Joint International Conference

Technologically modified environment – environmentally modified technology

Climate change and adaptation
– why technology is highly needed –

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Institute of Meteorology and Climate Research

Climate change …

IPCC AR4, 2007: Increase in global air and ocean temperatures, melting of snow and ice and rising sea level now clearly indicate a significant warming of the Earth, which is to a large extent due to human interference.

Changes in precipitation patterns, droughts, storms, and flooding are probable. Impacts of changes in mean and extreme events will affect modern societies in many respect.

Climate change … and societal change

… will coincide with the demands of a

- rapidly increasing population in many countries,
- needing food, energy, water, health care

River Rhine, Oct. 1, 2009, Speyer

Sri Lanka, 2001

Dresden, August 2002

Climate change … and societal change

… will coincide

- with increasing public and private properties
- changing vulnerability of technological infrastructure (buildings, traffic systems, energy and water supply …), and
- a highly automized and interdependent information society in developed countries

Pictures: courtesy B. Ruck, IFH

Global perspective

Air temperature difference in future periods to 1980-1999

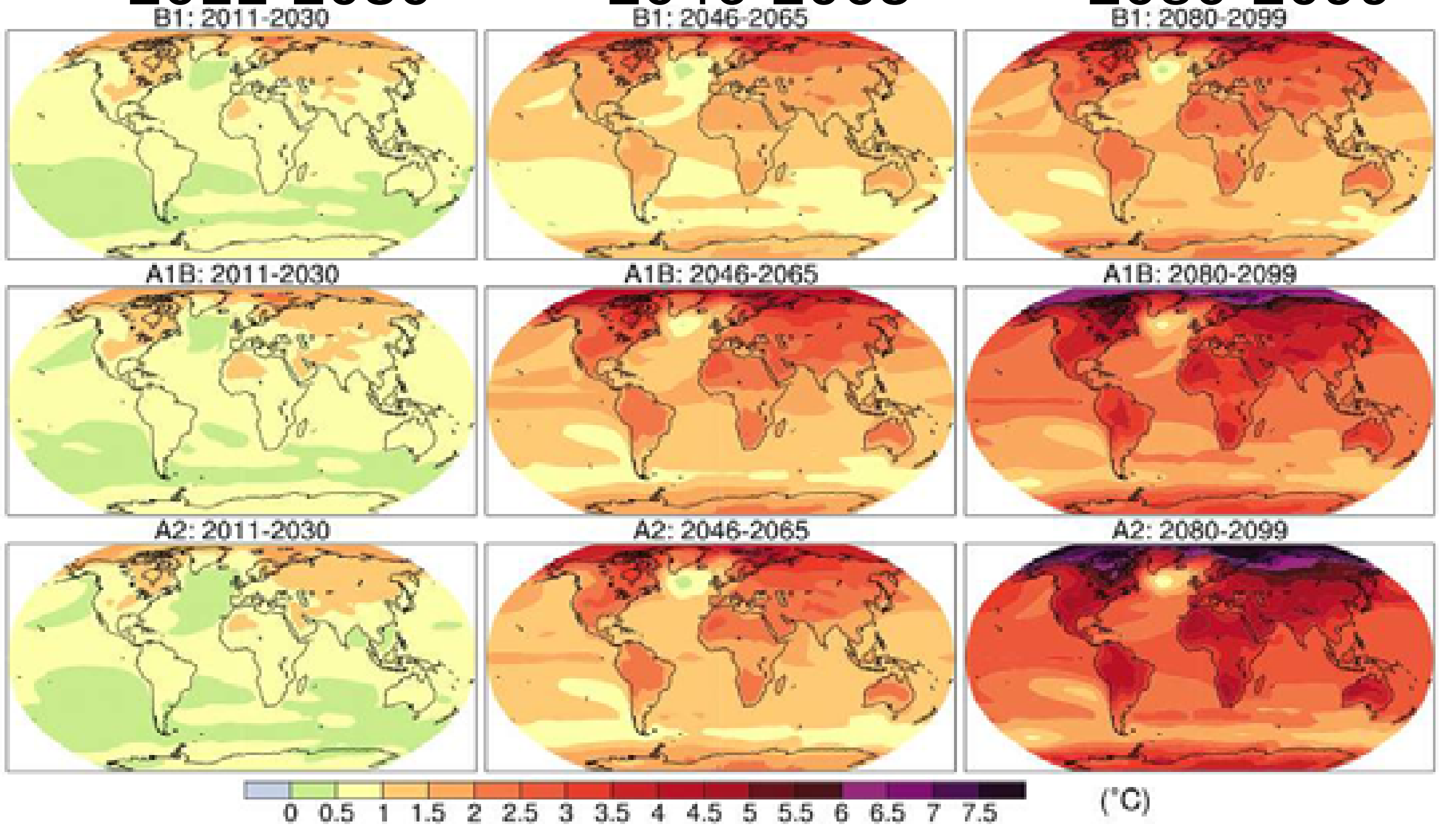
2011-2030 2046-2065 2080-2099

Emission scenarios

550 ppm B1

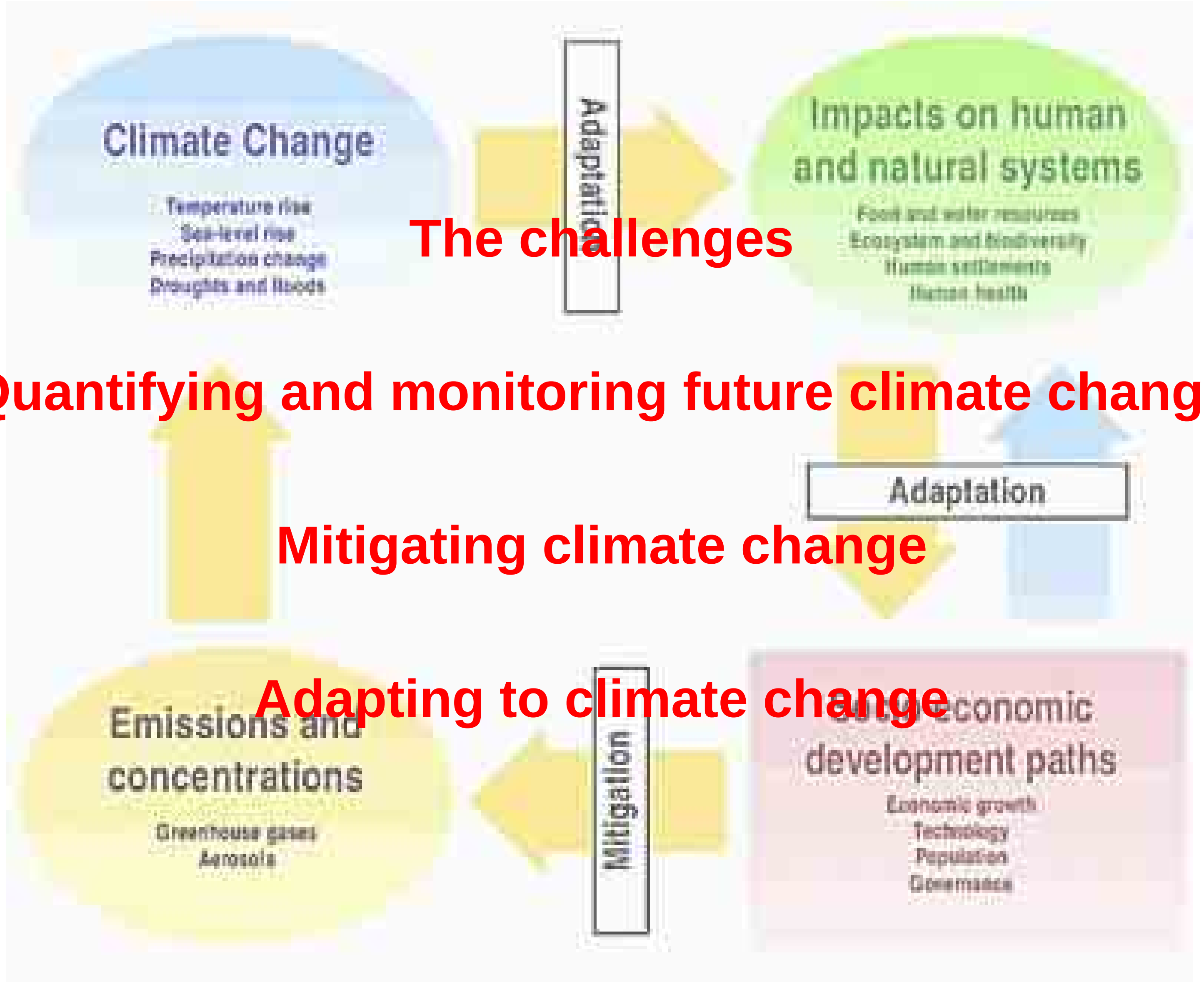
720ppm A1B

850 ppm A2



Quelle: IPCC AR4 2007

Challenges



The challenges

Quantifying and monitoring future climate change

Mitigating climate change

Adapting to climate change

Climate research at KIT

The Karlsruhe Institute of Technology strengthens its efforts in the field of climate change research by

pursuing its leadership role and numerous research projects in the Helmholtz Programme „Atmosphere and Climate“ (with FZJ, GFZ)

combining Earth and engineering sciences in the KIT-Center Climate and Environment

focussing on climate and geological risks in the Center of Desaster Management and Risk Reduction Technology (CEDIM, with GFZ)

transferring scientific results to politicians, industry, and the media via the The Southern Germany Climate Office

Topics

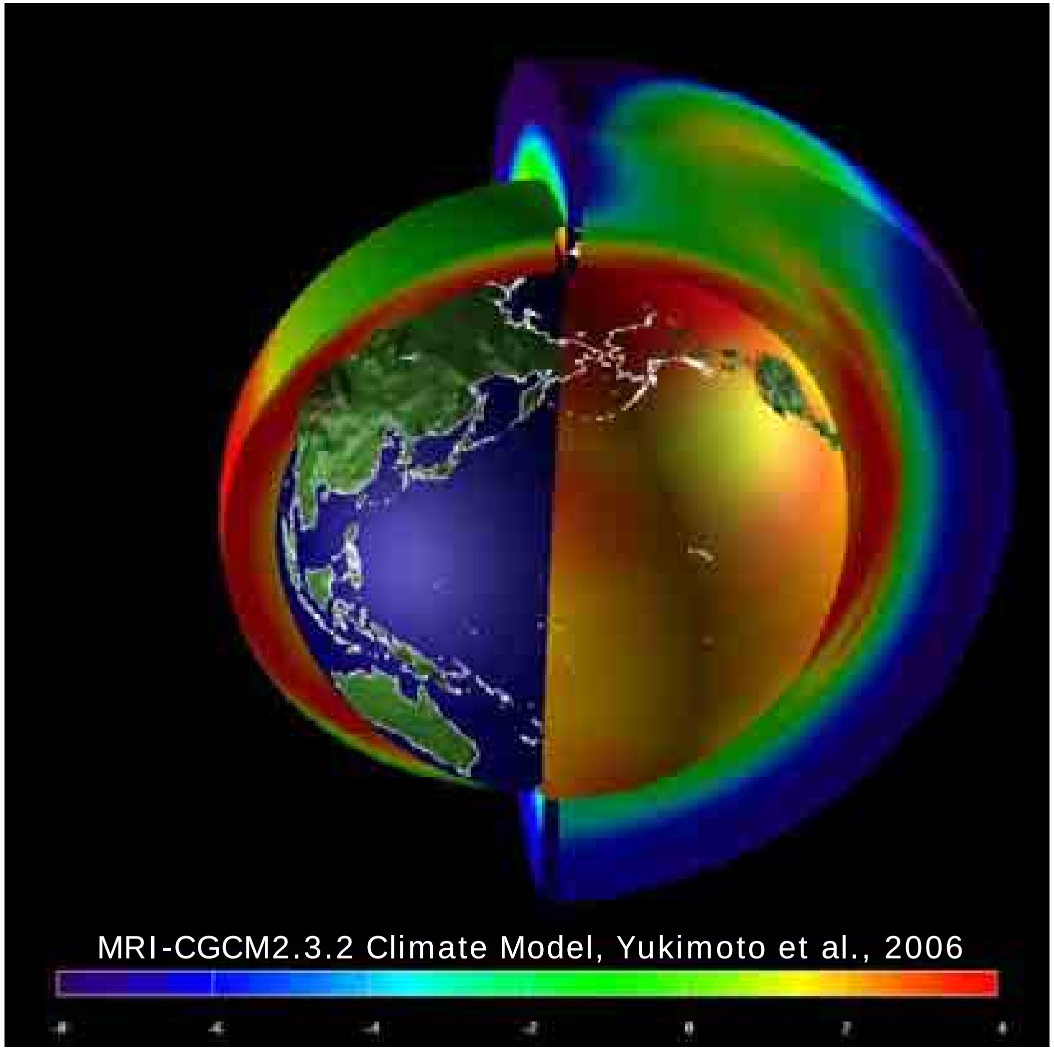
(with examples from current research at KIT)

