POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

P I K

Modeling hydro-climatic extremes and flood damages under climate change conditions

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Potsdam Institute for Climate Impact Research

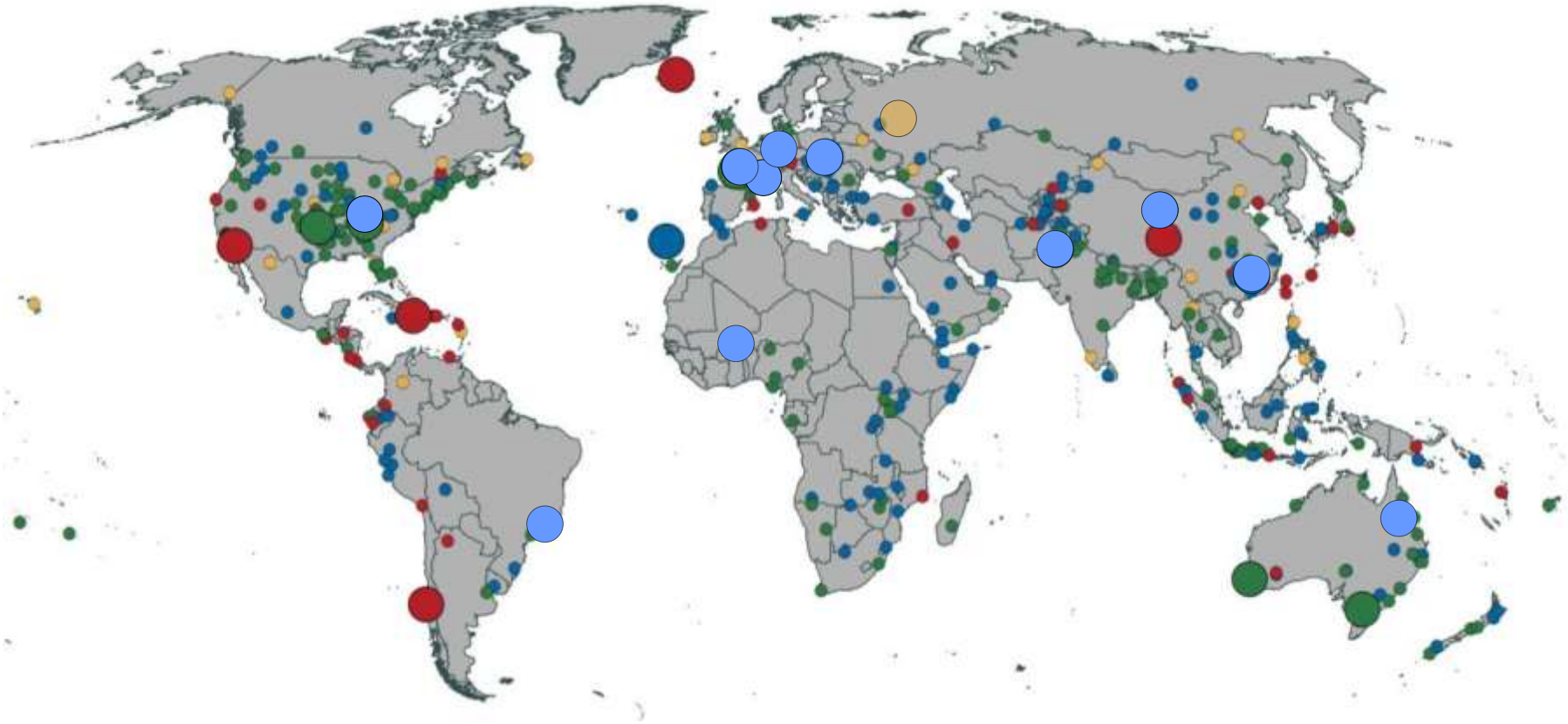
Leibniz Gemeinschaft

Potsdam Institute for Climate Impact Research
RD2 Climate Impacts & Vulnerability

Outline

- Introduction – hydro-meteorological extremes under climate change
- Methodology
  - Model system
  - Data
  - Calibration and validation
  - Bias correction
- Results
- Conclusions

Significant floods 2010



- Natural catastrophe
- Significant events
- Geophysical event
- Meteorological event
- Hydrological event
- Climatological event

