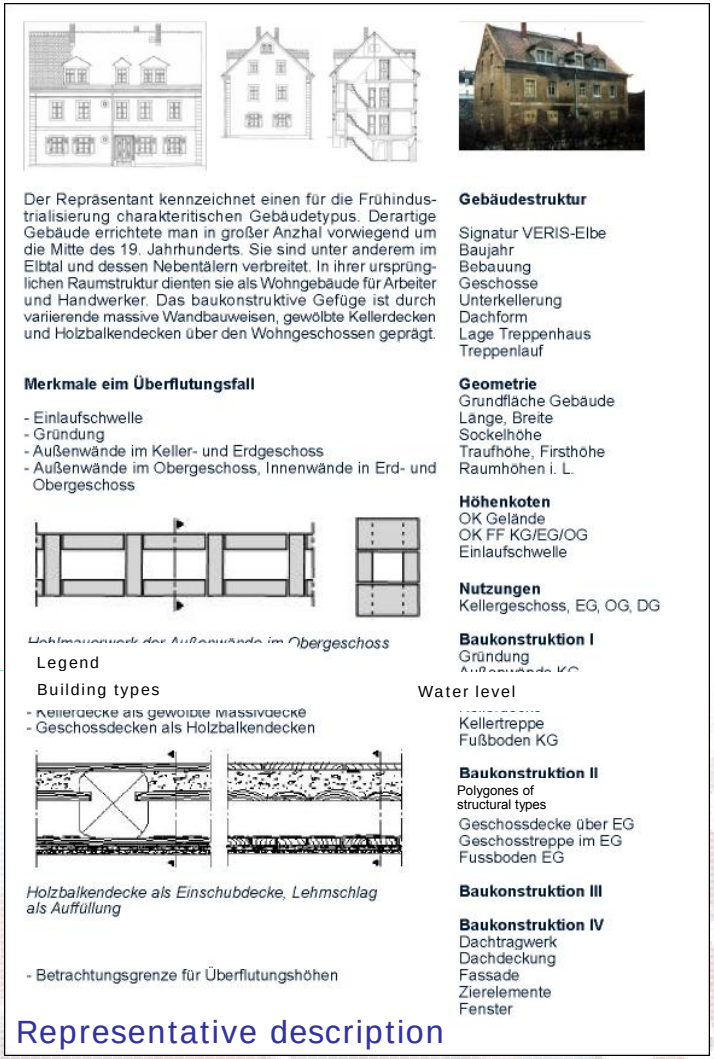


Perspective view heights by factor 10

Flood damage simulation model (HOWAD)



Representative of a building type
(Deilmann, Naumann & Schanze 2006)



Naumann (2006)