1. Challenges of downscaling global climate change scenarios to regional prediction

2. Technology for mitigation (KIT example of carbon storage)

3. Technology for adaptation (KIT examples of adaptation to mitigate flood and storm risks)

Global modelling and uncertainty

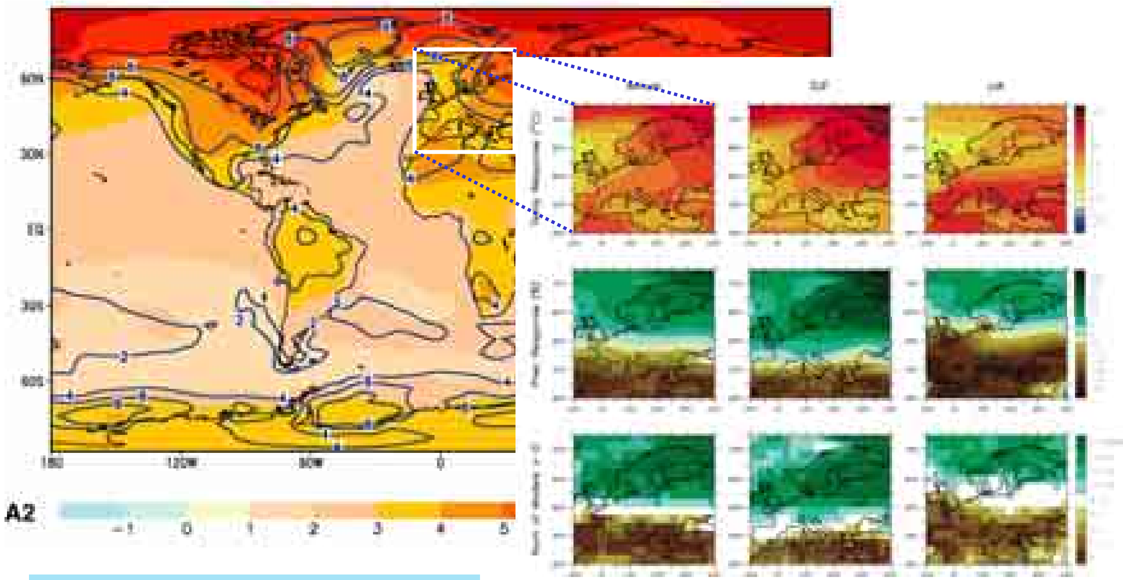


We (have to) rely on modelled climate change scenarios depending

- uncertain emission rates and composition change
- simulations of a very complex physico-bio-chemical system
- models being only validated for present climate

3D-temperature change 2070-2100 - present

Global perspective Regional perspective



Temperature change in °C, end vs. beginning of 20th century, IPCC TAR

Temperature and precipitation change, model consistency end vs. beginning of 20th century, IPCC AR4

Global perspective Regional perspective

MMD-A1B Simulations for Europe.

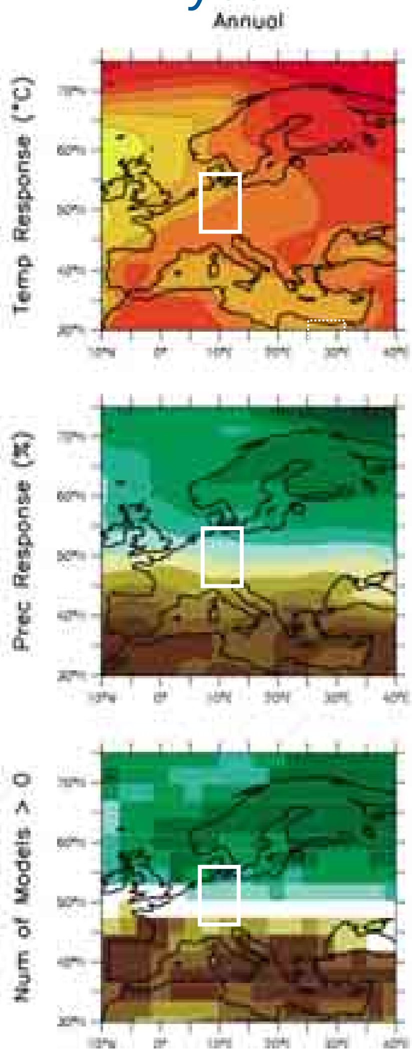
Differences (2080-2099) vs. (1980-1999), 21 model average.

year | winter | summer

temperature

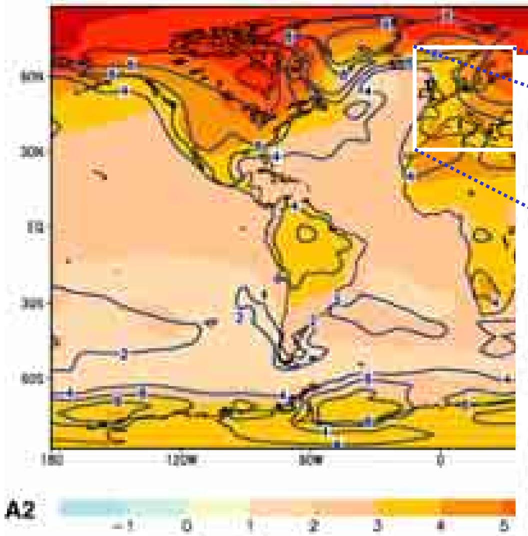
precipitation

Numbers of models giving more precip

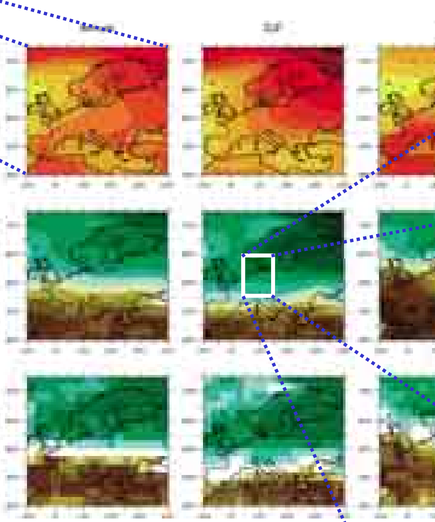


IPCC AR4, TS 20

Global perspective   Regional perspective

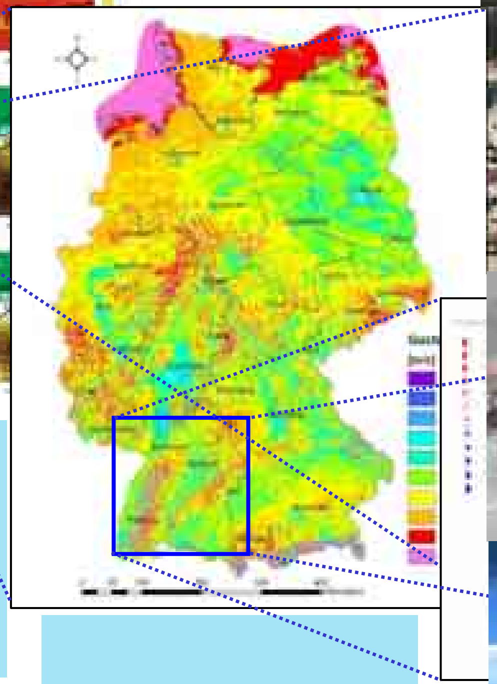


Temperature change in °C, end vs. beginning of 20th century, IPCC TAR



Temperature and precipitation change, model consistency end vs. beginning of 20th century, IPCC AR4

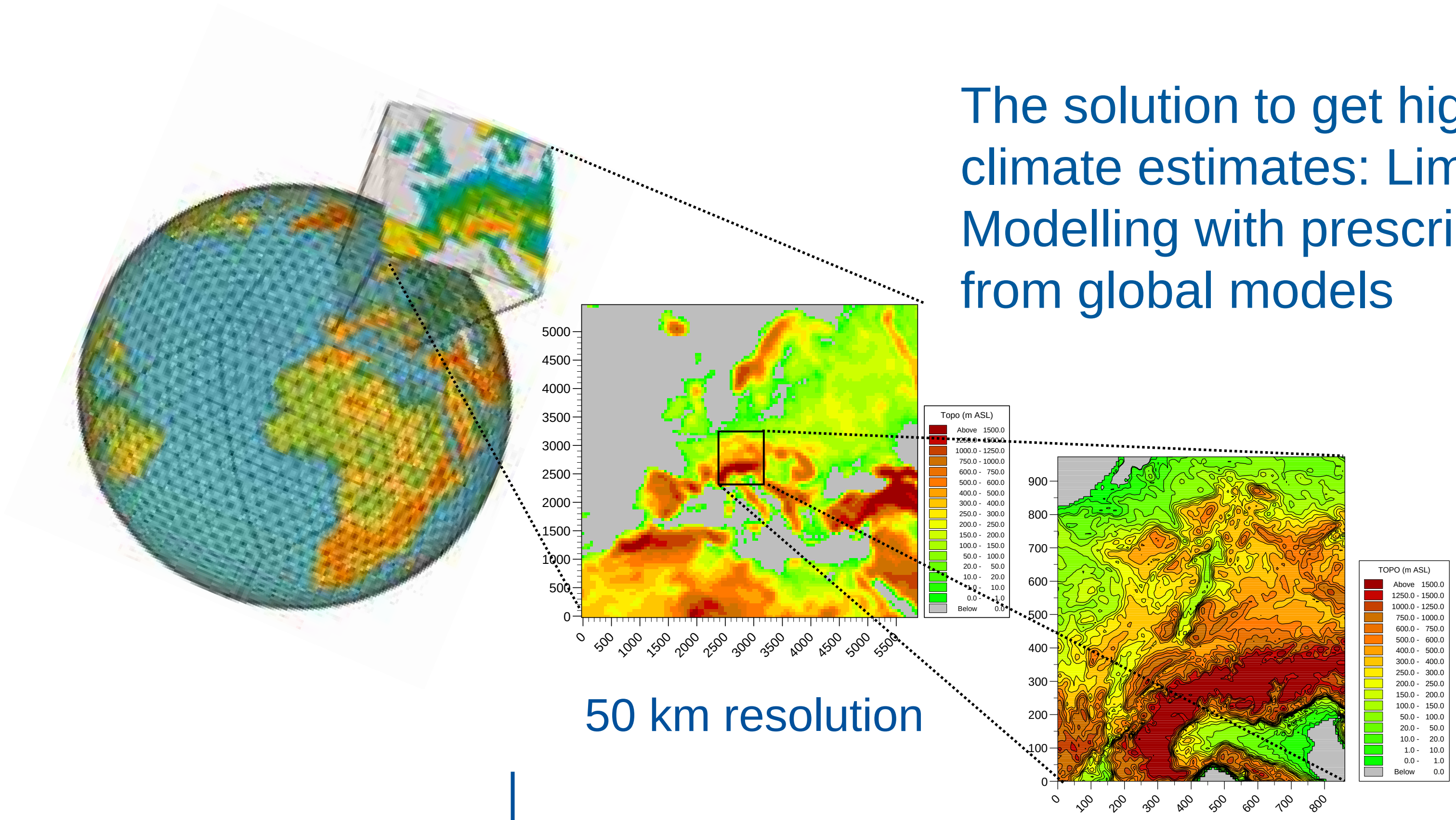
National perspective



CEDIM Wind risk map for Germany, present climate

Downscaling global scenarios

The solution to get high resolution climate estimates: Limited Area Modelling with prescribed forcing from global models



50 km resolution

7 km resolution

Global models:

NCEP, ERA40, GME

ECHAM5, ECHO-G

Nested COSMO model system at KIT (IMK-TRO)

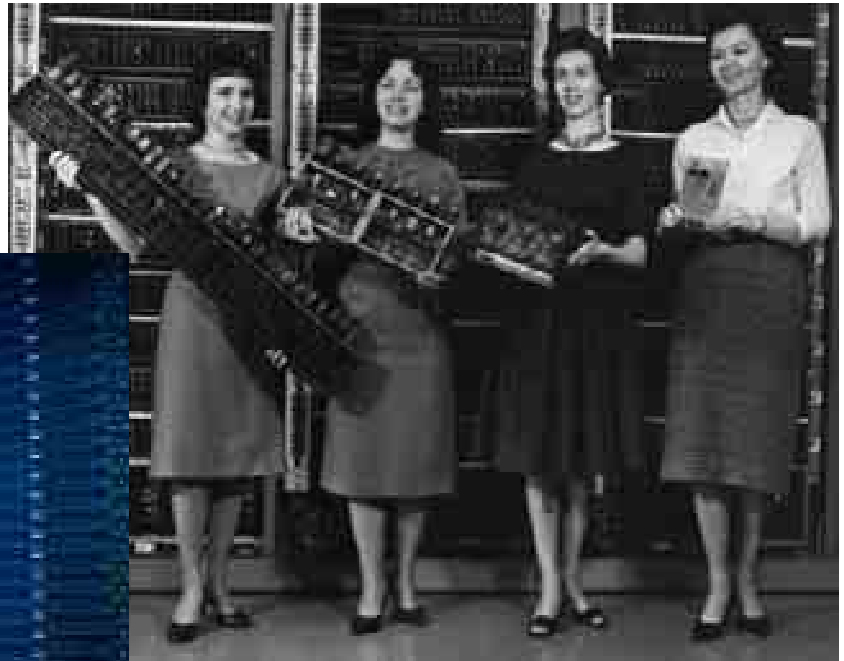
HLRS Stuttgart, NEC SX8, total (single) CPU time 2008: 2983 days, 55 Tbyte storage