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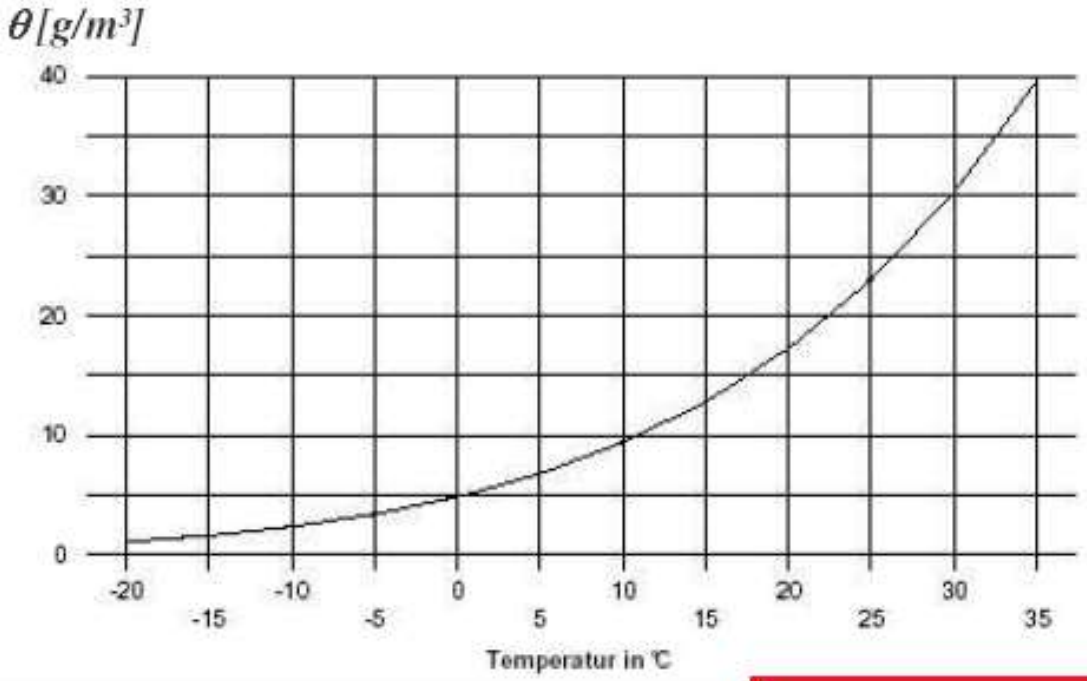
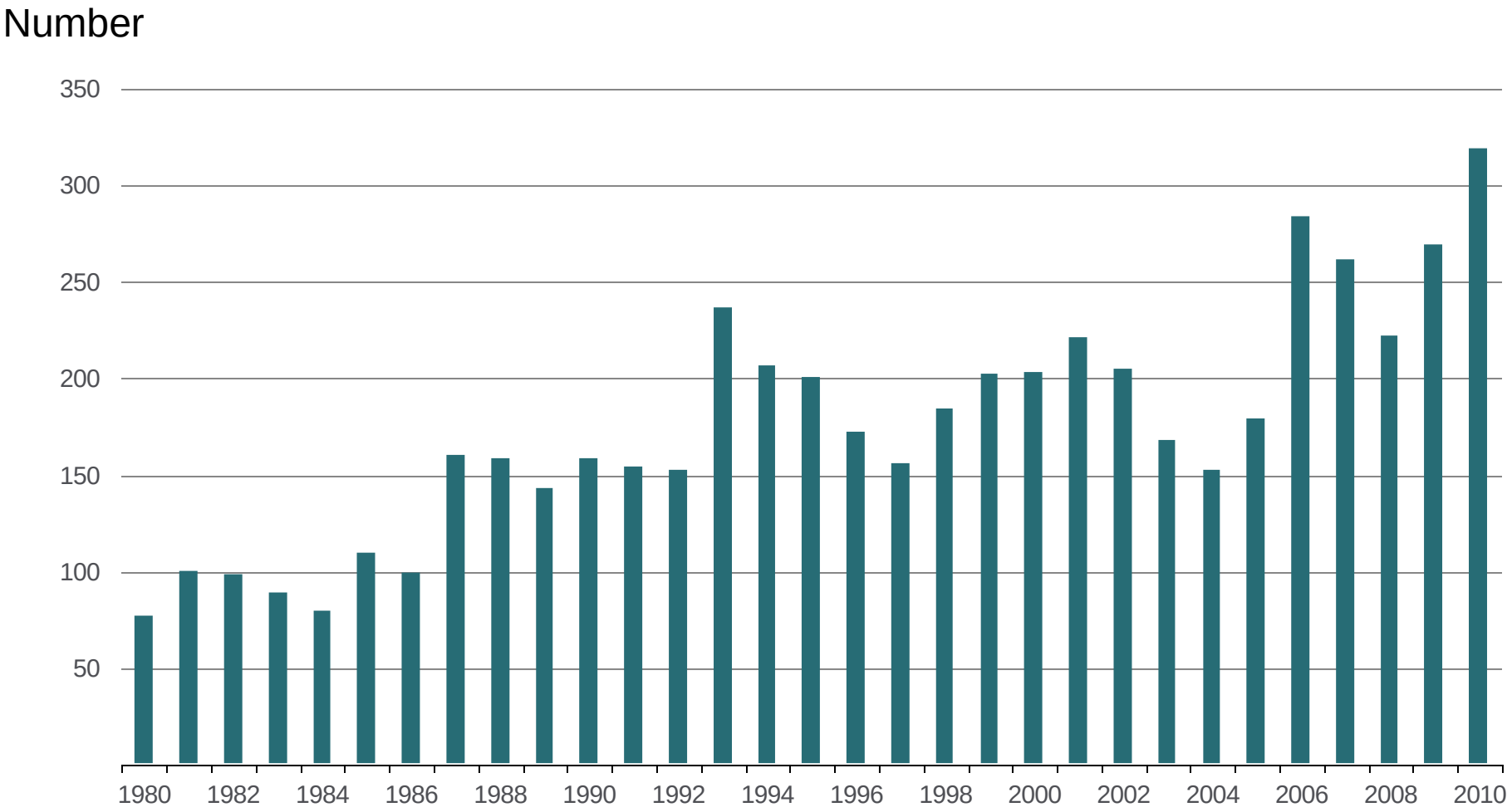
Clausius-Clapeyron: saturated moisture content in the atmosphere is a non-linear function of temperature



Temperature [°C]	0	10	15	18	20
Saturated (maximum) water content [g/m³]	4.8	9.4	12.9	15.4	17.3