Representative description

Examples of building representatives

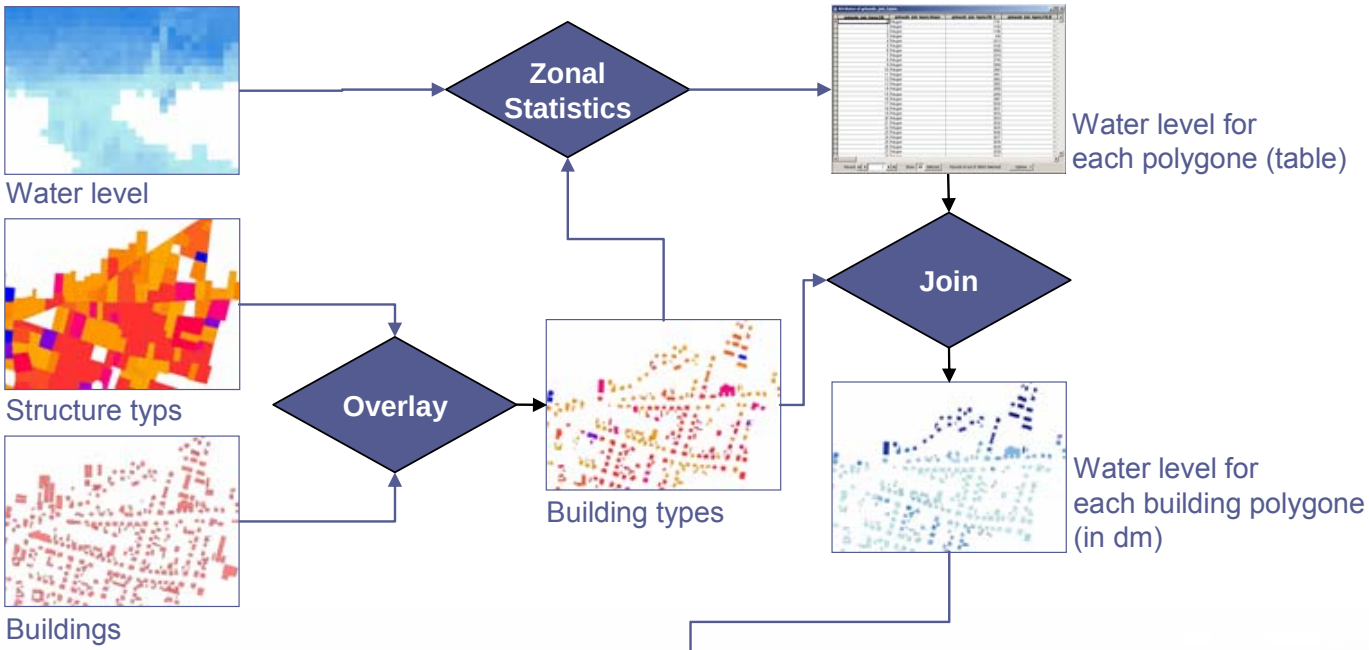
ME 2

ME 3

ME 7

EE 4

Model structure of HOWAD



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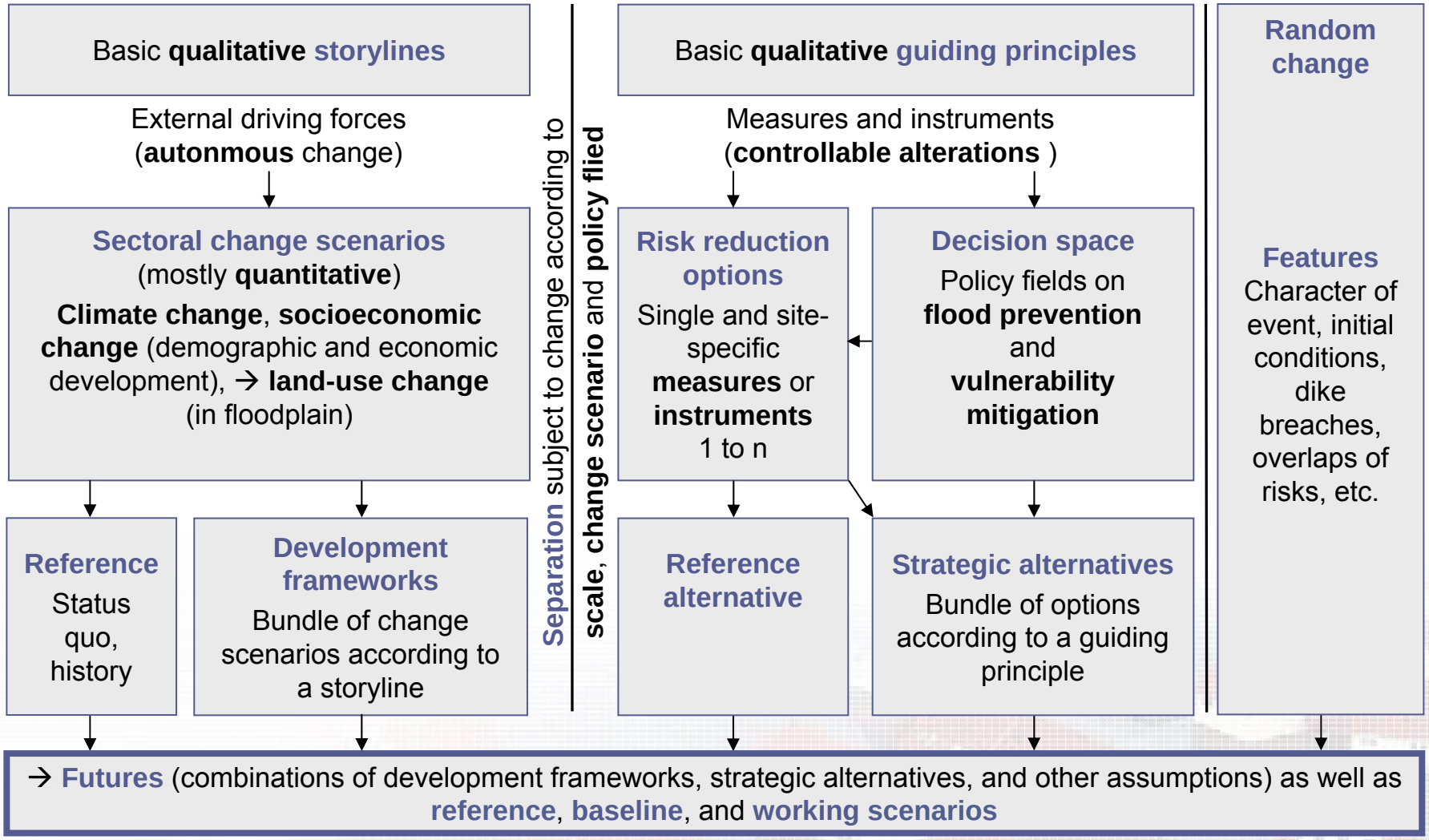
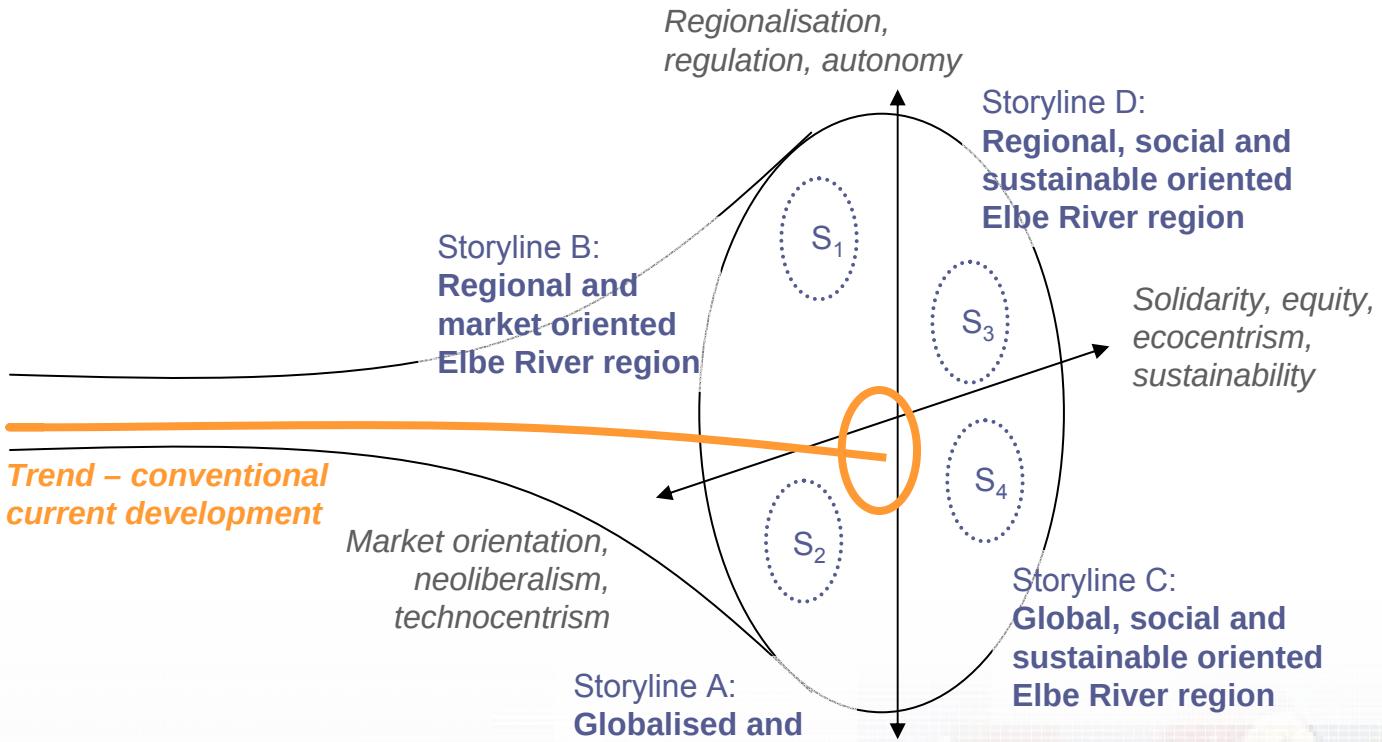
Components of „futures“



Storylines for futures of the Elbe River region



S = Scenario within a storyline quadrant

Luther (2007, adopted and refined from Nakićenović et al. 2000)

Development frameworks with sectoral scenarios

Driving forces	VERIS-Elbe storylines			
	A: "Global and market-oriented Elbe region"	**B: "Regional and market-oriented Elbe region"**	**C: "Local, social and sustainable oriented Elbe region"**	**D: "Regional, social and sustainable oriented Elbe region"**
Climate change	High	Medium-high	Low	Medium-low
Role of governments	Weak	Strong	Medium	Strong
Demographic development	Decrease, locally growth (lowest variant)	Decrease, locally growth (second lowest variant)	Decrease, locally growth (second highest and / or medium variant)	Constant, locally growth (highest variant)
Economic development	Locally high growth	Average growth	Average growth	Low growth
Environmental orientation	medium	Medium	High	High
Land-use change (urbanization)	High suburbanisation, extensification	Moderate suburbanization, intensification	Focus on dense urban structures	Focus on dense urban structures, intensification