ENIAC, 1946

First useful weather forecasts

L. F. Richardson (1881-1953)

n



27 t weight,

5000 additions or 357 multiplications oder 38 divisionen per second

SCC/KIT
15.77 TFLOPS = 15770000000000 operations per seconds

Quelle: Wikipedia

Aristoteles
384 v.Chr.–322 v.Chr.
Meteorologica „Die Lehre von den Himmelserscheinungen"

Technology: High performance computing

ECHAM5 / MPI-OM für IPCC AR4 mit T63L31 (≈200km, 1.87°) Auflösung

18 Experimente
insgesamt 5000 Jahre Simulationszeit
80 CPU Stunden pro Simulationsjahr

Quelle: http://www.dkrz.de/pdf/tf/TerraFlops_6_10_MidREZ.pdf

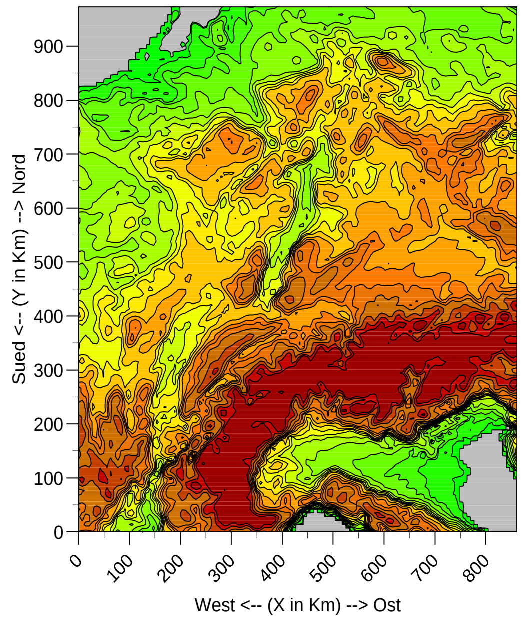
CLM mit 50km (0.44°) Auflösung

118 x 110 x 40 Gitterzellen
Δt = 240s (Runge-Kutta)
100 CPU Stunden pro Simulationsjahr

CLM mit 7km (0.0625°) Auflösung

124 x 140 x 40 Gitterzellen, Δt = 40s (Leapfrog)
360 CPU Stunden pro Simulationsjahr

Source: H.-J. Panitz, KIT



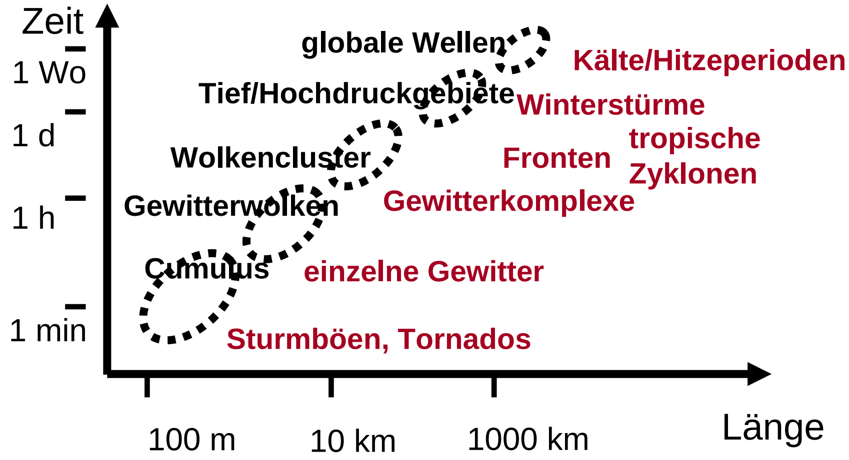
KIT approach to climate downscaling: ensembles

initial state

deterministic predictions

-> limits weather forecasts to about 14 days (deterministic chaos)

climate scenarios / prediction: possible futures decades ahead



Ensemble setup:

different global models

different global model realizations

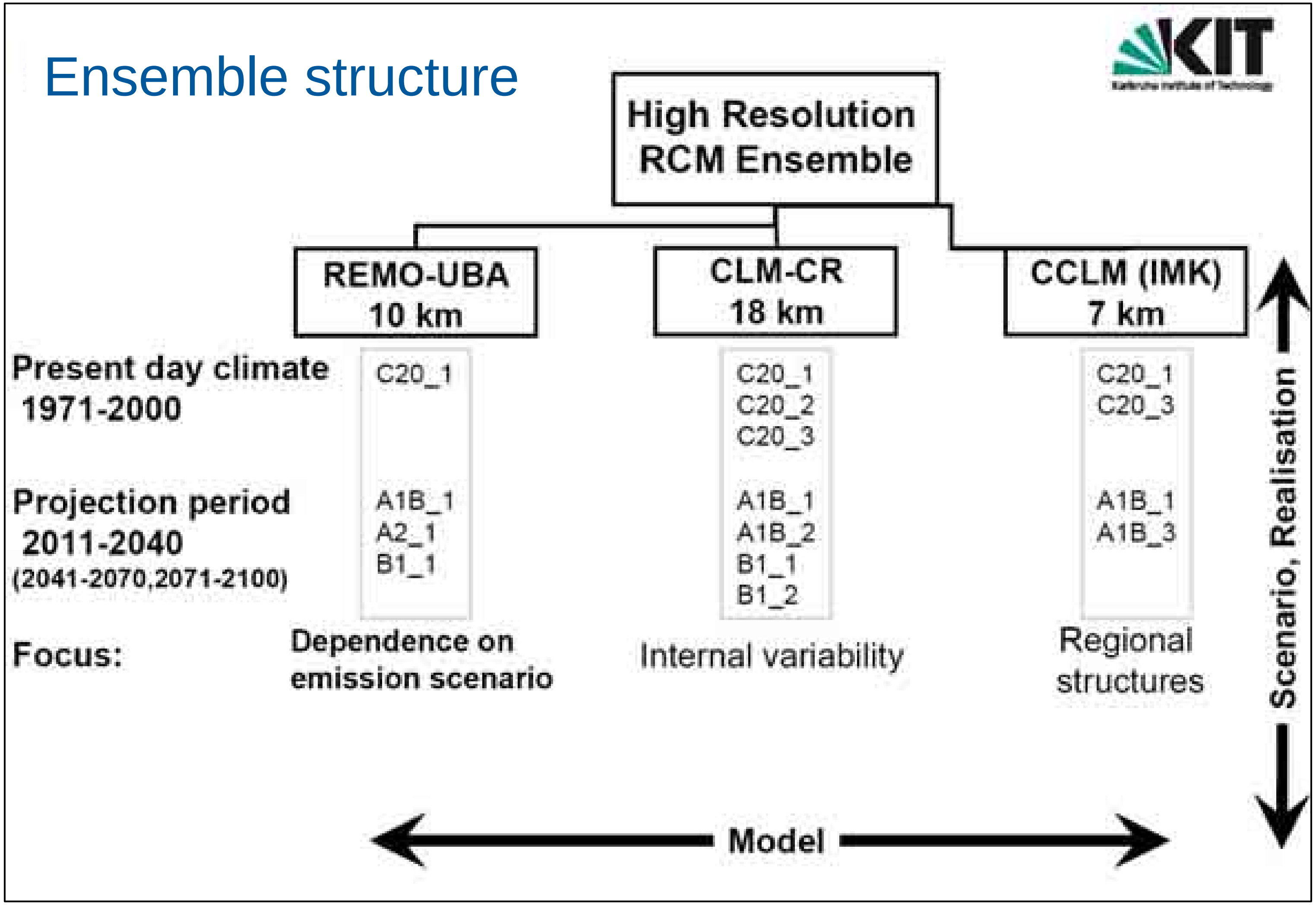
different SRES scenarios

different downscaling methods

different regional models

different resolution, physical process parameterizations …

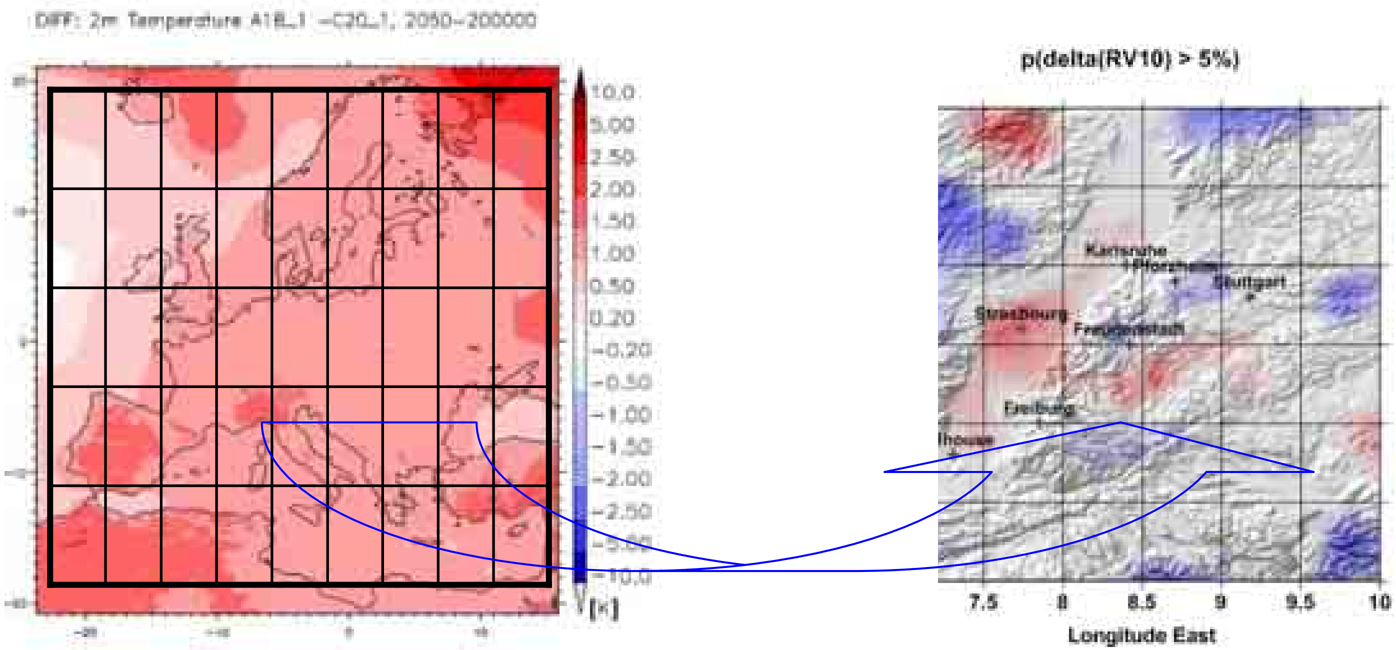
KIT approach to climate downscaling: ensembles