$$\theta(18°C) - \theta(15°C) = 2.5\ g/m^3 \quad (= 19{,}4\ \%)$$

Number of major floods 1980 - 2010



Source: MunichRe

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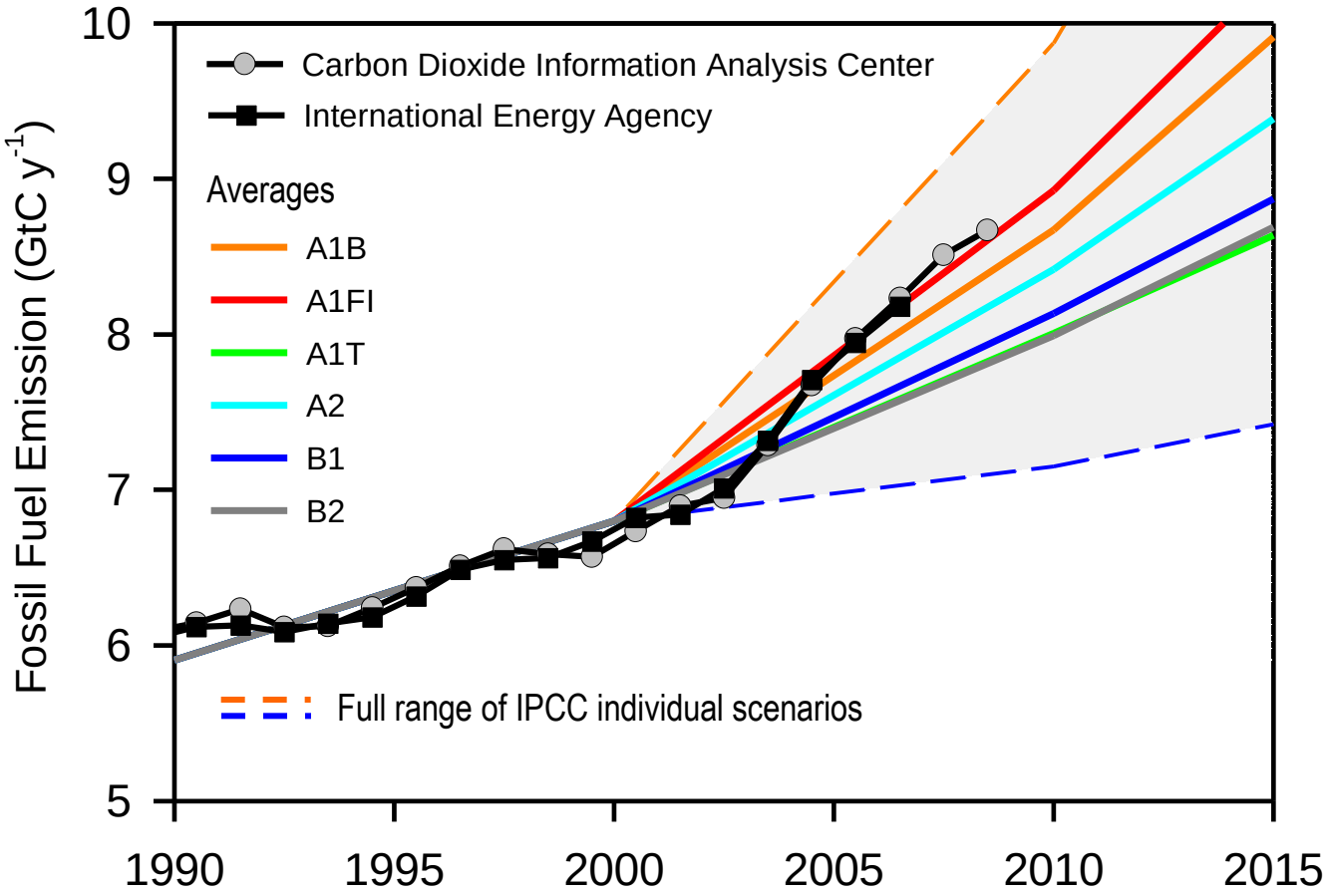
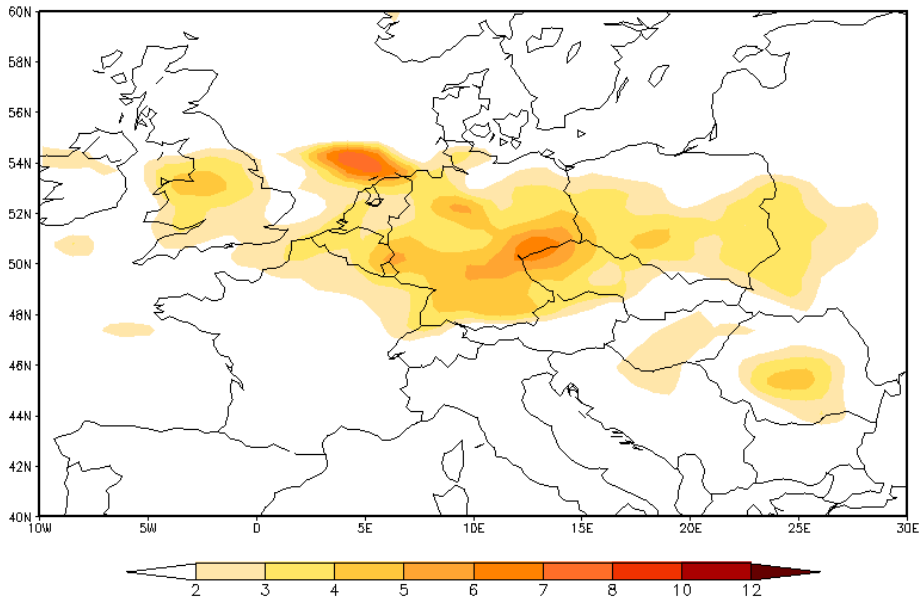
Global CO_2-Emissions in Gt/year



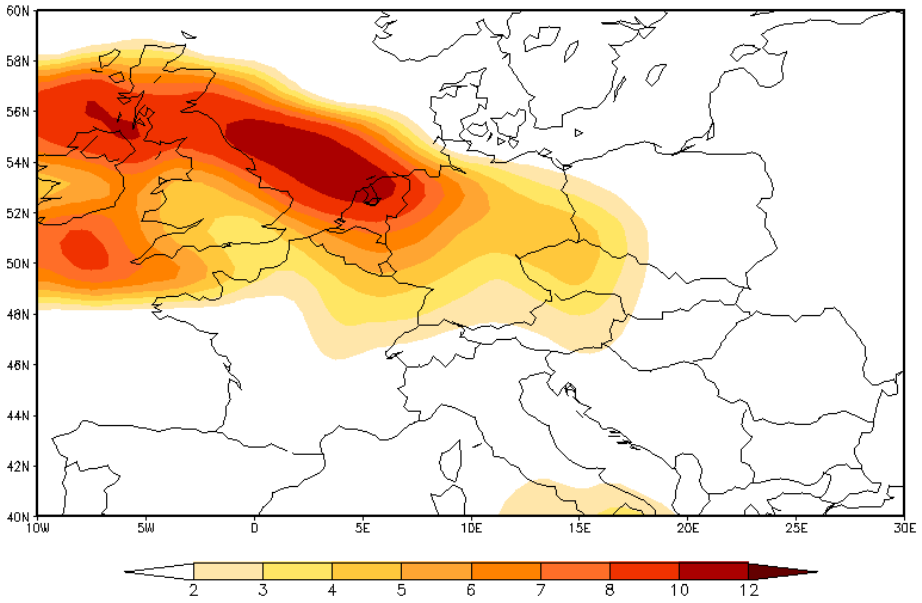
Raupach et al. 2007, PNAS, updated; Le Quéré et al. 2009, Nature Geoscience; International Monetary Fund 2009

Storms observed and projected

The strongest strom oberved: Kyrill



Possible storm in future: EH5_1: 2079-01



Storm intensity (wind speed)

Co-operation with the leading Insurance Companies (German Insurance Association)

Leading questions:

- **How will climate change impact on flood generation in Germany?**
- **Do we have more or less intense floods under climate change?**
- **What is the approximated magnitude of the projected losses?**