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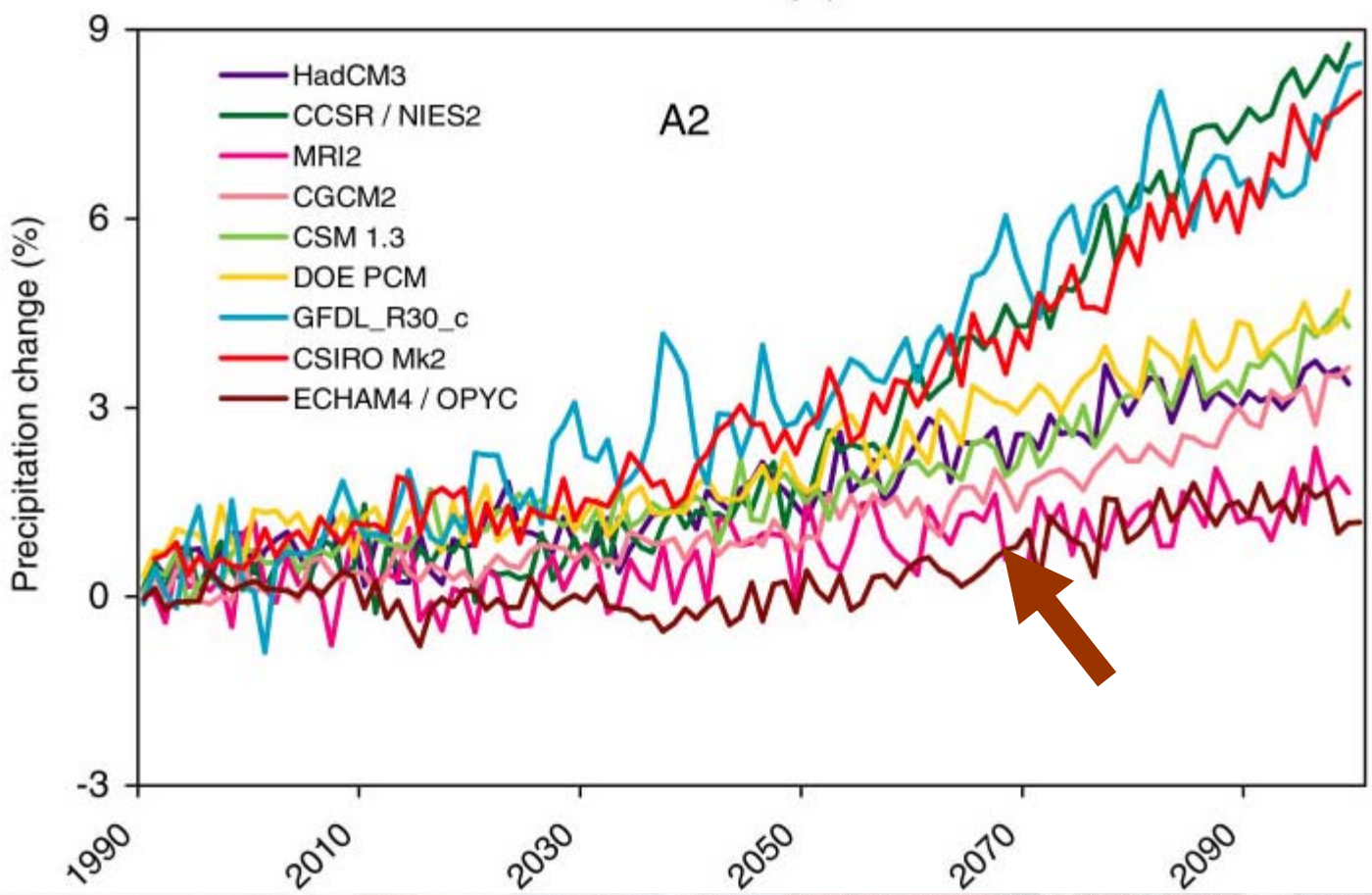
Projected precipitation of global circulation models (GCM)



IPCC (2007)

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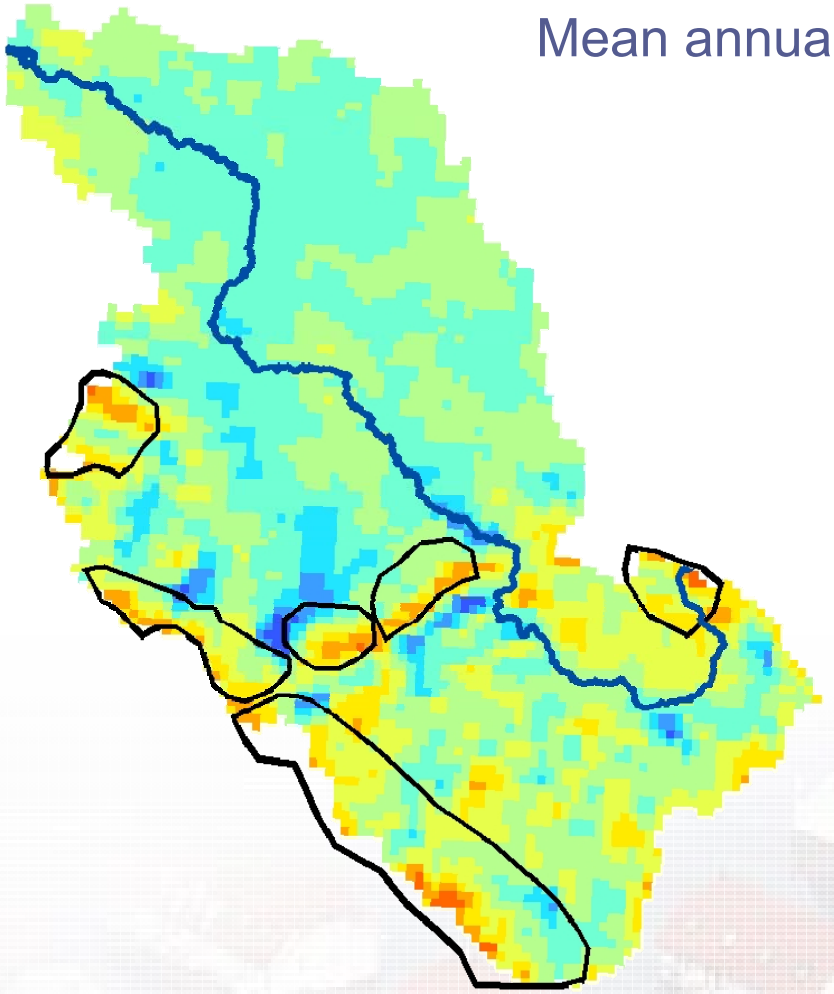
Climate change downscaling with REMO and STAR

Mean annual precipitation (1951 - 2000)