KIT approach to climate downscaling: ensembles

Present   Future

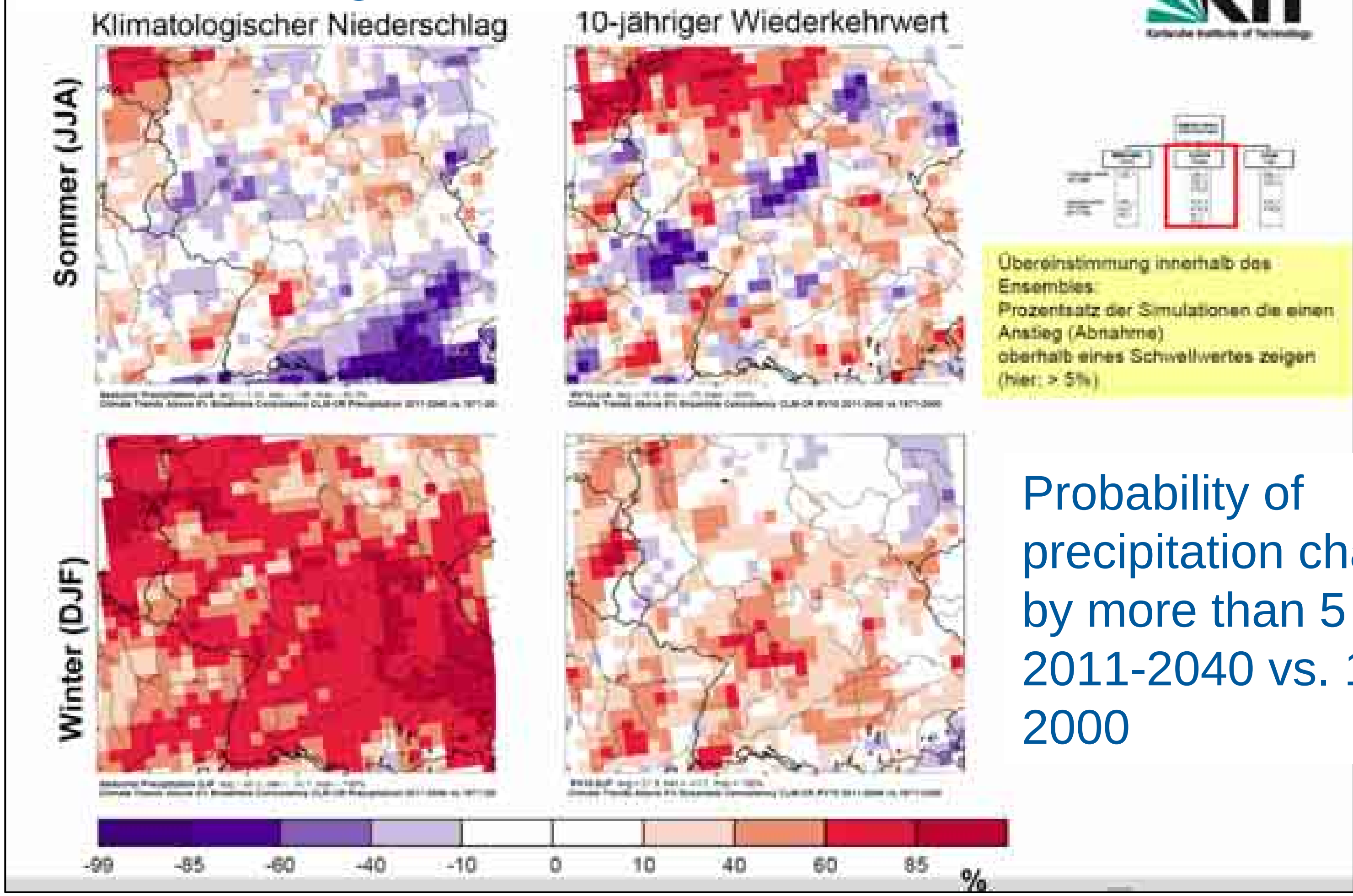
much higher information detail, probabilistic, more realistic



CLM-Konsortialläufe: Differenz der 2m-Temperaturen A1B_1 - C20_1
1981-2000 vs. 2031-2050

Probability map of a temperature increase by more than 1 K

Ensemble agreement



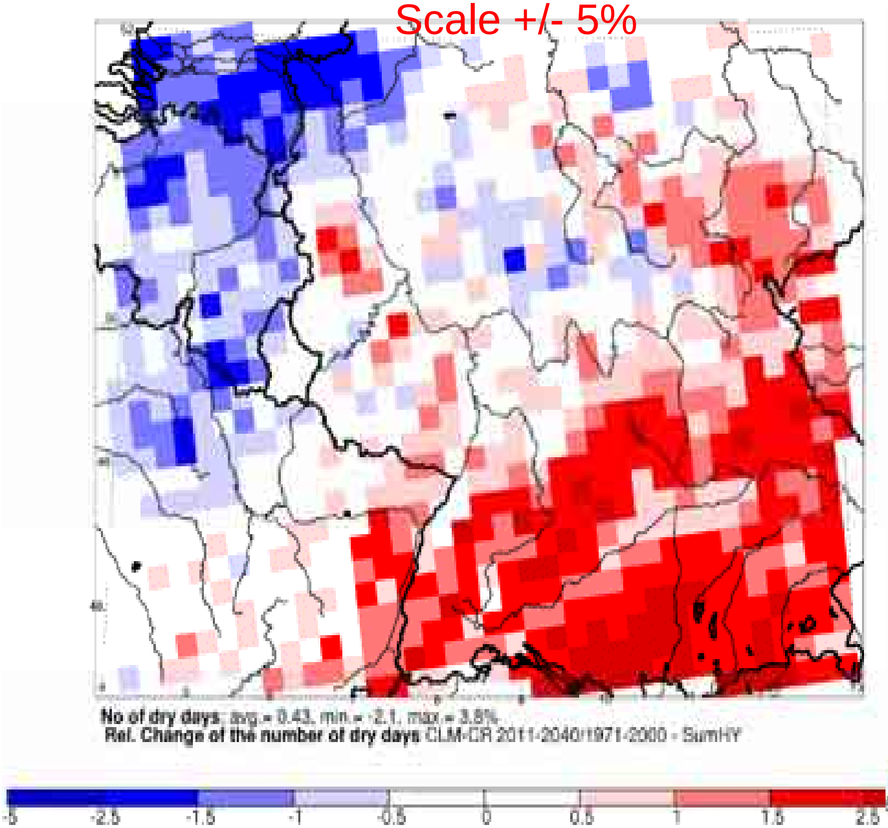
Probability of precipitation change by more than 5 % 2011-2040 vs. 1971-2000

KIT approach to climate downscaling: ensembles

Number of dry days – summers 2011-2040/1971-2000 (CLM-CR Ensemble)