Group meetings with the insurance experts every 2-3 month

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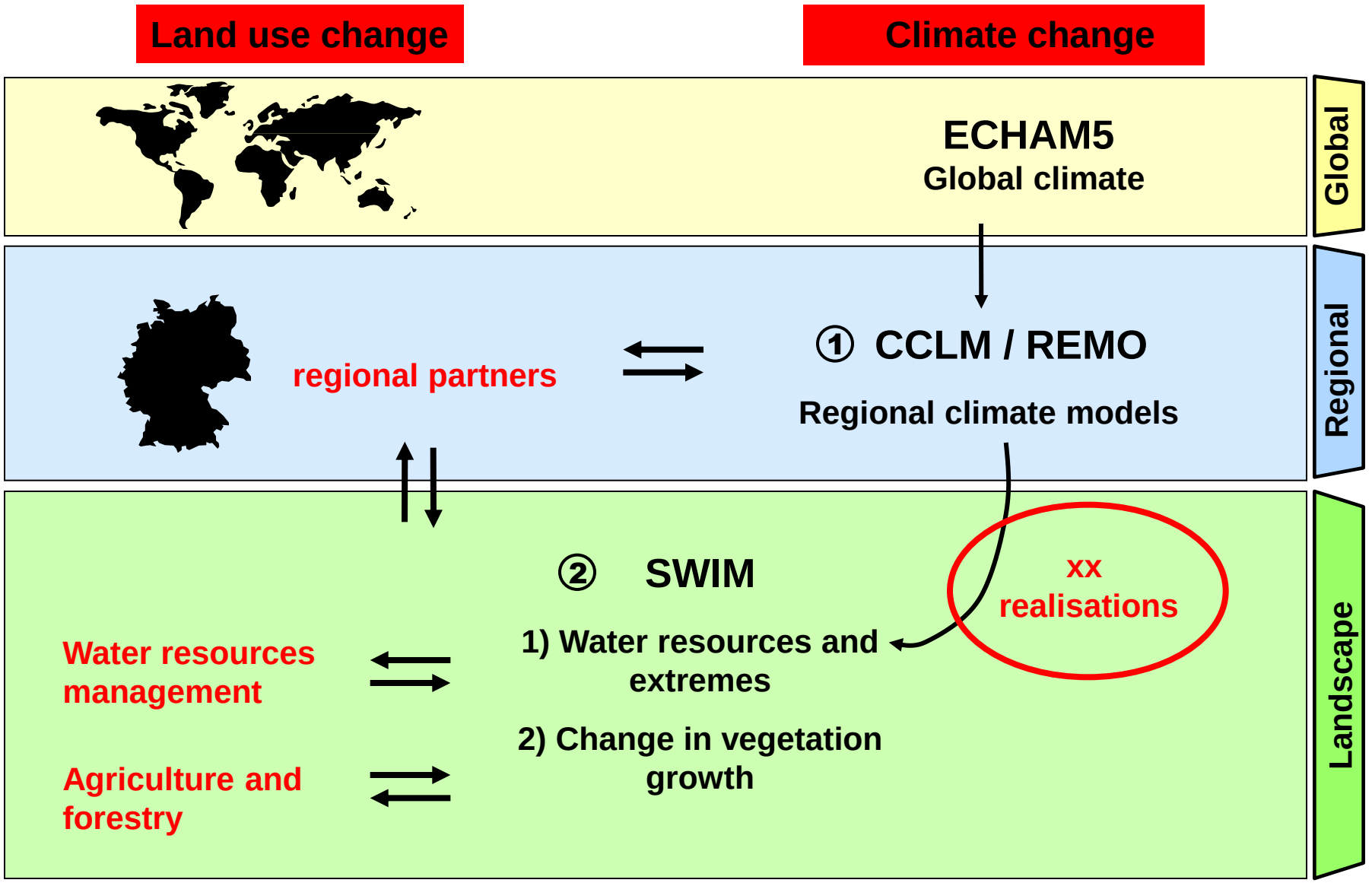
Model system



Methodology: From climate extremes to financial losses

Step 1: regional climate by CCLM and REMO (multiple scenario and realisations)

Step 2: modelling hydrological processes for each realisation using SWIM (for ~5000 river reaches/ sections)

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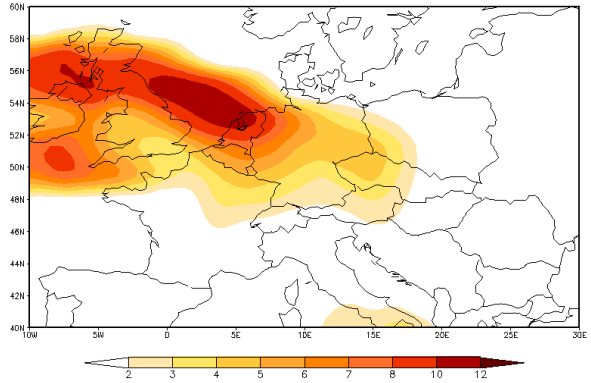
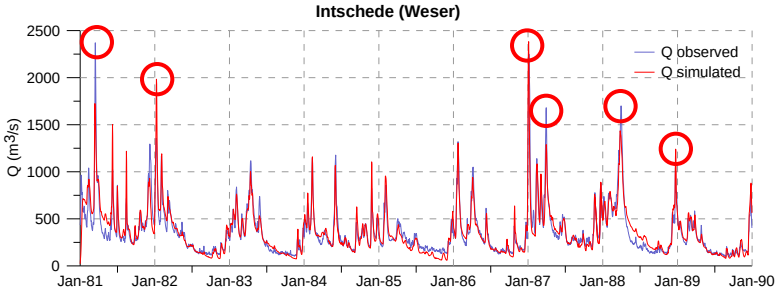
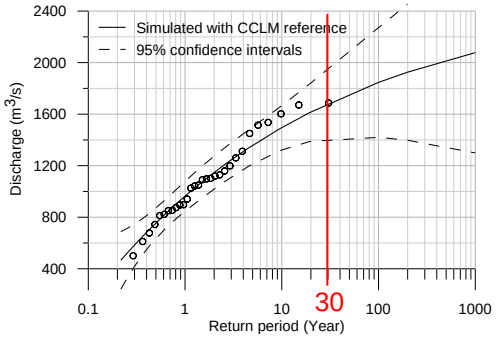
Step 4: linking runoff and damages using GPD, calculate flood damages for each river reach and scenario day



Downscaling and hydrological modelling (~5000 river sections)



Calculation of extreme value distributions



General Pareto Distribution:

$$F_u(x) \approx G(x;\tilde{\sigma},\xi,u) = 1-\left[1+\frac{\xi(x-u)}{\tilde{\sigma}}\right]^{-1/\xi}$$

Developed for return interval *T*:

$$T = \frac{\sqrt[\xi]{\frac{q-u}{\tilde{\sigma}}\cdot\xi+1}}{n_u \cdot \Pr(x>u)}$$

$q = runoff$

$u = threshold$

$\xi, \sigma = parameters$

The regional climate models and the hydrological model

(German) Regional Climate Models:

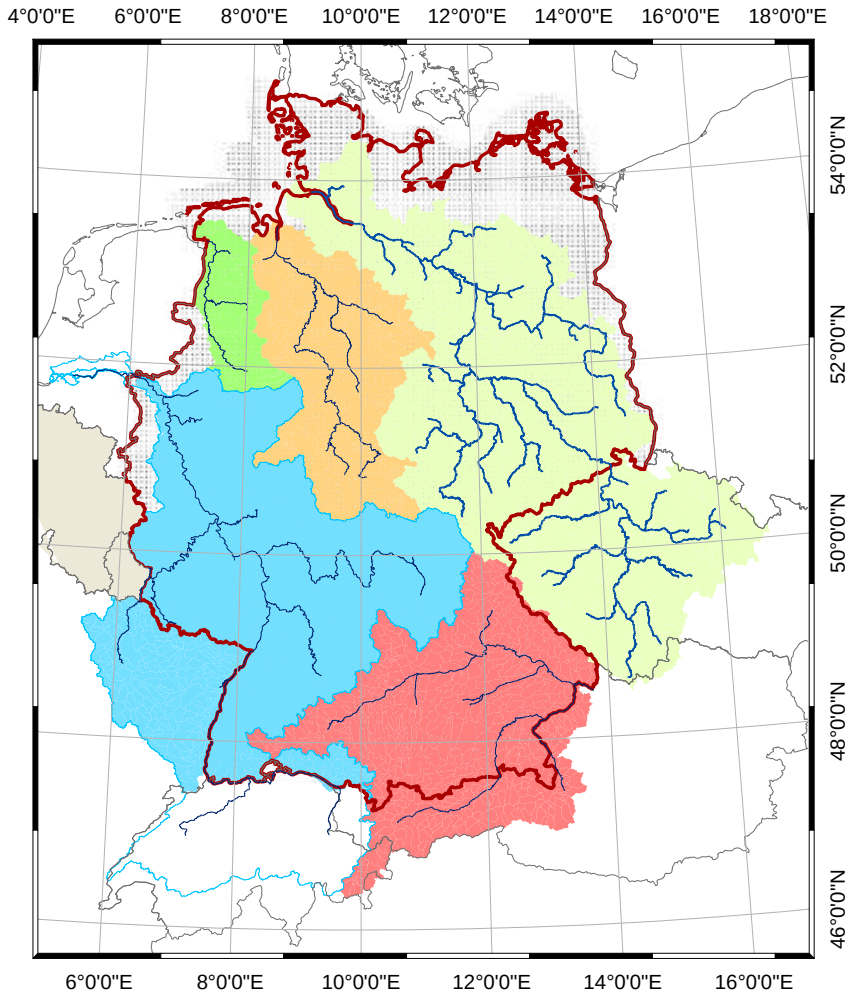
REMO – model domain Central Europe, grid size 10 km, szenarios A1B, A2 and B1 with one realization each

CCLM – model domain Europe, grid size ~18 km, szenarios A1B and B1 with two realizations each

(Eco)-hydrological Model:

SWIM – Soil and Water Integrated Model – offspring of SWAT, soil processes and routing same as in SWAT, improved snow module (Huang et al. 2010)

Data: Main German river basins



5473 subbasins/ river reaches, thereof 3766 in Germany

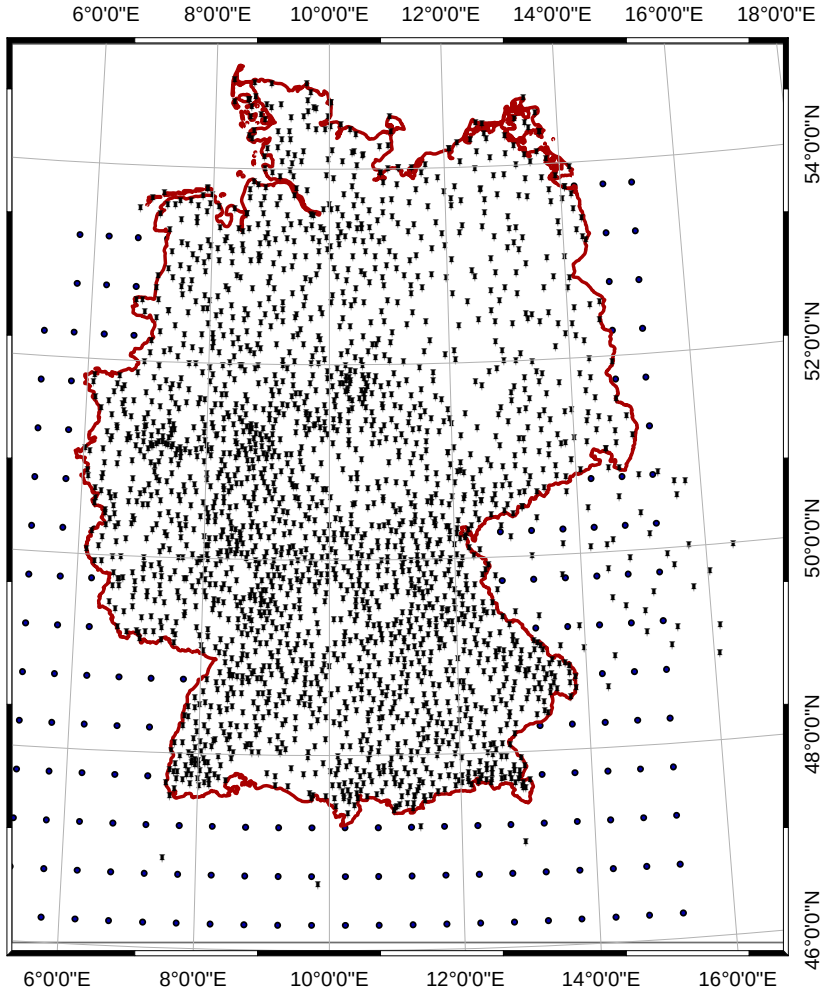
Subbasins in Germany

- River nets
- Other countries
- Germany
- Rhein
- Donau
- Elbe
- EMS
- Weser
- Other basins in Germany

0 100 200 Kilometers

Graph made by Shaochun, Huang, PIK

Data – Climate



2342 climate stations

Climate stations:
(Min. T, Mean T, Max. T, Precipitation, Radiation, Humidity)