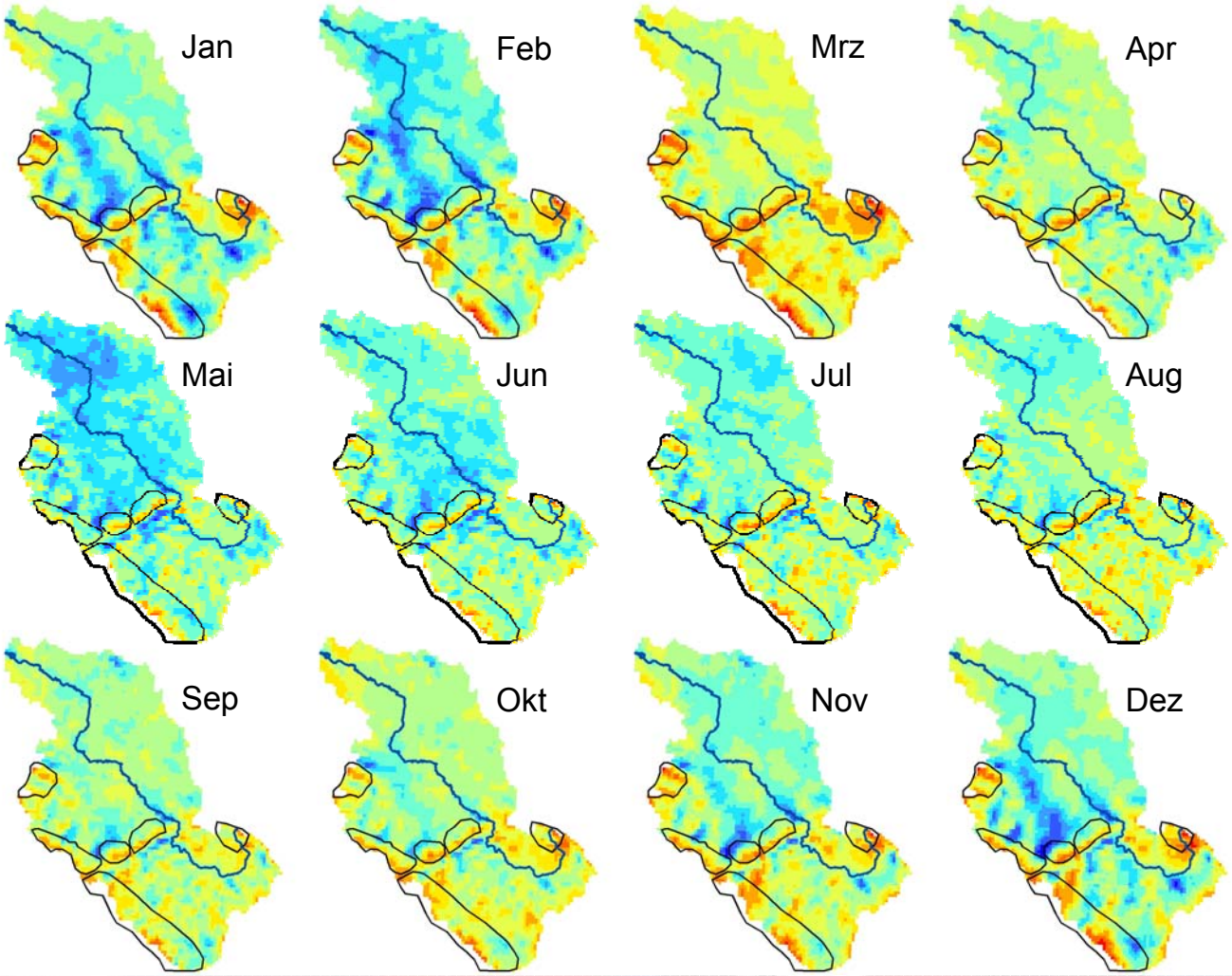
20 - 35	REMO =drier
35 - 50	
50 - 65	
65 - 80	
80 - 100	
100 - 125	
125 - 150	
150 - 175	
175 - 200	
200 - 250	
250 - 330	REMO = wetter

in % of
STAR BASZ

= flood generating area

Wagner (2007)

Comparison REMO - STAR (monthly precipitation)



Wagner (2007)

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Guiding principles for strategic alternatives

Guiding principles	**Prevention flood hazard**					**Mitigation vulnerability**			
	Flood-polder	Flood-ways	Dikes			Building bans for floodplain	Flood proofing	Evacuation	
			New	Height-ening	Reloca-tion			Persons	Live stock
„Resistence"	**x**	**x**	**x**	**x**	**x**				
„Resilience"						**x**	**x**	**x**	**x**
(„Public measures")	x	x	x	x	x	x		(x)	
(„Private measures")							x	X	x
(„Urban development")			x	x	x		(x)	(x)	
(„Floodplain development")	(x)	x			(x)	x			
„Combination"	**(x)**		**(x)**	**(x)**		**x**	**(x)**	**x**	
„All measures"	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Reference									

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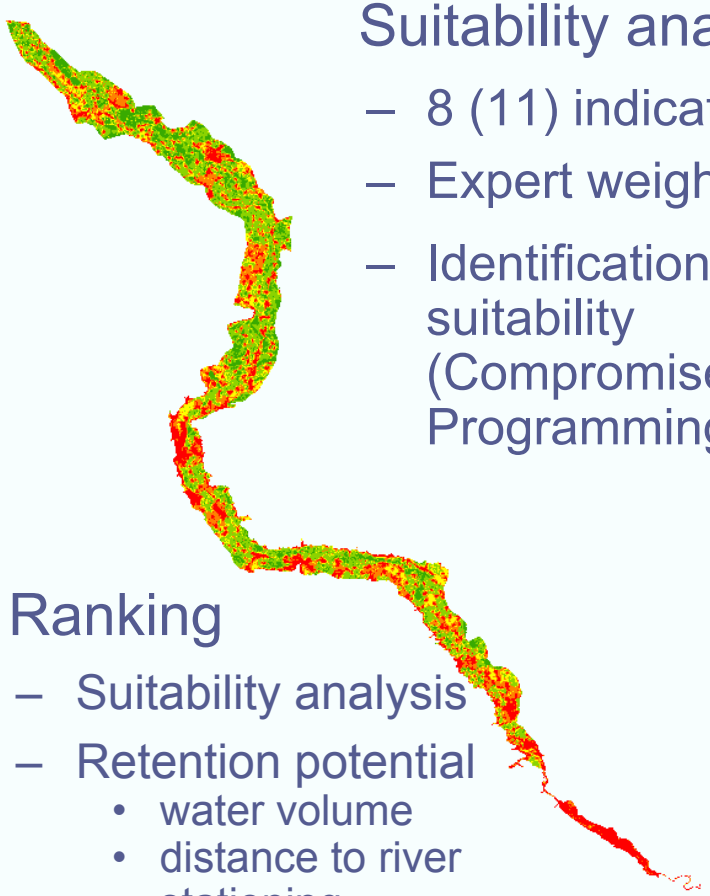
Suitability of areas for flood polders

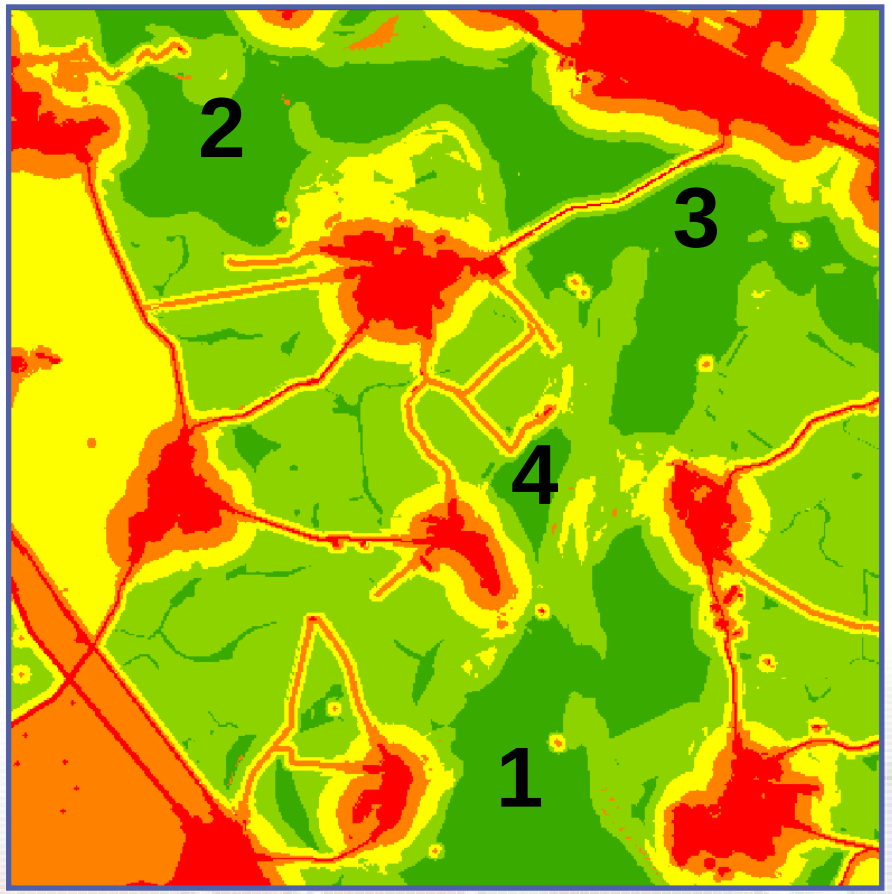


Suitability analysis

- 8 (11) indicators
- Expert weighing
- Identification of suitability (Compromise Programming)