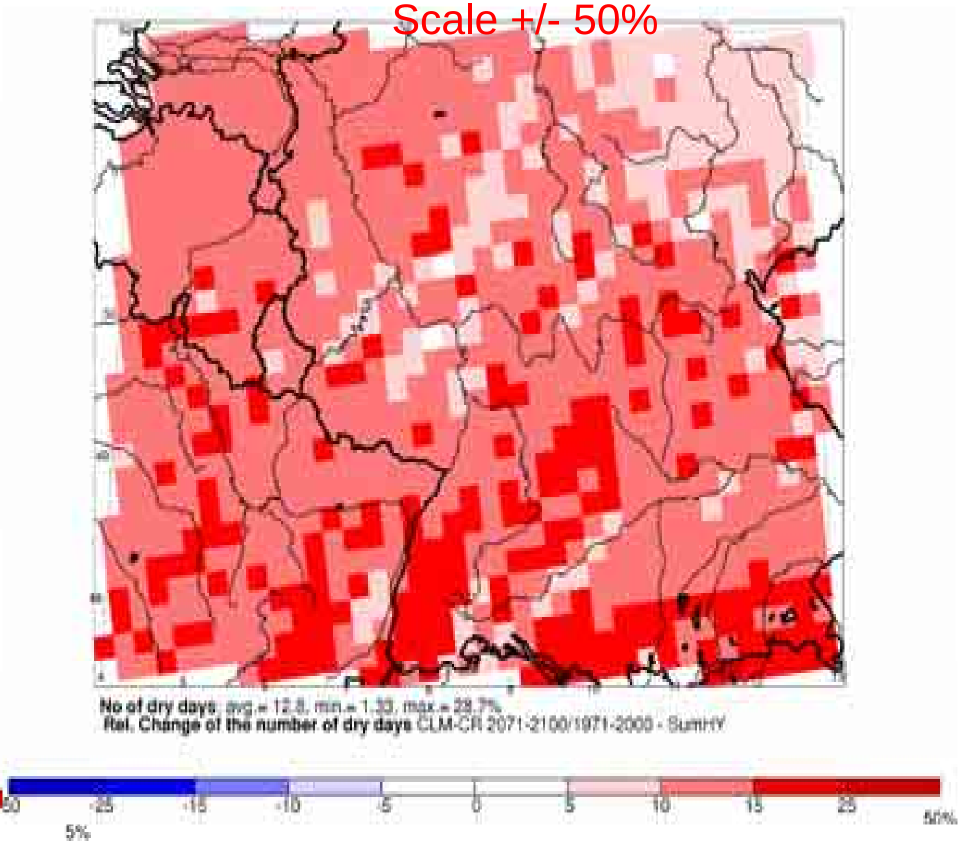
2011 – 2040 vs. 1971 – 2000

Scale +/- 5%



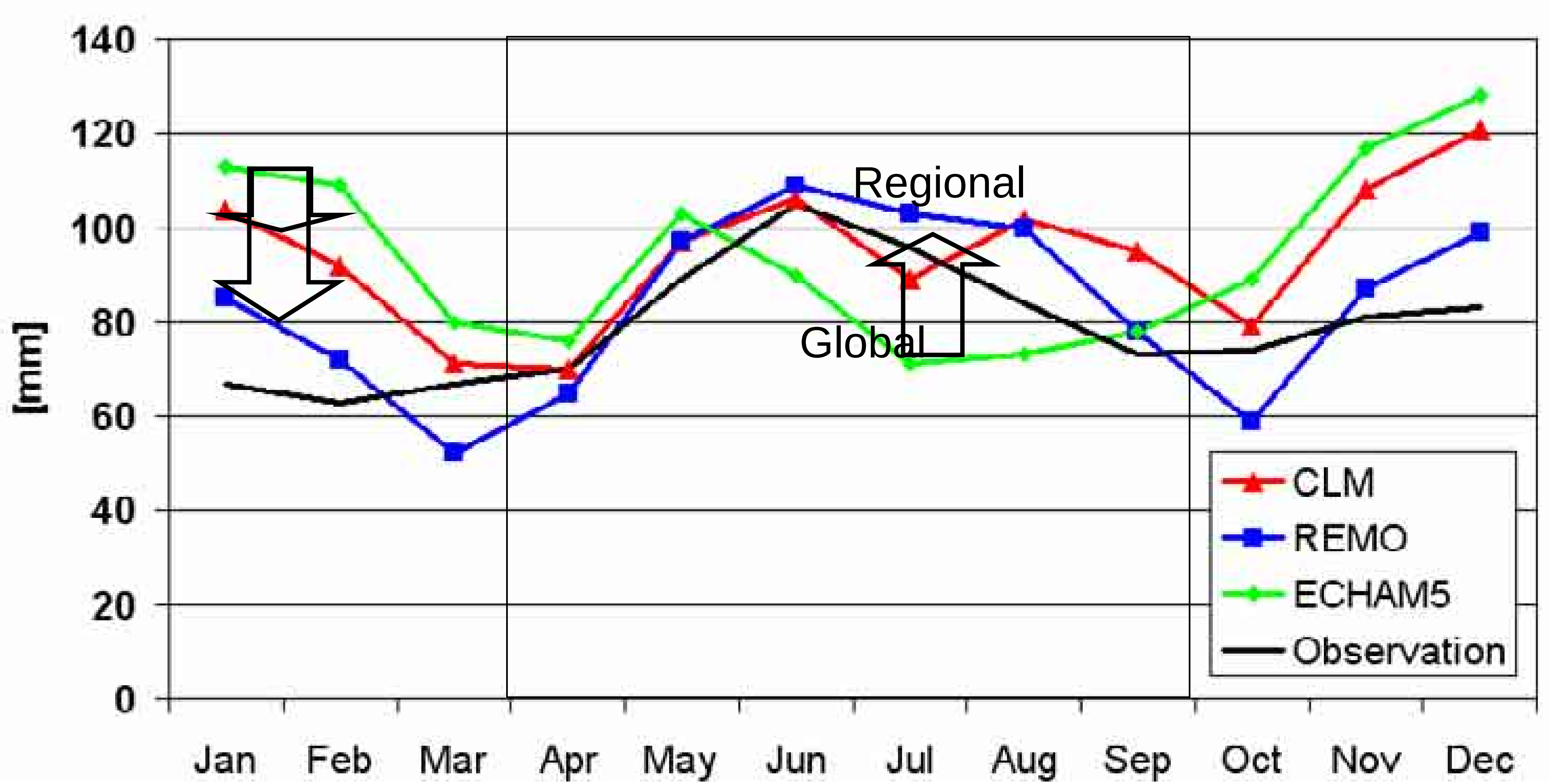
2071 – 2100 vs. 1971 – 2000

Scale +/- 50%

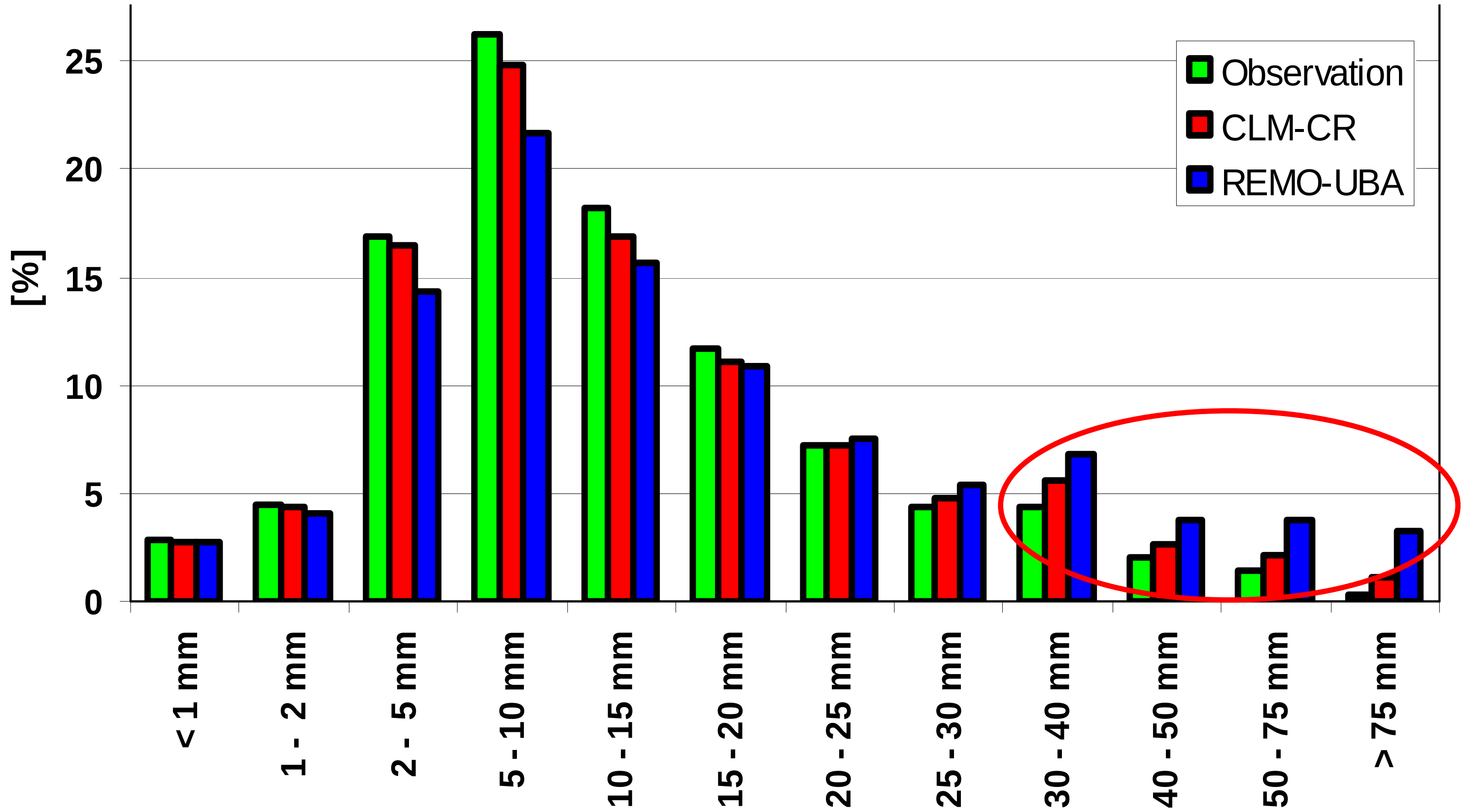


Regional modelling results - validation

Mean annual cycle of precipitation 1971-2000
in Baden-Württemberg, monthly sums in mm

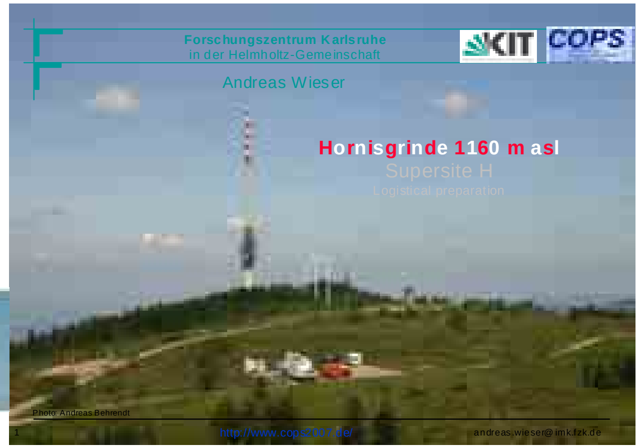


Frequency distribution of daily precip in Baden-Württemberg
Contribution to total precip in %



COPS/TRACKS 2007 (KIT co-leadership)

- 7 radiosonde stations
- 9 aircraft, 1 airship
- 5 „Supersites“ with Radar, Lidar …
- mesonet stations for soil moisture, turbule fluxes, precipitation, GPS IWV, …
- >300 participants from 10 countries



Topics

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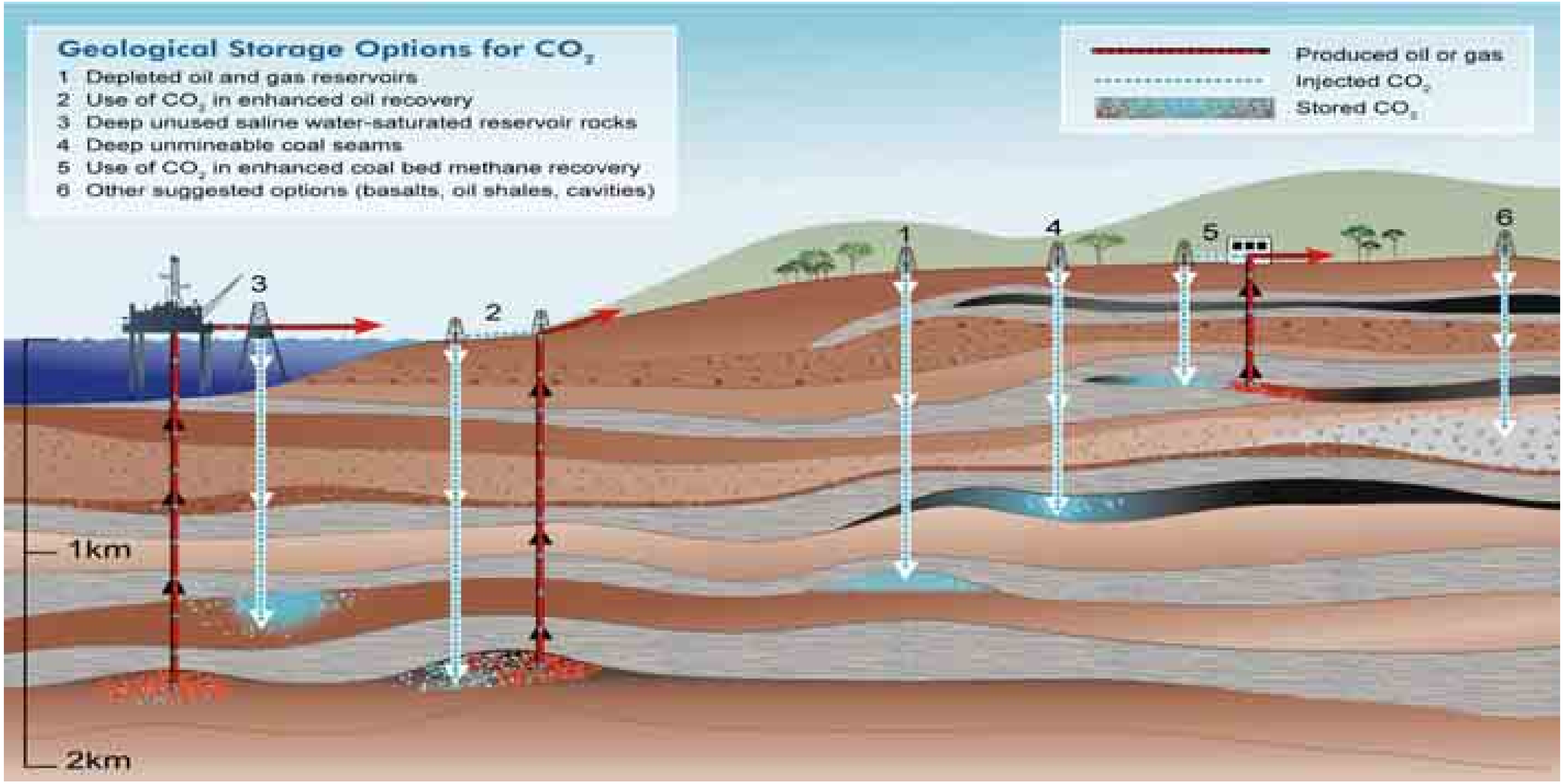
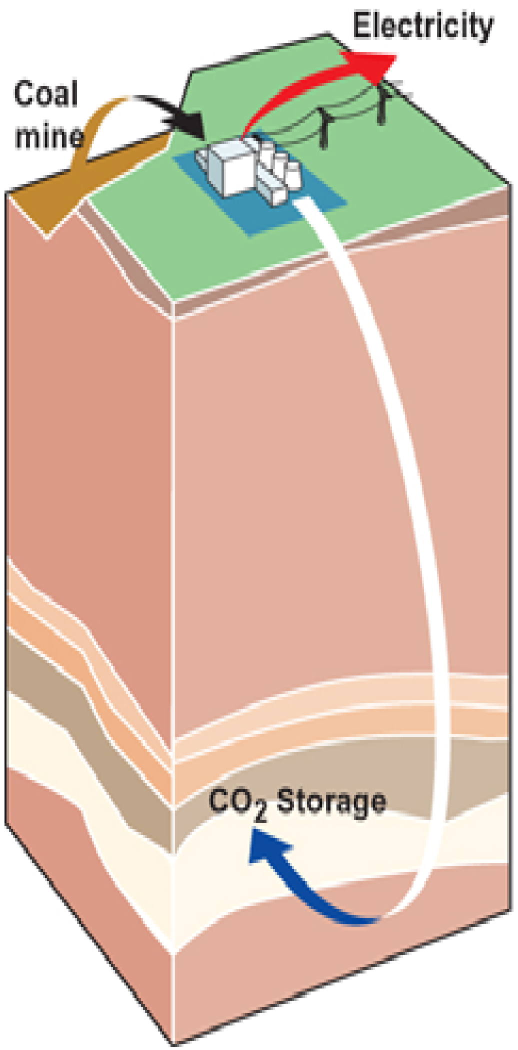
Geological processes affecting subsurface storage of CO_2

FOCO2S Project$_t$



IBF, IMG, SMG of KIT

Technology for mitigation - Carbon Capture and Storage (CCS)



Christensen (2008)

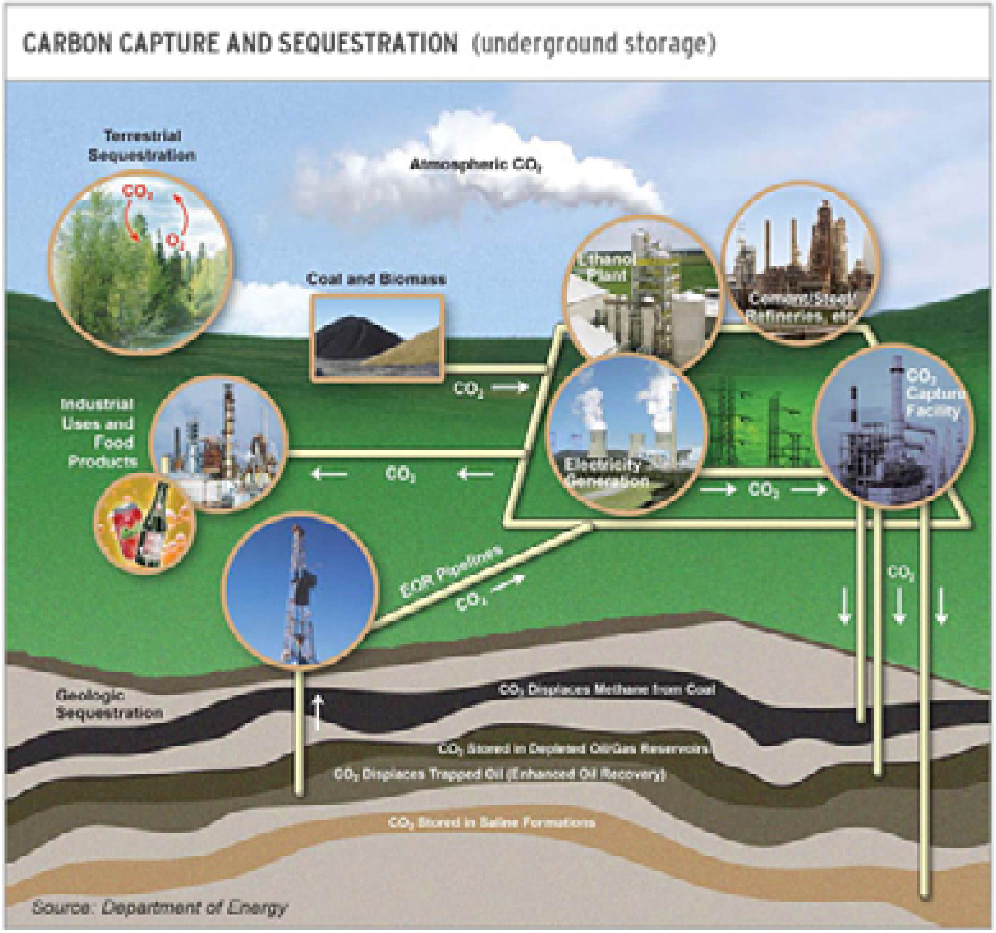
- ***Capture*** **CO_2 from fossil fuel (coal, gas, oil) and biomass before or after combustion**
- ***Compress*** **CO_2 into liquid form and *transport* in ordinary pipes**
- ***Store*** **CO_2 in a deep geological structure in a safe and controlled manner**
- ***Monitor*** **storage to ensure storage behaves as expected**

IBF, IMG, SMG of KIT

Technology for mitigation - Carbon Capture and Storage (CCS)