Source: PIK

Country

- Germany
- 2399 observed climate stations
- Climate data from models

0 100 200 Kilometers

N W E S

Graph made by Shaochun, Huang, PIK

Data – da

Damage fun ssociatin

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One damage o code

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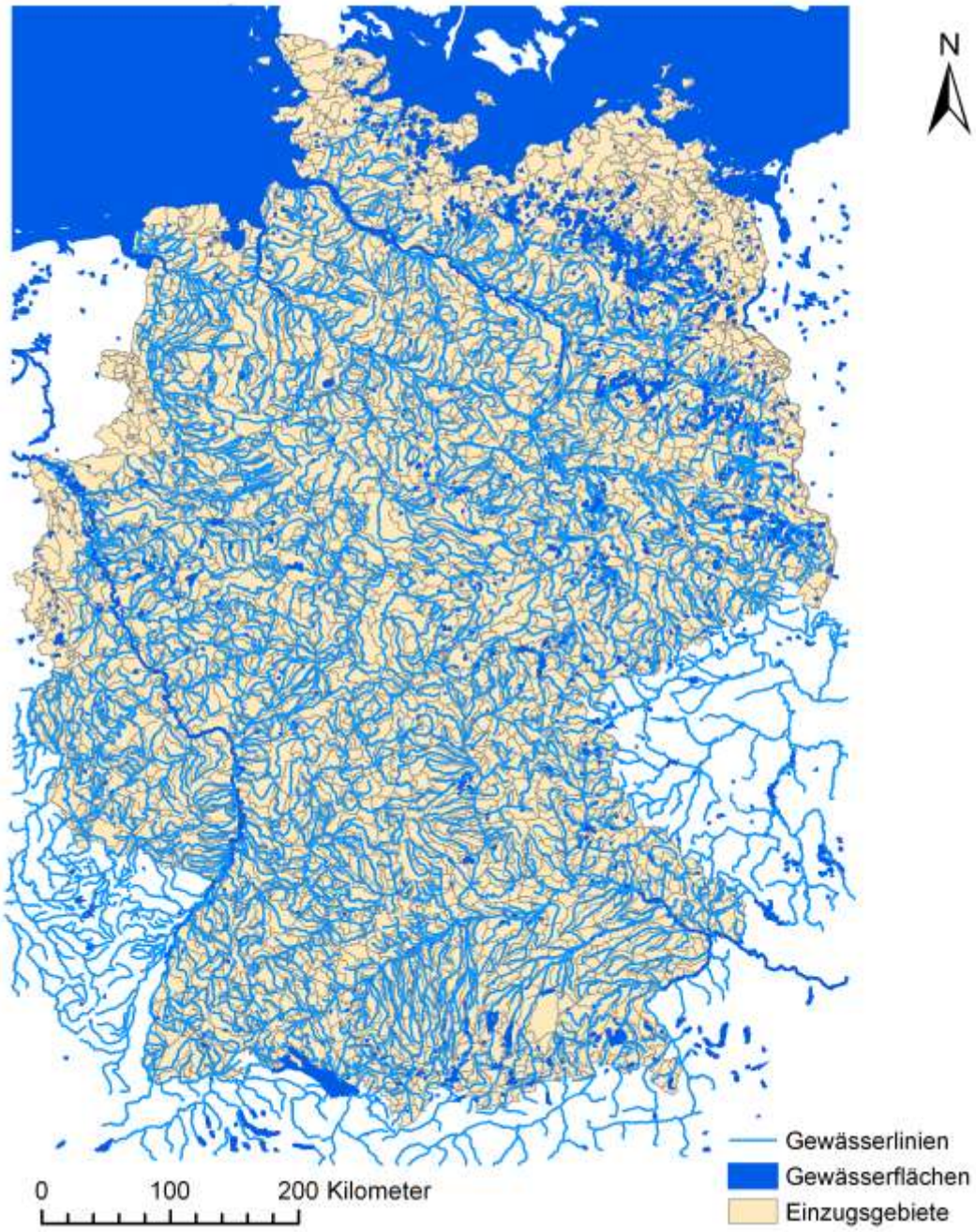
Linked to the

Considered

Average loss year



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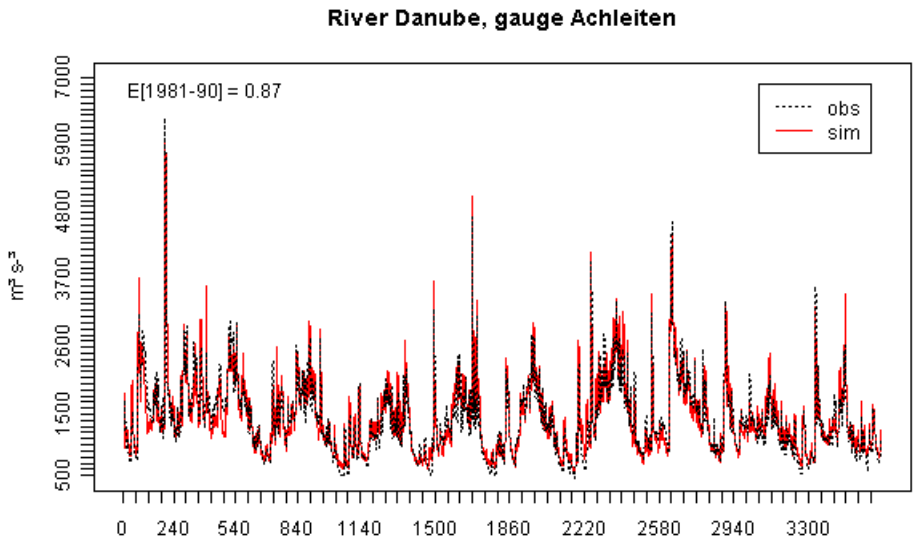
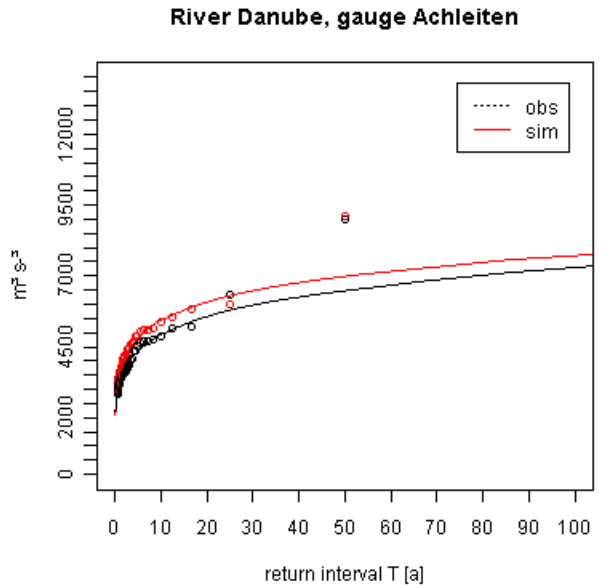
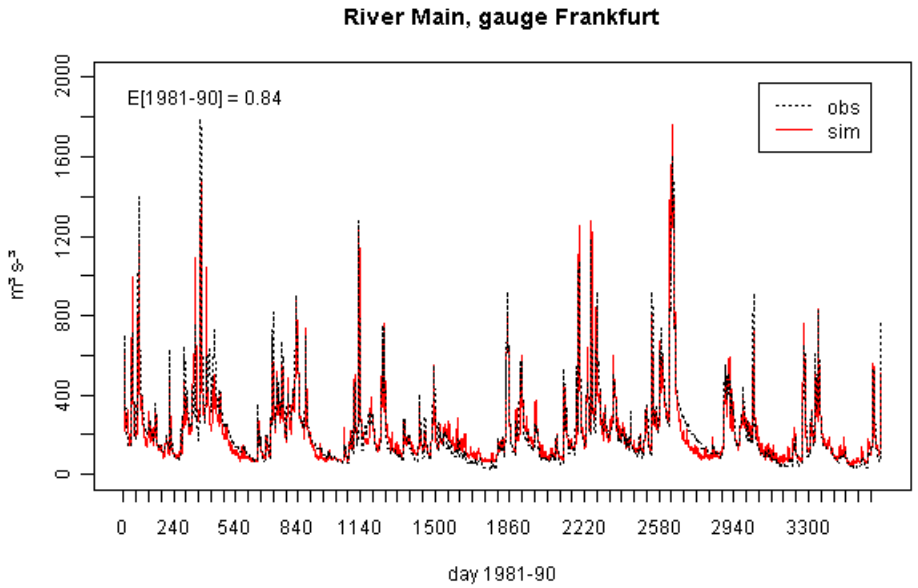
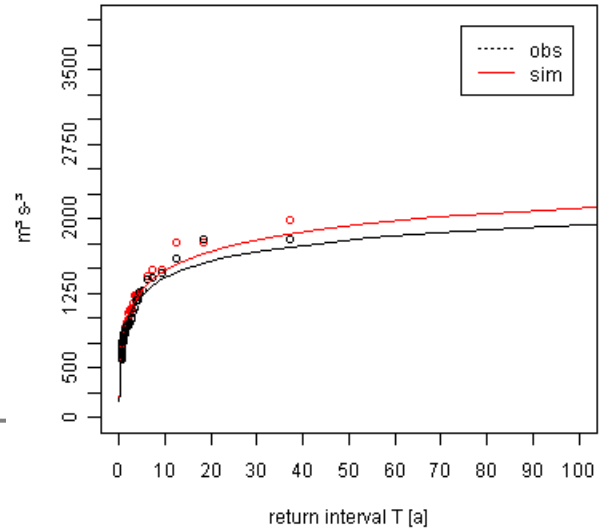
Calibration and validation using observed climate data