Ranking

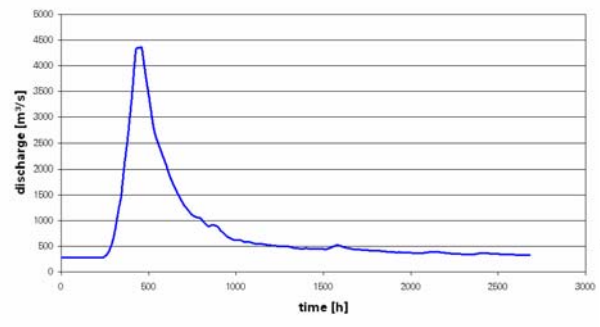
- Suitability analysis
- Retention potential
  - water volume
  - distance to river
  - stationing
- Ranking (Hasse-diagram technique)



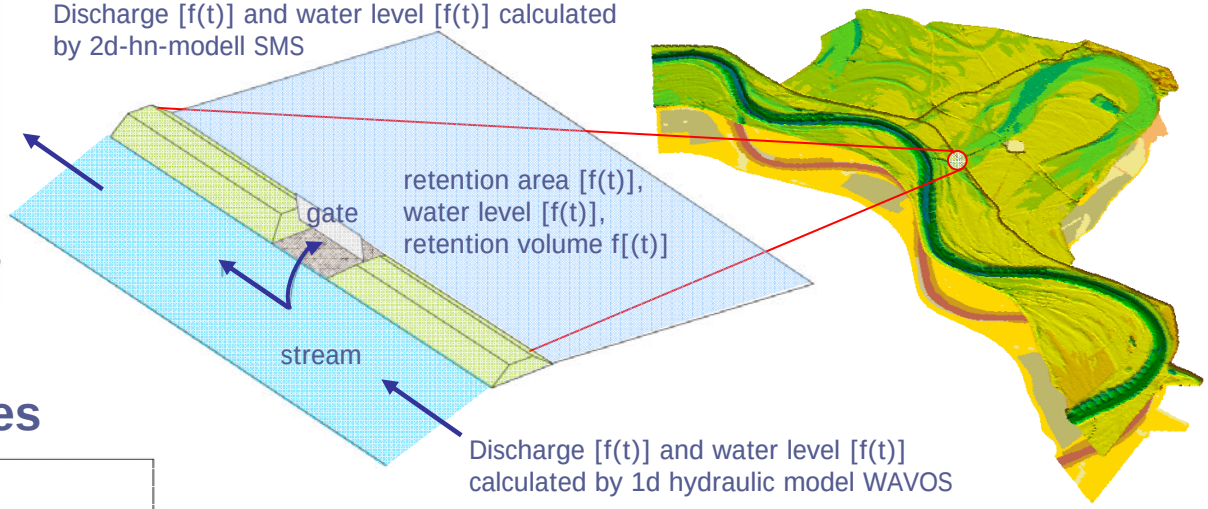
Vogel (2008a)

Design and modeling of flood polders

Modeling hydrodynamic effects

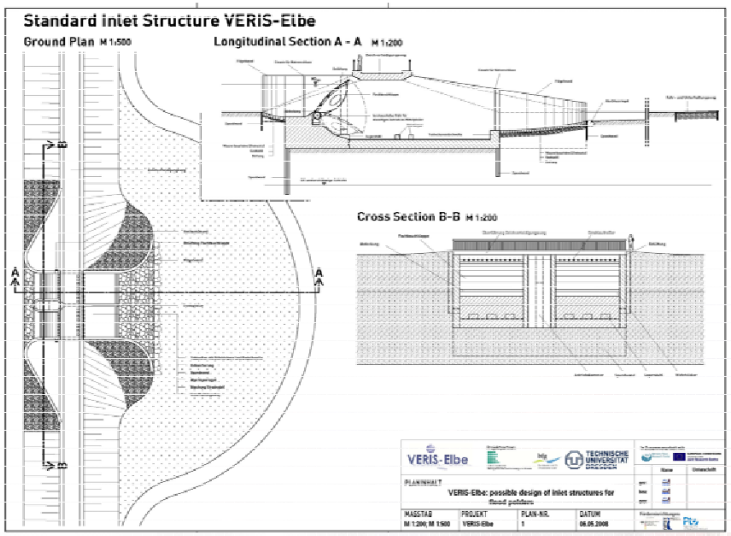


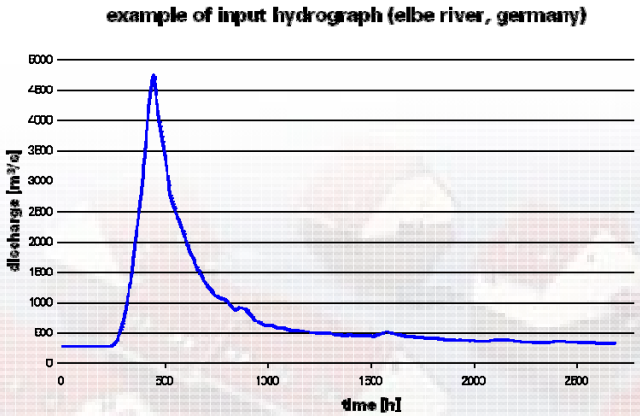
Discharge [f(t)] and water level [f(t)] calculated by 2d-hn-modell SMS



Discharge [f(t)] and water level [f(t)] calculated by 1d hydraulic model WAVOS

Predefinition and design of possible inlet structures





Kopp, Carstensen (2007)

Composing “futures”

Strategic alternatives		Development frameworks				Present
		Storylines with sectoral change scenarios				Measured data, reanalyses
Guiding principles		A	B	C	D	G
„Resistance“	**I**		**ES-B(S,GL100)-I** **ES-B(S,GL300)-I**			
„Resilience“	**II**		**ES-B(S,GL100)-II** **ES-B(S,GL300)-II**			
“Combination"	**II I**	**ES-A(S,GL100)-III** **ES-A(S,GL300)-III**	**ES-B(S,GL100)-III** **ES-B(S,GL300)-III**	**ES-C(S,GL100)-III** **ES-C(S,GL300)-III**	**ES-D(S,GL100)-III** **ES-D(S,GL300)-III**	
„all Measures“	**I V**		**ES-B(S,GL100)-IV** **ES-B(S,GL300)-IV**			
Reference alternative	**0**		**ES-B(S,GL100)-0** **ES-B(S,GL300)-0**			RS-G(S,GL100)-0 RS-G(S,GL300)-0
		BL-A(S,LS100)-0	**BL-B(S,LS100)-0**	**BL-C(S,LS100)-0**	**BL-D(S,LS100)-0**	RS-G(S,LS100)-0 RS-G(S,LS200)-0 RS-G(S,LS300)-0
			BL-B(R,LS100)-0			RS-G(R,LS100)-0 RS-G(R,LS200)-0 RS-G(R,LS300)-0
						RS-G(M,LS50)-0 **RS-G(M,LS100)-0** **RS-G(M,LS200)-0** **RS-G(M,LS300)-0**