Current research

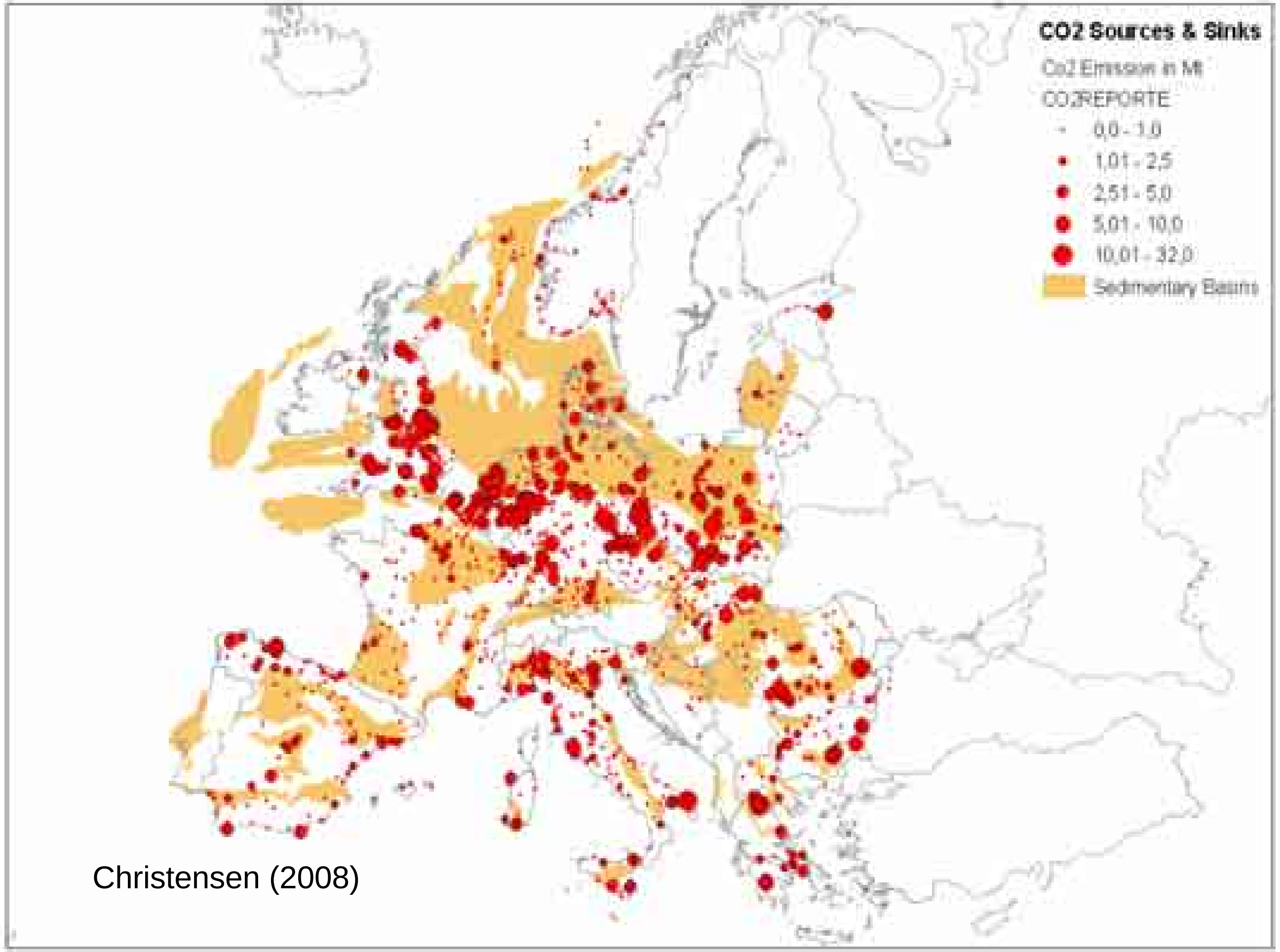
- Pathways for CO_2-capture and storage (technologies, infrastructure, time scales)
- Life cycles balances of all interacting processes
- CCS efficiency for mitigation compared to other relevant options



- CCS as a bridging technology towards renewable energy systems

IBF, IMG, SMG of KIT

Emissions and storage



Deutschland

- CO_2-emissions of power plants > 300 Mt/a
- CO_2-storage:
  - empty gas reservoirs (2,5 Gt),
  - deep aquifers (12-28 Gt),
  - deep coal mines (3,7-16,7 Gt)

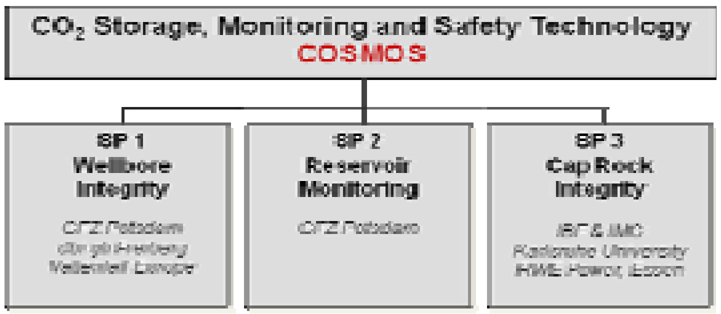
Global

- CO_2-emissions: 27,3 Gt/a
- CO_2-storage: 1.660 Gt

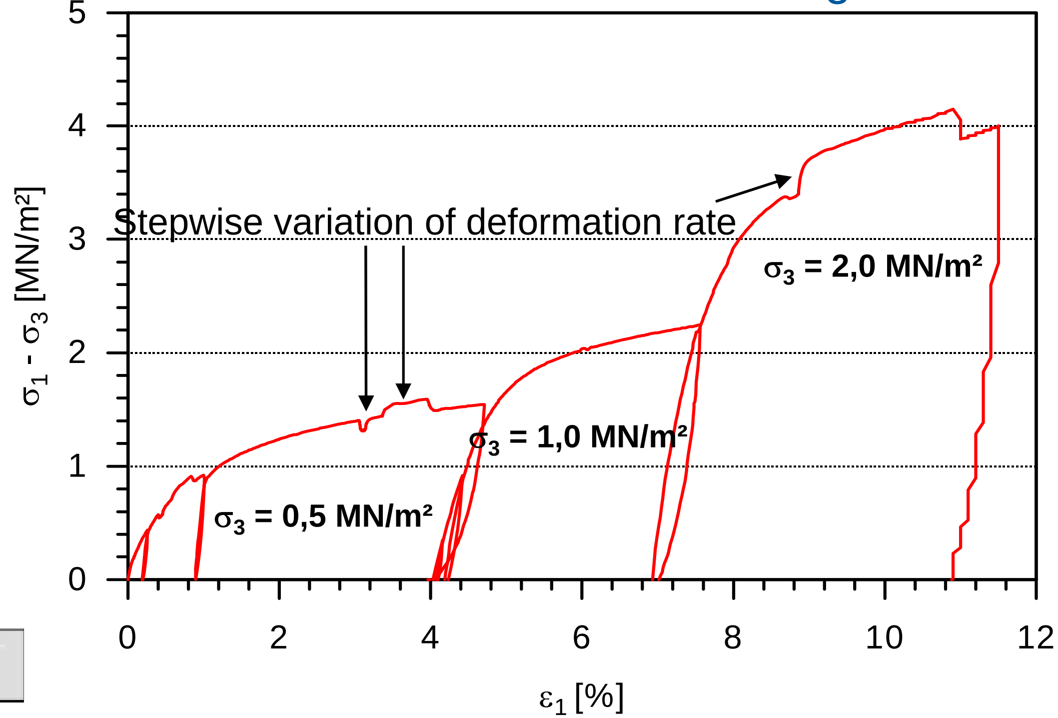
IBF, IMG, SMG of KIT Source: BMU (2007)

Technology for mitigation - Carbon Capture and Storage (CCS)

Installation of deformation measuring devices



Stress-strain-curve of a multi-stage test



First results: Pelitic cap rocks do not show scale effects

Institut für Bodenmechanik und Felsmechanik

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Flood risk management

Flood precaution

Areal precautions

- adapted use

Building precautions

-adapted building

Water retention

- activating of retention room

Risk precaution

- insurances

Technical risk reduction

Shelter buildings

- dikes, wallsDämme
- mobile shelters

Barrages,
Retention basins

River development

-Locally at certain locations

Physical protection

Operations

Early warning

-quantitative precipitation forecast

Prediction

- runoff, water levels

Alarm plans

- regional, supraregional

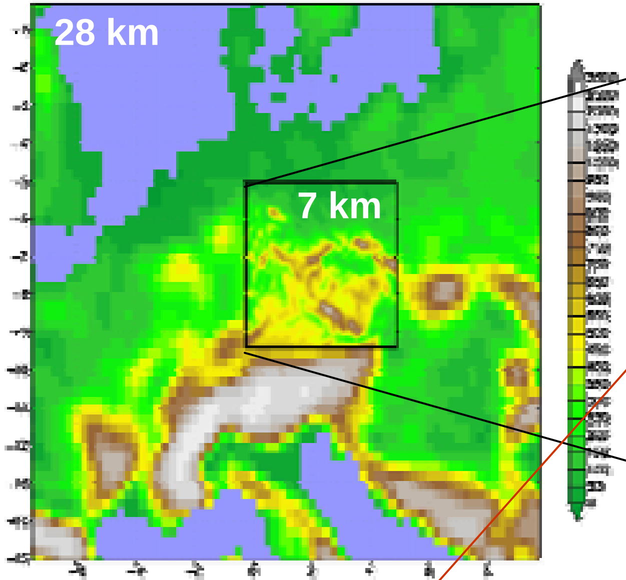
Operation schedule

- evacuations
- dike defense

IWG, IMK (KIT)

Flood risk management: chain of numerical models

weather precip prediction / ***global***



hydrology / N-A-progress / (***supra)regional -EZGe***

hydraulics, geotechnical/
local flood risk / ***local***

Source: IWG, IMK (KIT)

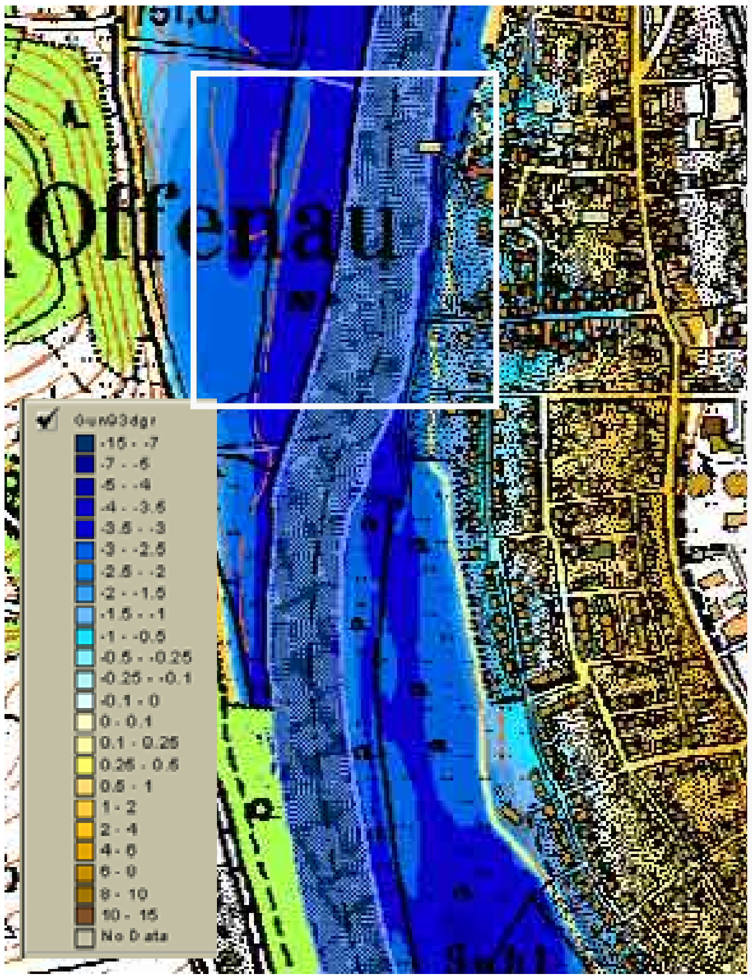
Flood risk management: risk modelling

risk analysis

hydrological / hydrological modelling

vulnerability / cadastral data

object-related (mikroscale) resolution



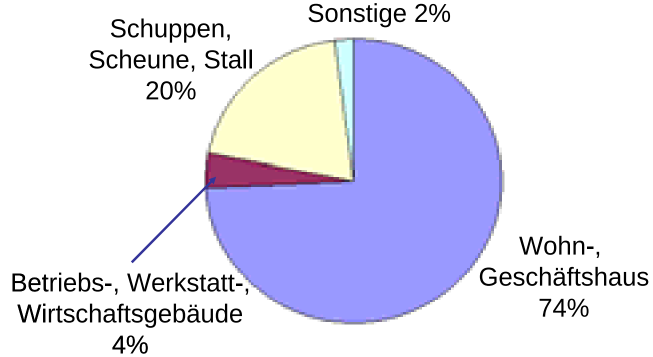
source: IWG (KIT)