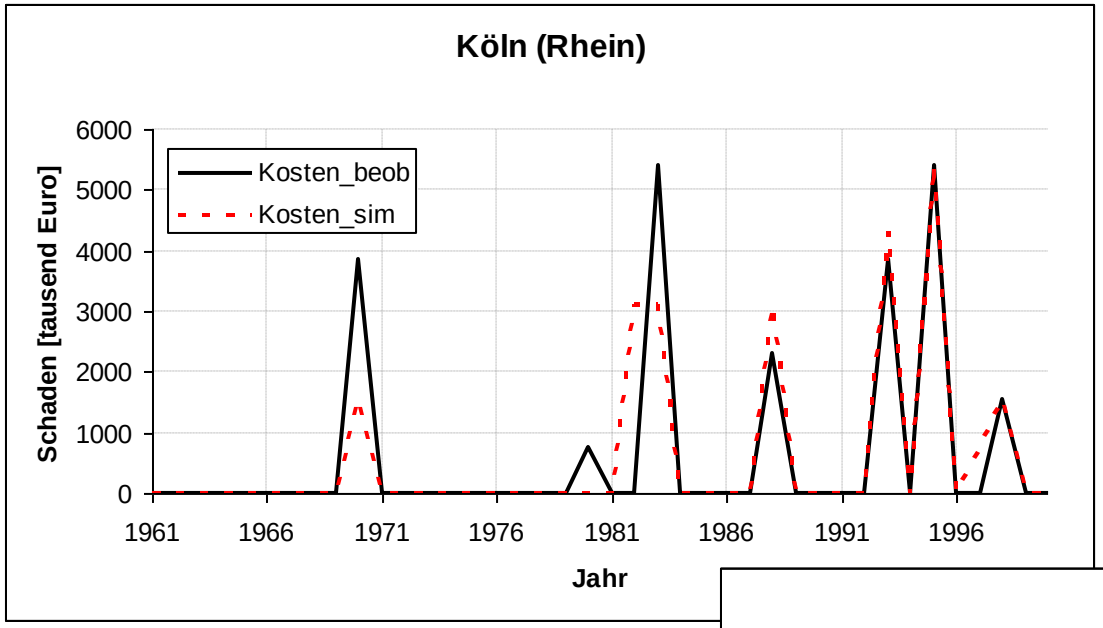
Danube

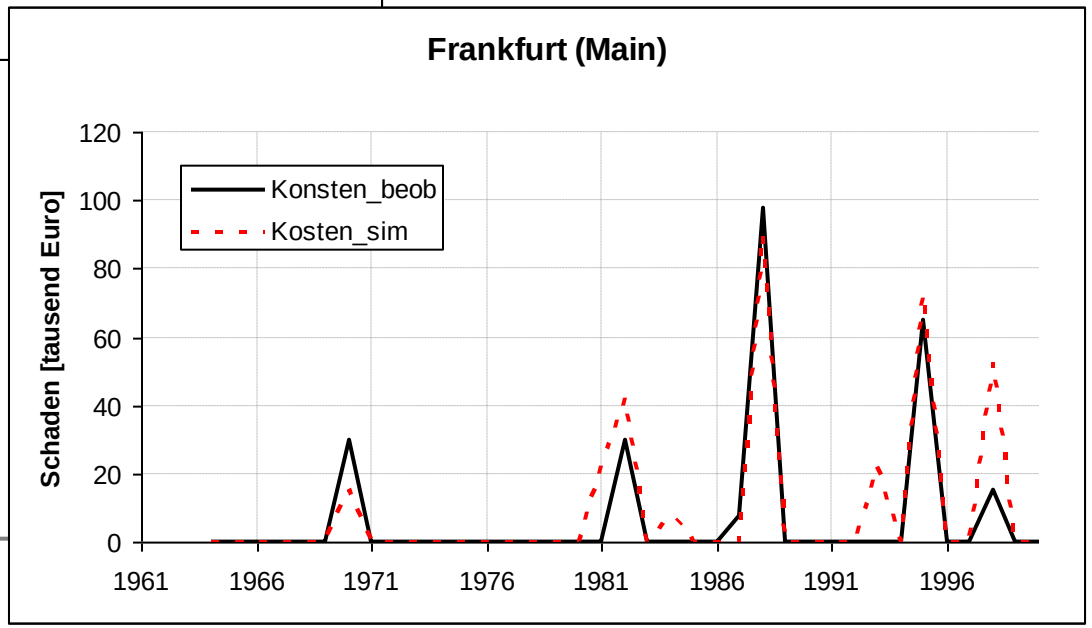




Rhine

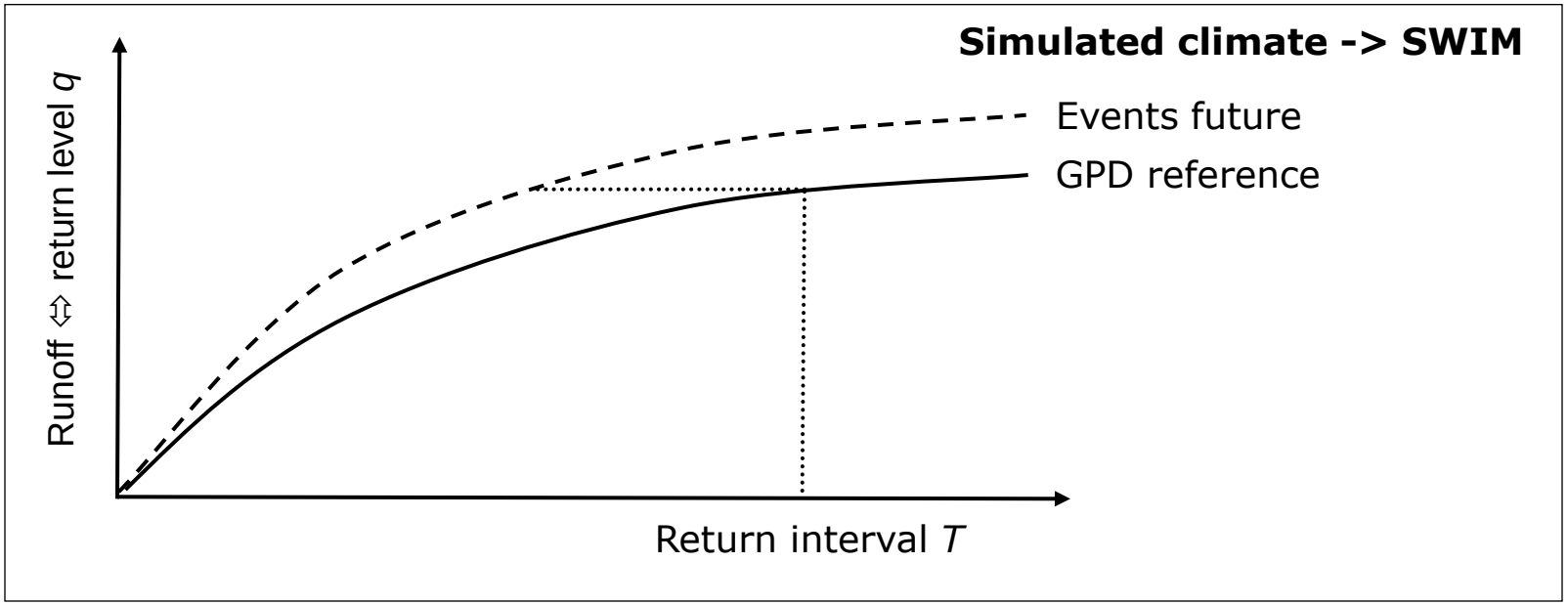
Flood damages for specific river reaches – Rhine at Cologne and Main at Frankfurt