Luther & Schanze (2007)

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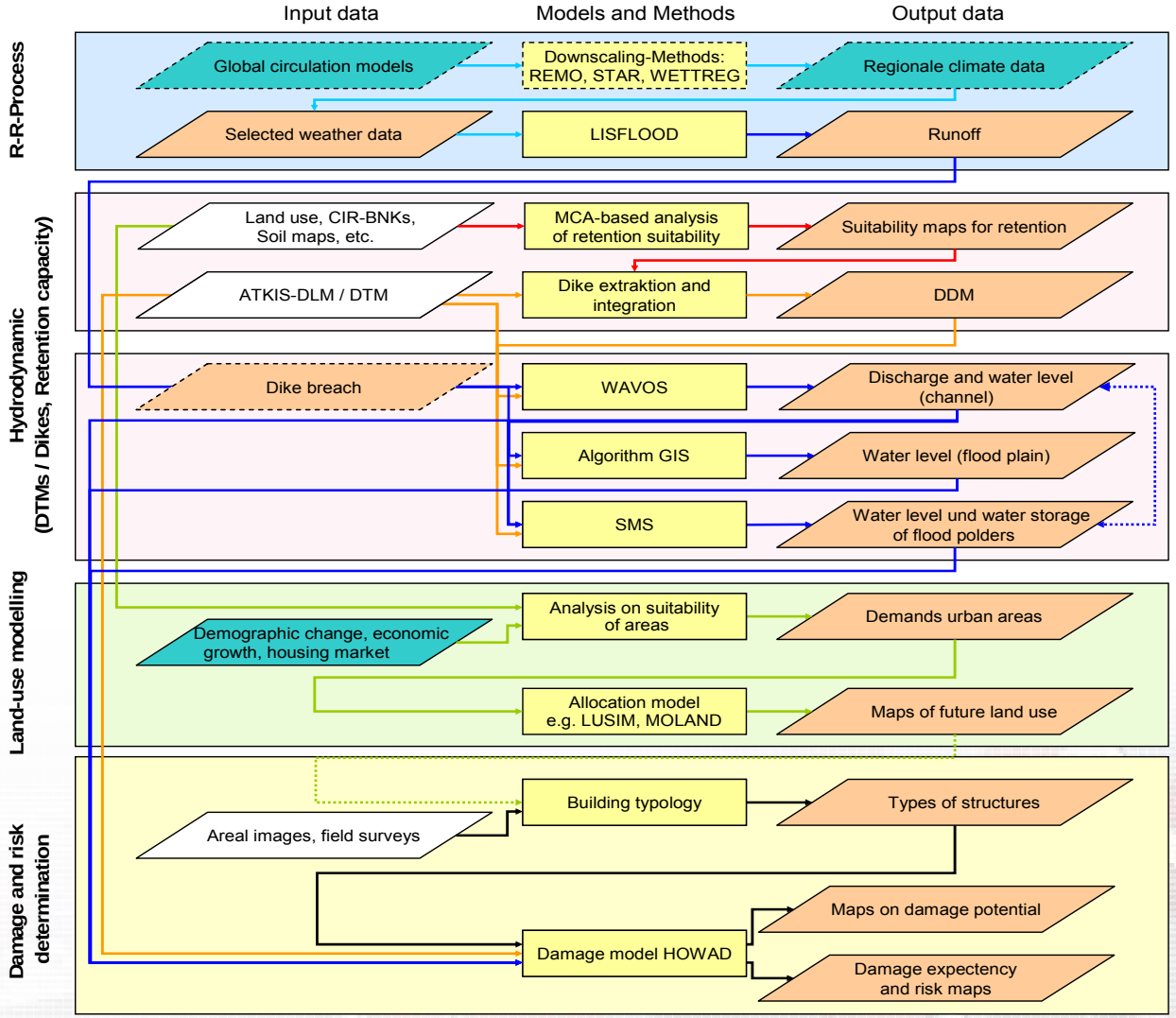
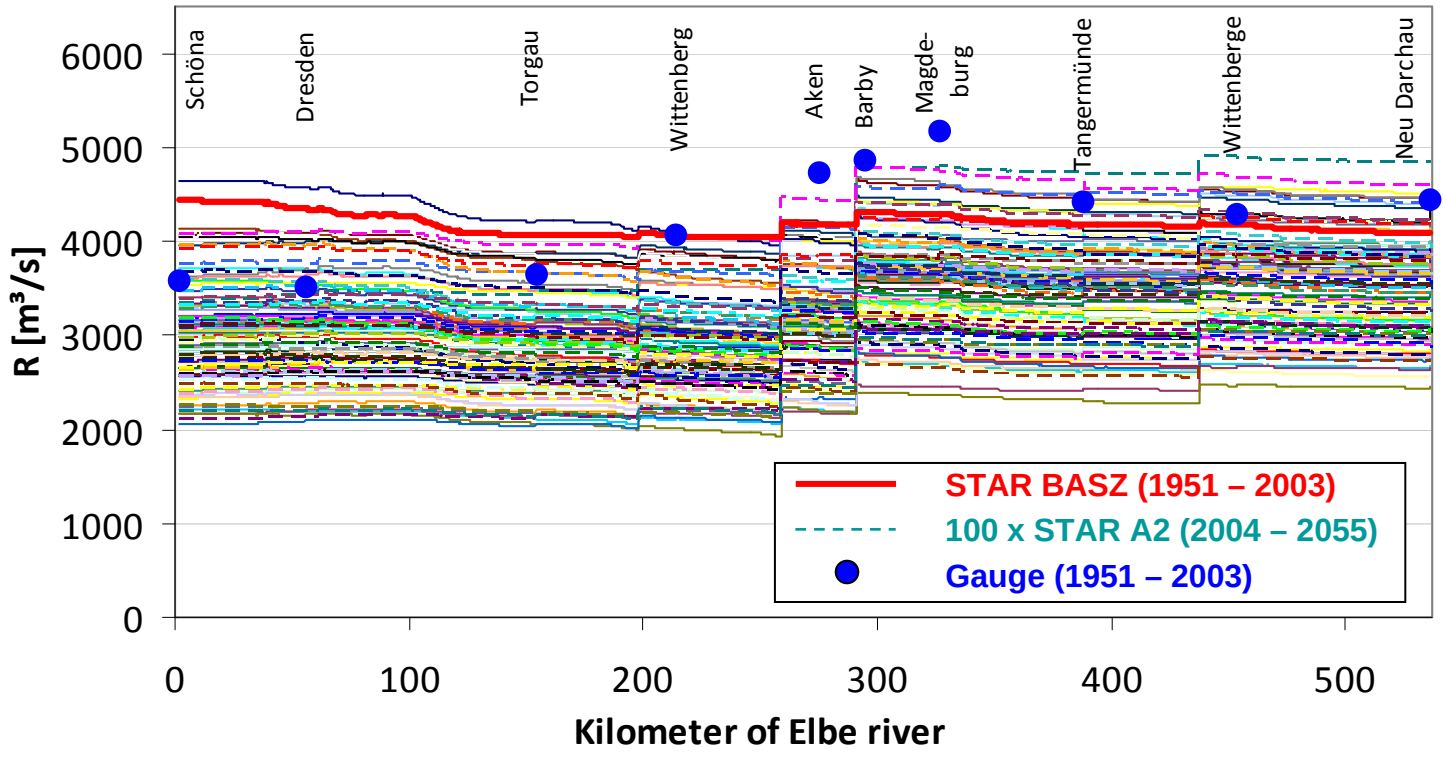
Model-based data flow for scenario analysis