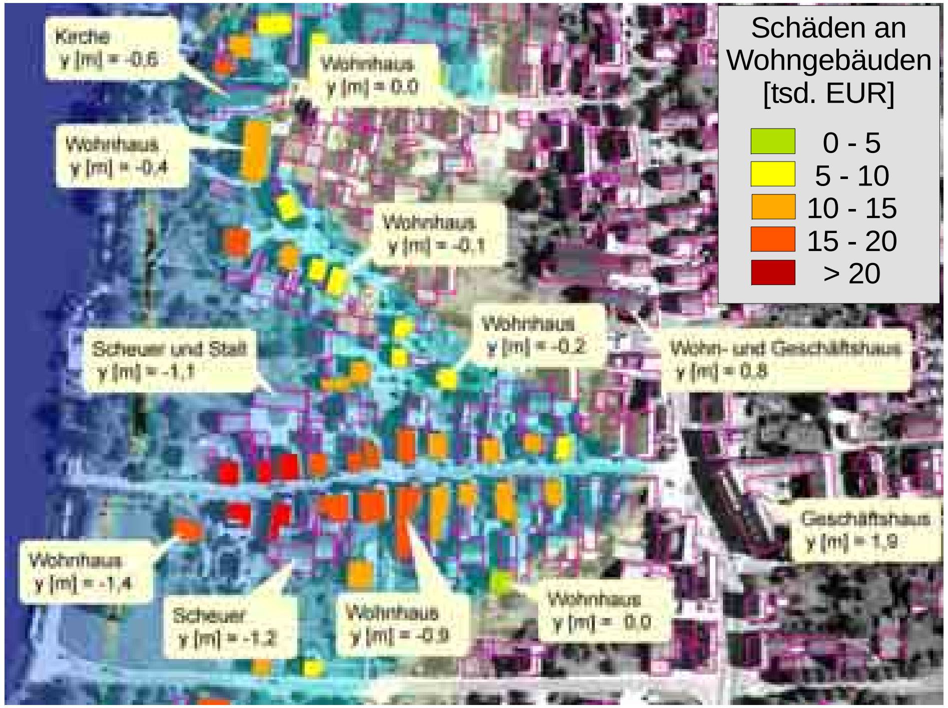
Pilot study: Offenau

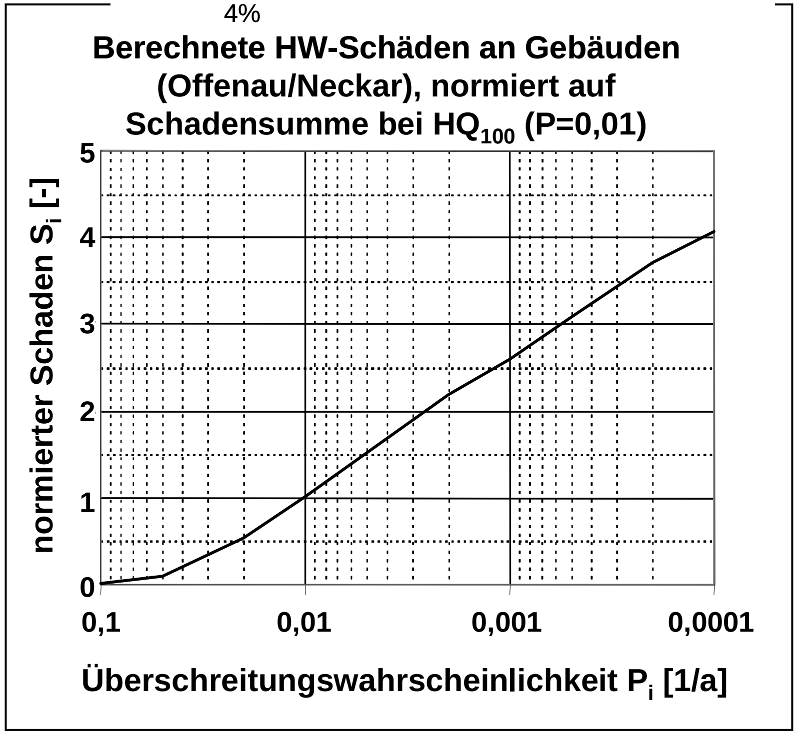
Calculated damage of residential buildings

left: individual damage for HW1993,

right: integrated damage HQ_T







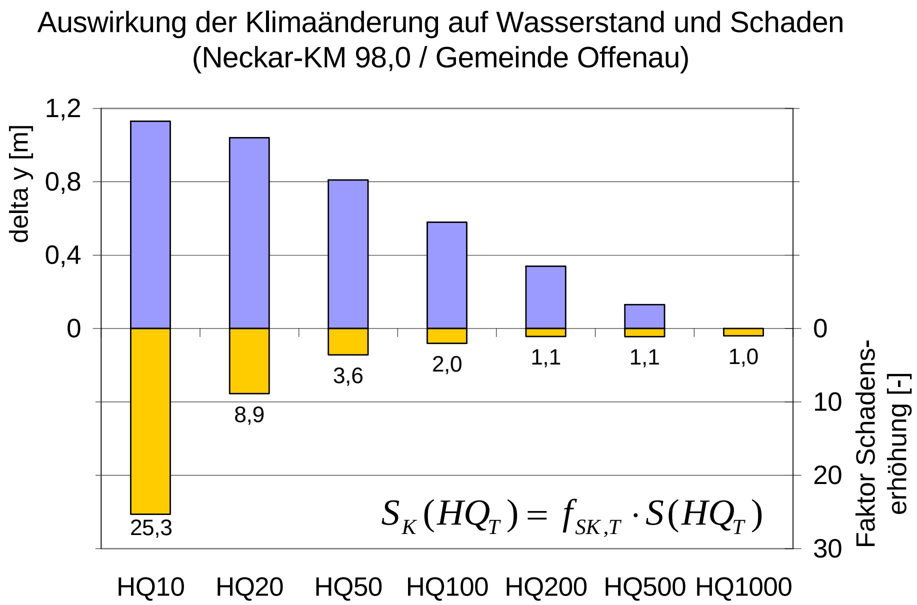
source: IWG (KIT)

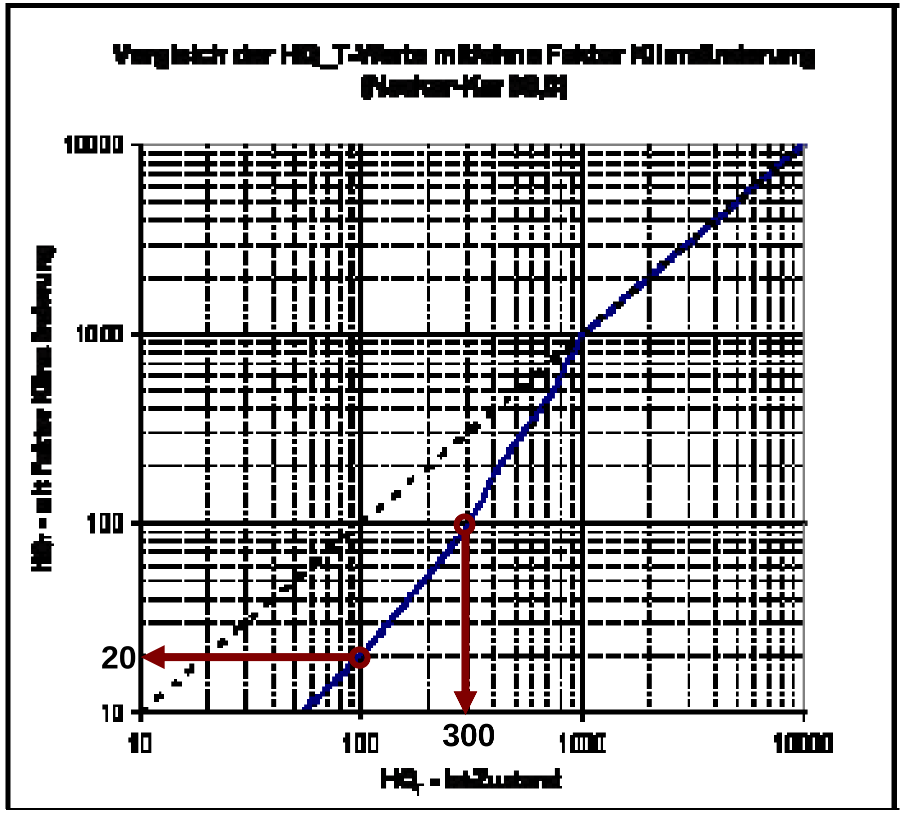
Flood risk: climate change

Effects of climate change on flood risk (Example Offenau/Neckar)

- Increase of potential flood damage due to high maximum water level
- Increase of flood risk due to modified flood statistics

$$HQ_{Tn,K} = f_{T,K} \cdot HQ_{Tn}$$





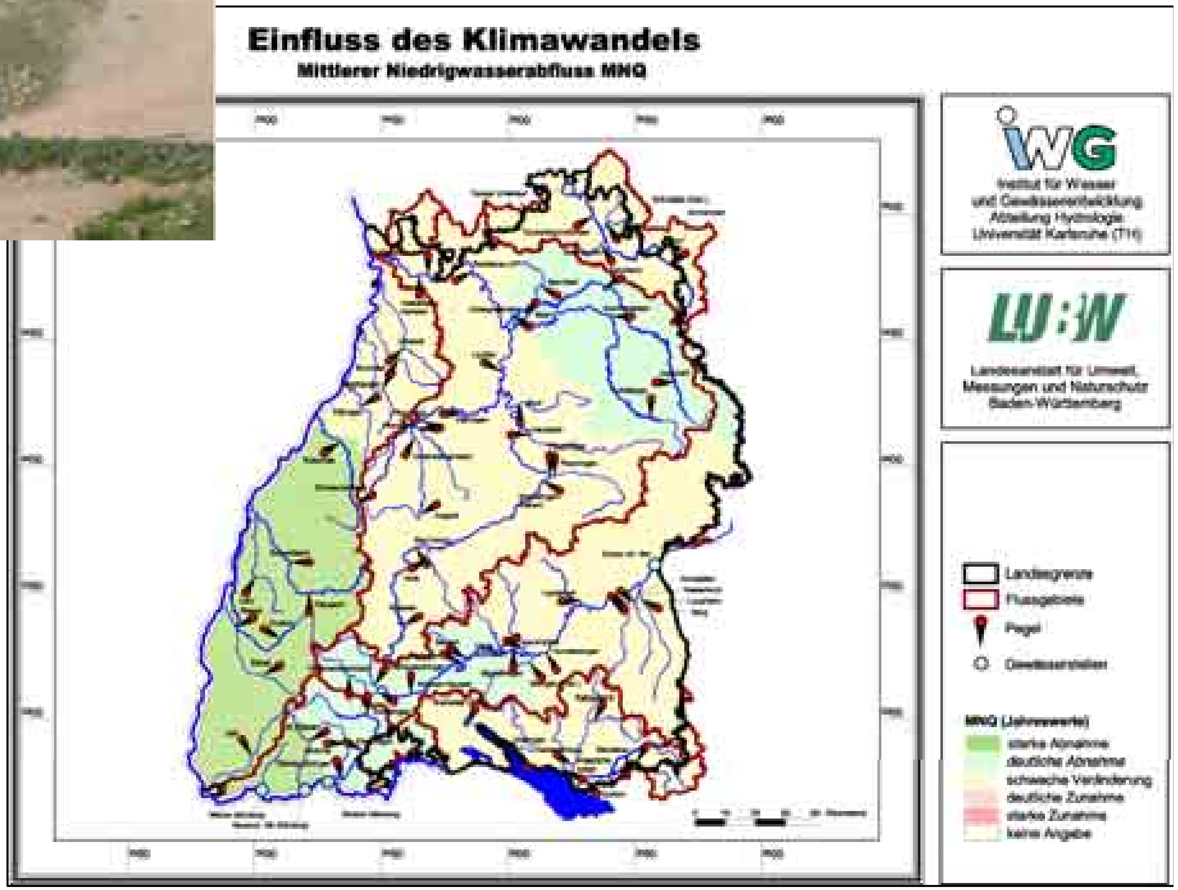
source: IWG (KIT)

* Klimaveränderung und Konsequenzen für die Wasserwirtschaft

Climate change: low runoff and level periods

Niedrigwasser am Rhein 2003 bei Düsseldorf,
Wasserstand am Pegel Düsseldorf 51 cm,
Quelle: Jahresbericht 2003, Landesumweltamt NRW

source: IWG (KIT)



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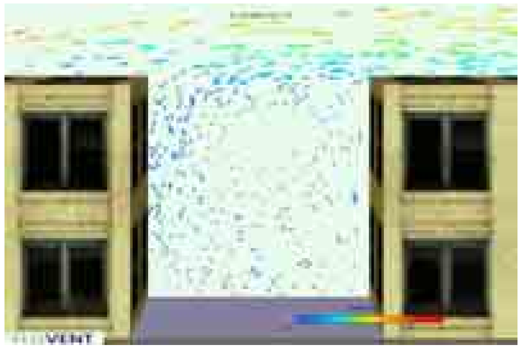
Climate change: urban climate and ventilation