Schanze & Luther (2007)

Impact of climate change based on STAR (1:200)

1951-2003 (Gauge / STAR-BASZ) vs. 2001-2055 (STAR A2)

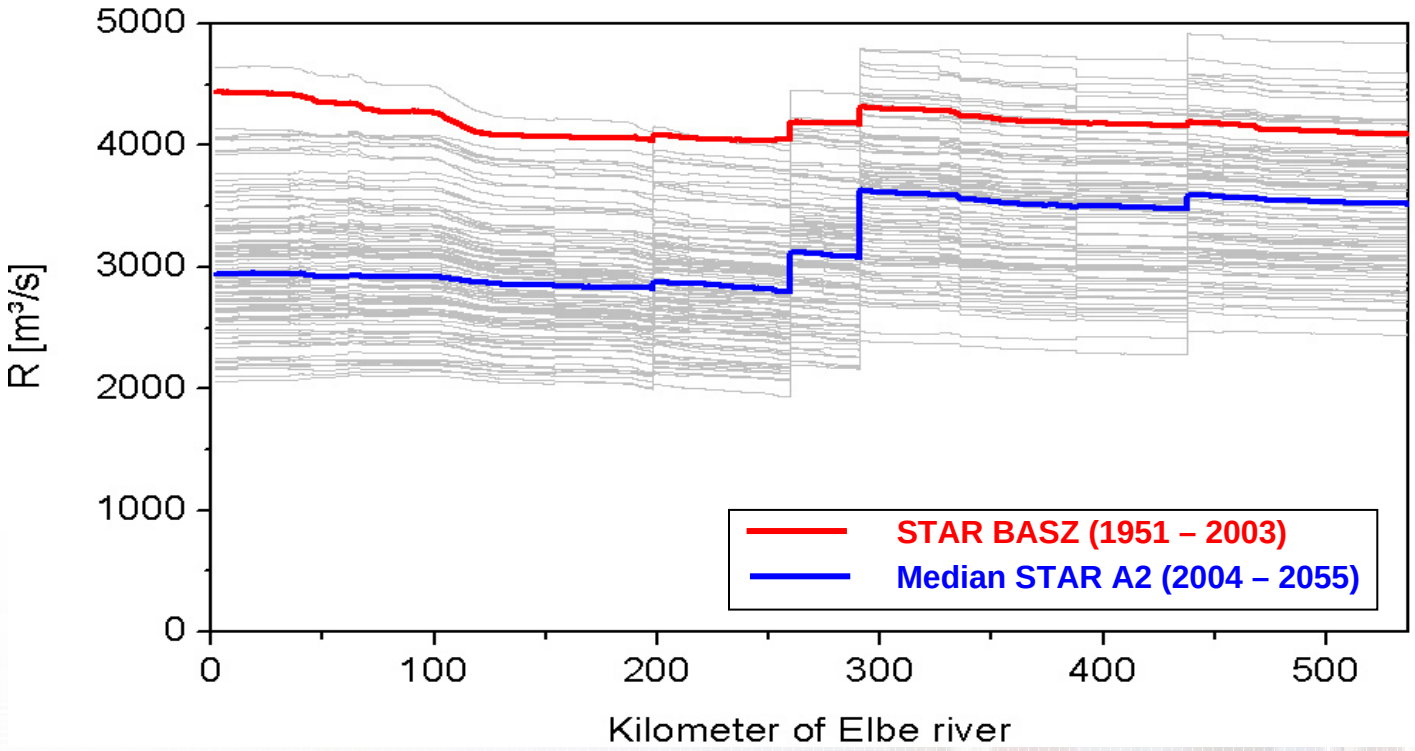


LISFLOOD and WAVOS with STAR BASZ and A2 data in comparison to statistical survey on measured discharge (generalized extreme value distribution (GEV))

Wagner, Schmidt & Schwarze (2007)

Impact of climate change based on STAR (1:200)

1951-2003 (Gauge / STAR-BASZ) vs. 2001-2055 (STAR A2)

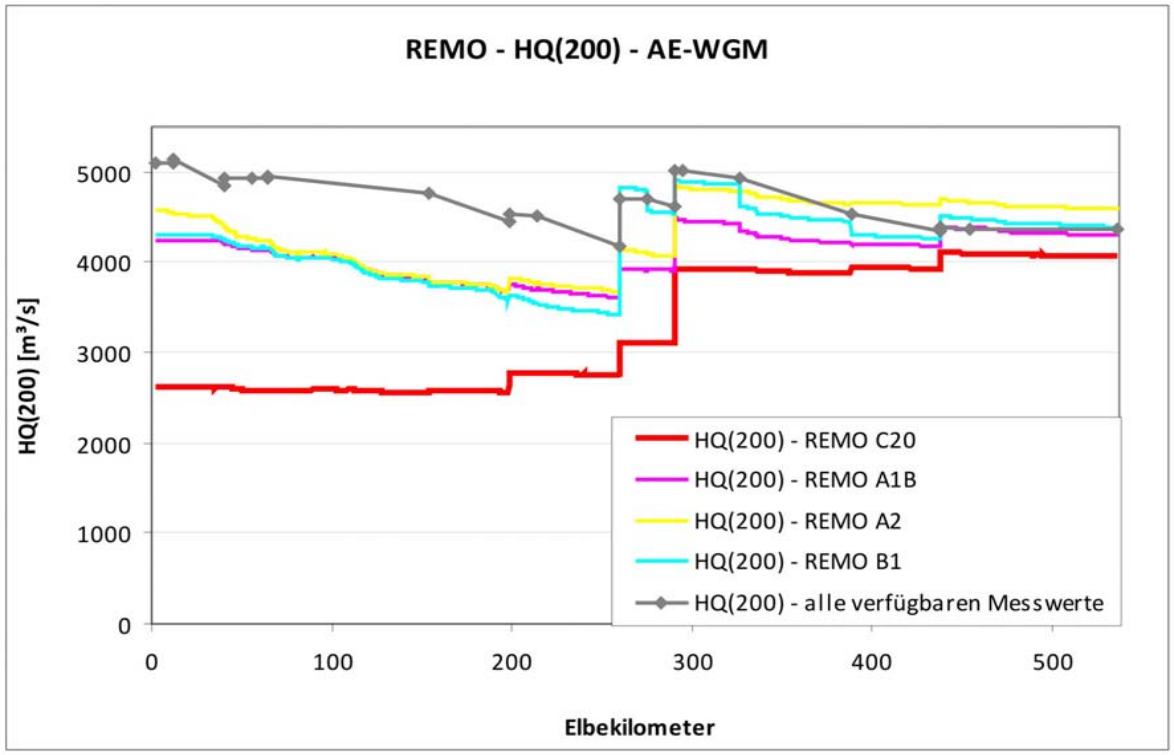


LISFLOOD and WAVOS with STAR BASZ and A2 data (generalized extreme value distribution (GEV))

Wagner, Schmidt & Schwarze (2007)

Impact of climate change based on REMO (1:200)

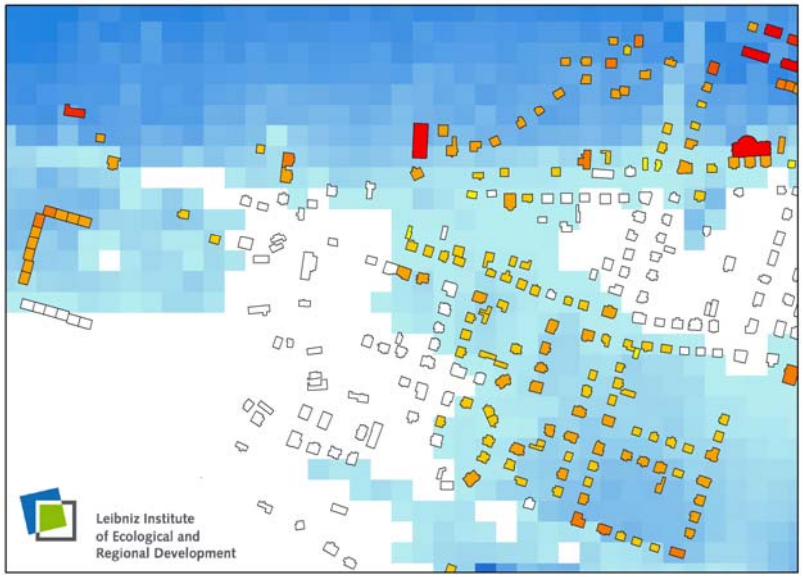
1851-2005 (Gauge) vs. REMO 1951-2000 (C20) & 2001-2100 (A1B, A2, B1)

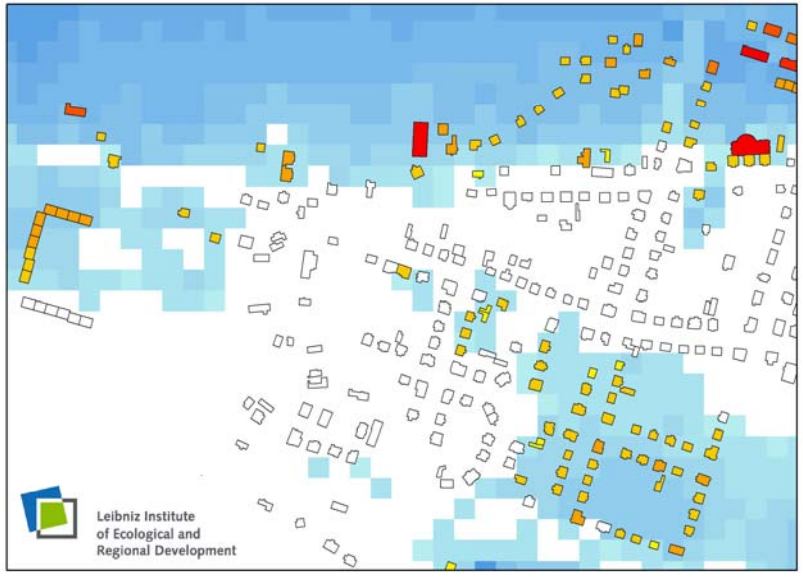


LISFLOOD and WAVOS with REMO C20 (re-analysis) and A1B, A2 and B1 data in comparison to measured discharge

Wagner, Schmidt & Schwarze (2007)

Damage simulation for scenarios BASZ and A2 (STAR, 1:200)





Neubert, Naumann & Deilmann (2008)

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Leibniz Institute of Ecological and Regional Development

TECHNISCHE UNIVERSITÄT DRESDEN

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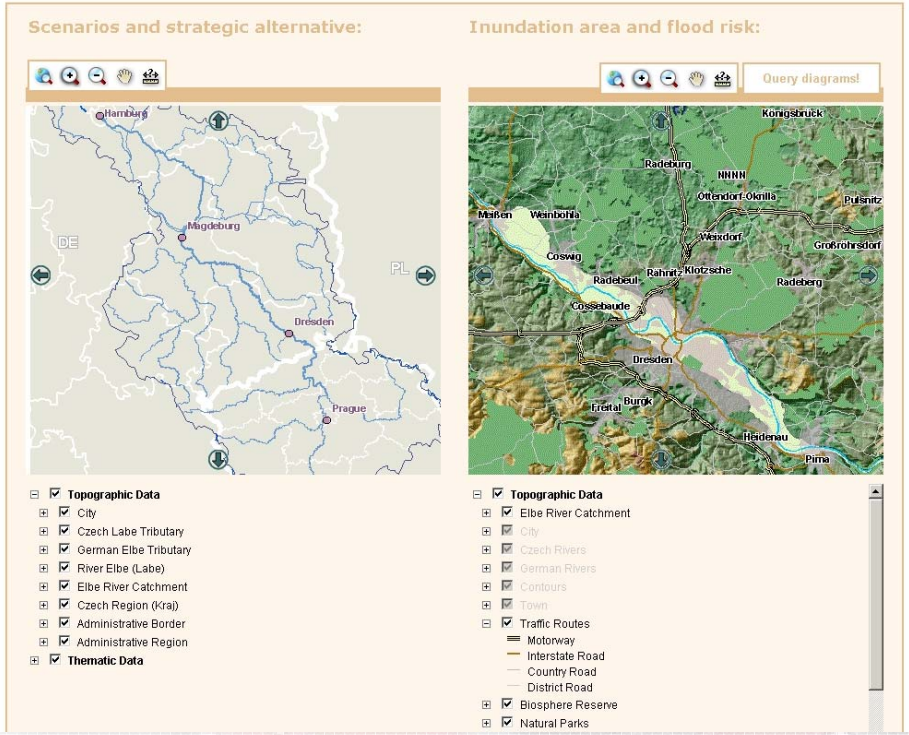
Contents

Outlook

- Flood risk curves with uncertainty bands for the entire Elbe River
- Multicriteria evaluation and ranking of the futures
- DSS tool with scenarios and ex-ante analysis (ArcGIS Server)



Petroschka, Walz, Schanze, Luther (2008)

Conclusions

- Flood risk appears in flood risk systems of many factors with their specific long-term dynamic or potential for alteration
- Coupling of recent models allow for calculating some processes of such systems under defined conditions
- Aleatory uncertainty can be explored by using the scenario approach considering individual factors in a consistent way
- Epistemic uncertainty can be indicated by comparing alternative models (e.g. GCMs, downscaling approaches, rainfall-runoff models)
- First estimates can be made for climate change impacts on the Elbe River with an indication of decreasing flood risks

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Consortium

Partners

- Leibniz Institute of Ecological and Regional Development (IOER), Dresden
- Technische Universitaet Dresden (TUD)
  - Institute of Hydrology and Meteorology (IHM)
  - Institute of Hydraulic Engineering and Applied Hydromechanics (IWD)
- Federal Institute of Hydrology (BfG), Koblenz

In co-operation with

- European Commission, DG Joint Research Center (JRC), Institute for Environment and Sustainability (IES), Ispra
- PlanEVAL
- Plan + Risk Consult

Associated partners

- Potsdam Institute for Climate Impact Research (PIK), Potsdam
- Max Planck Institute for Meteorology (MPI-M), Hamburg

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"Analysing dynamic flood risk systems is a means of understandig future uncertainties."

Thank you for your attention

http://www.VERIS-Elbe.ioer.de

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Funding

Project Management

Coordination

GFZ