- Spreading of pollutants
- Ventilation in street canyons
- Transport of respirable dust
- Natural particle sinks





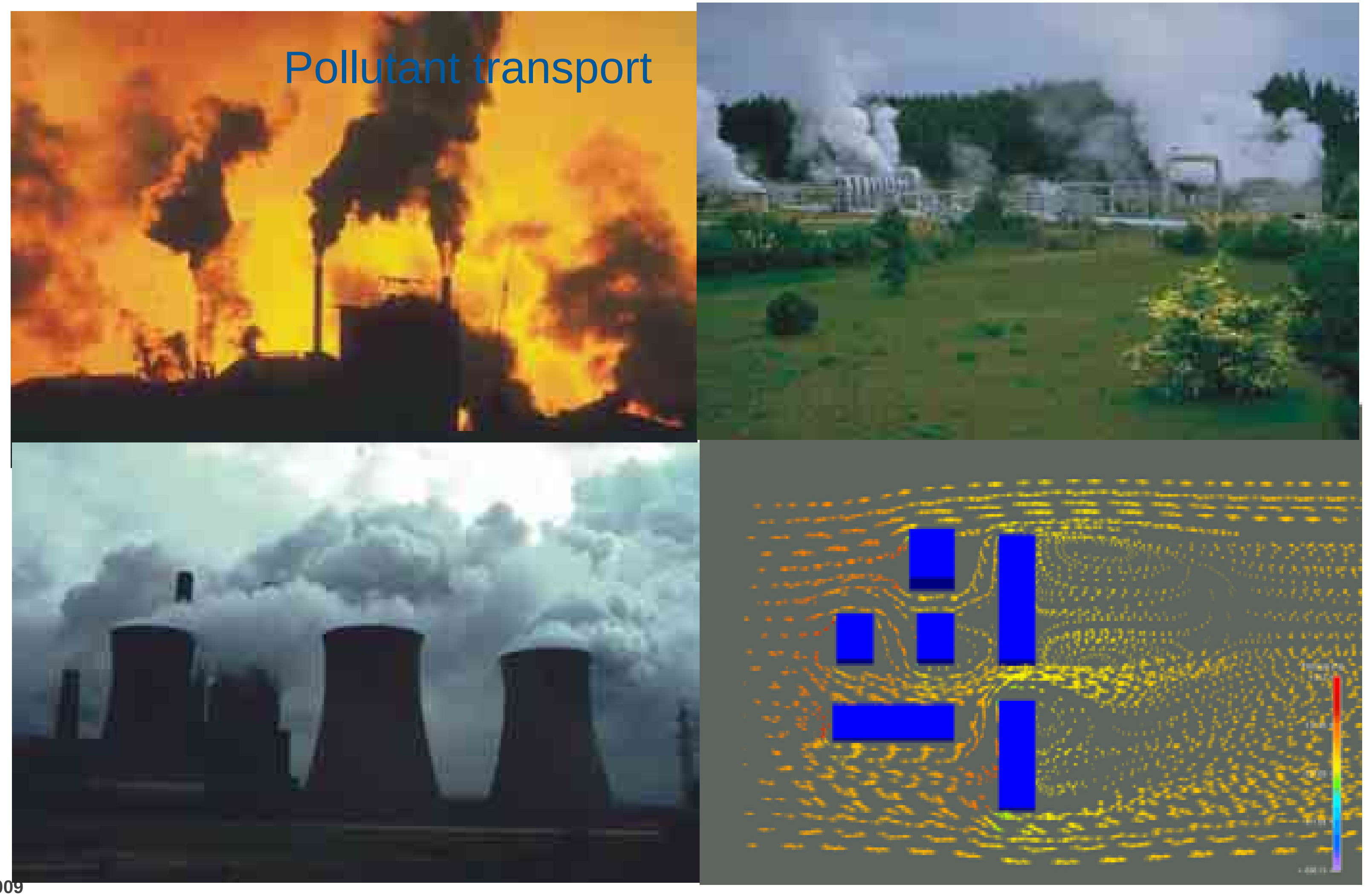





source: IfH (KIT)

Climate change: pollutant dispersion

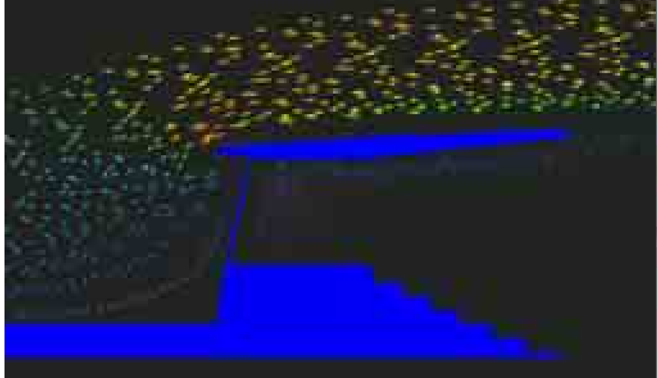
- Spreading of pollutants
- Protection against immissions
- Particle transport phenomena
- Deposition of particles and dust

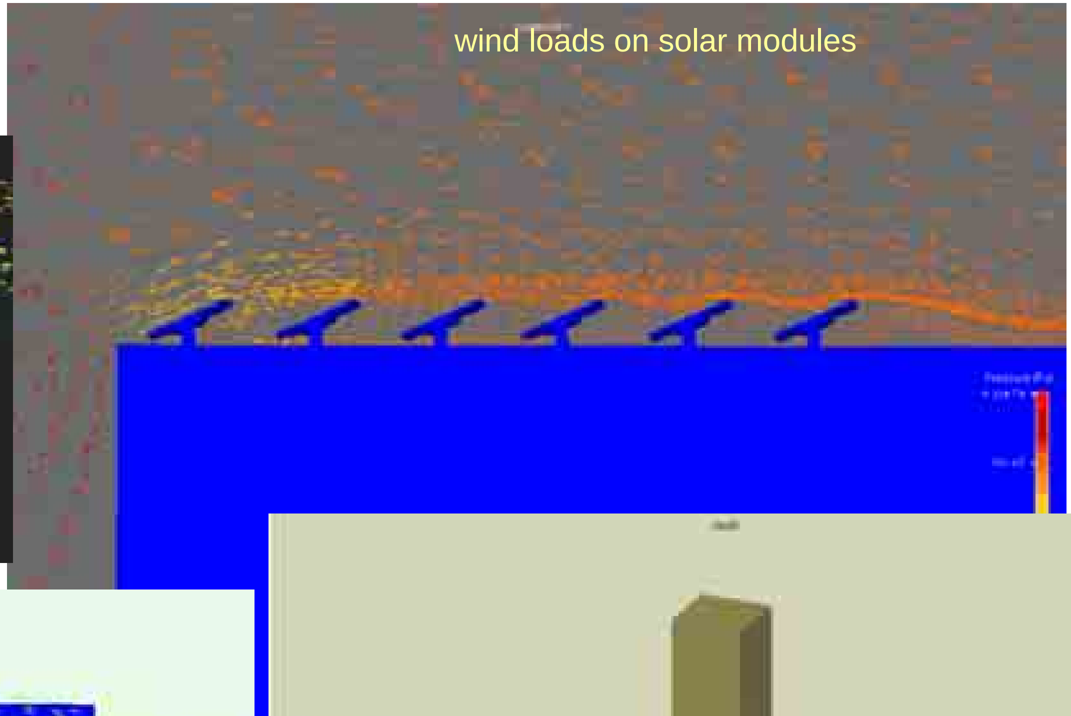


source: IfH (KIT)

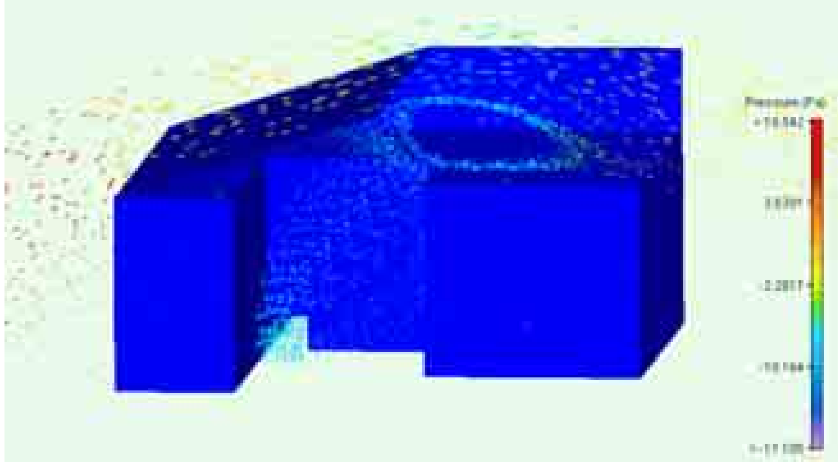
Climate change: wind loads on structures

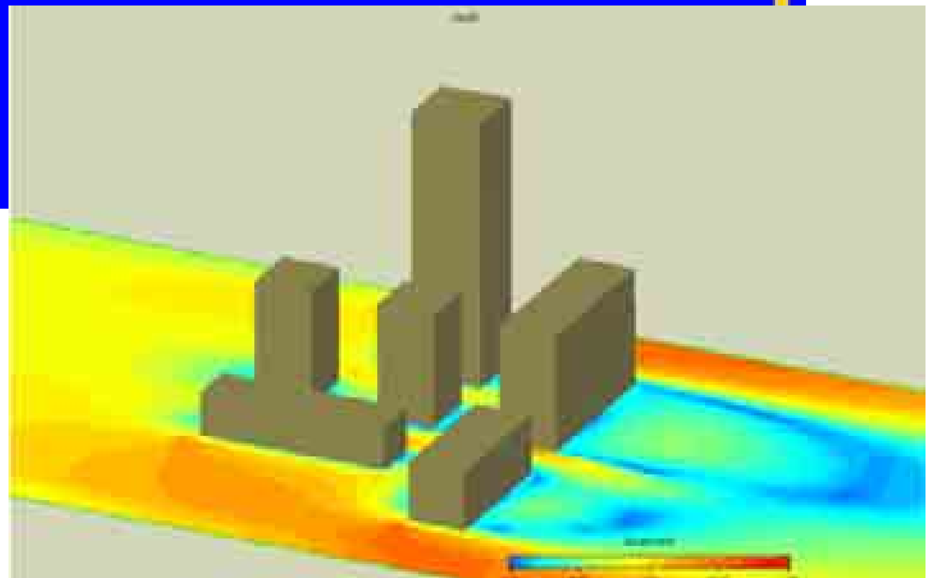
Building aerodynamics





wind-driven ventilation of buildings





wind comfort in cities

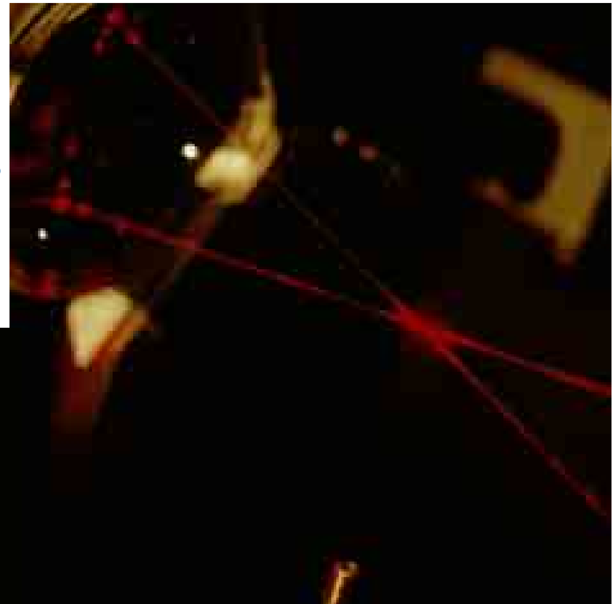
source: IfH (KIT)

Climate change: wind damages in forests

source: IfH (KIT)

Climate change: storm resistant structures and forestry

Developing and testing storm-resistant structures by wind tunnel experiments



source: IfH (KIT)

Climate change: increasing vulnerability

October 12, 2009
Ch. Kottmeier

Conclusions

Climate change and adaptation – why technology is highly needed

The global problem of climate change interferes with modern technology in many aspects:

• The anthropogenic influence on climate mainly arises from extensive use of fossil energy sources via **technological systems** (traffic, industrial production, …)

• The main research aspects of climate change need to build on modern technology, namely the

➢**prediction and monitoring** (technologies: HPC, satellite and observation networks) with a specific focus on regions and locations

➢**technology for mitigating** climate change like renewable energy, efficient energy conversion, carbon storage **…**

➢**technology for adapting** to climate change, e.g. by enforcing technical infrastructure and built environment as well natural environment to cope with changes in extreme weather and runoff conditions

• KIT and partner organisations will adress such problems with particular emphasis put on the interface of **regional climate change and technology**


Thanks for your attention!