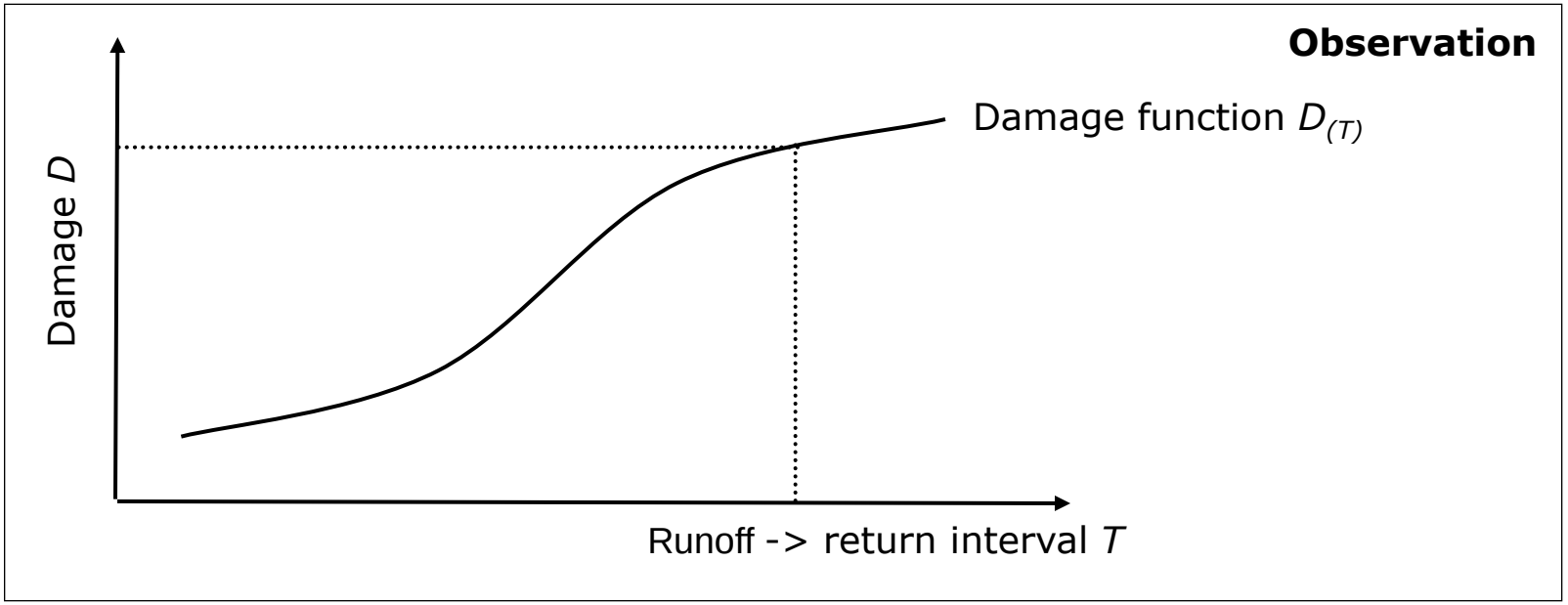




Losses calculated via a) observed runoff, flood statistics and damage funcitons and b) simulated runoff …

Bias correction





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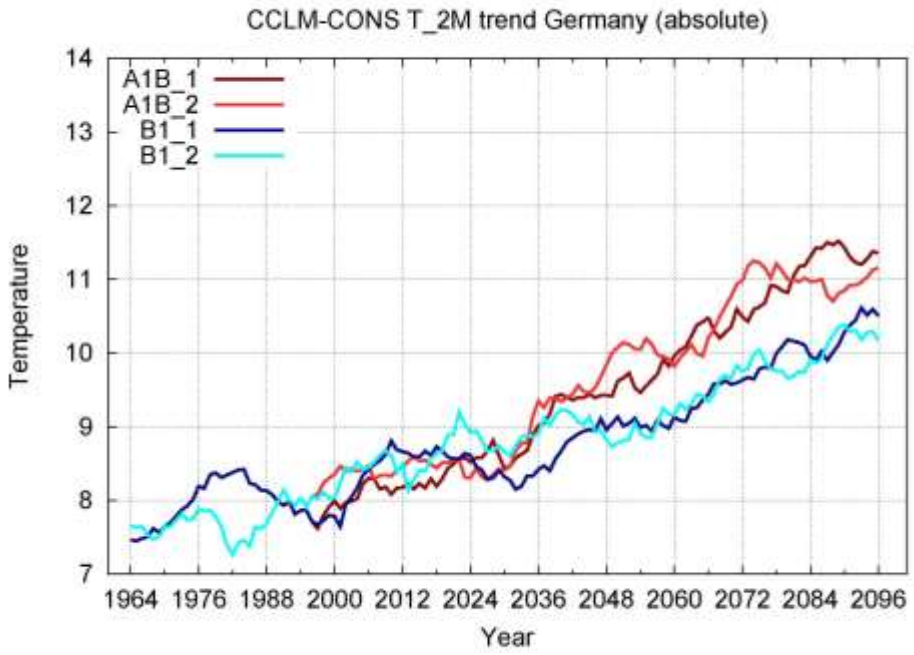
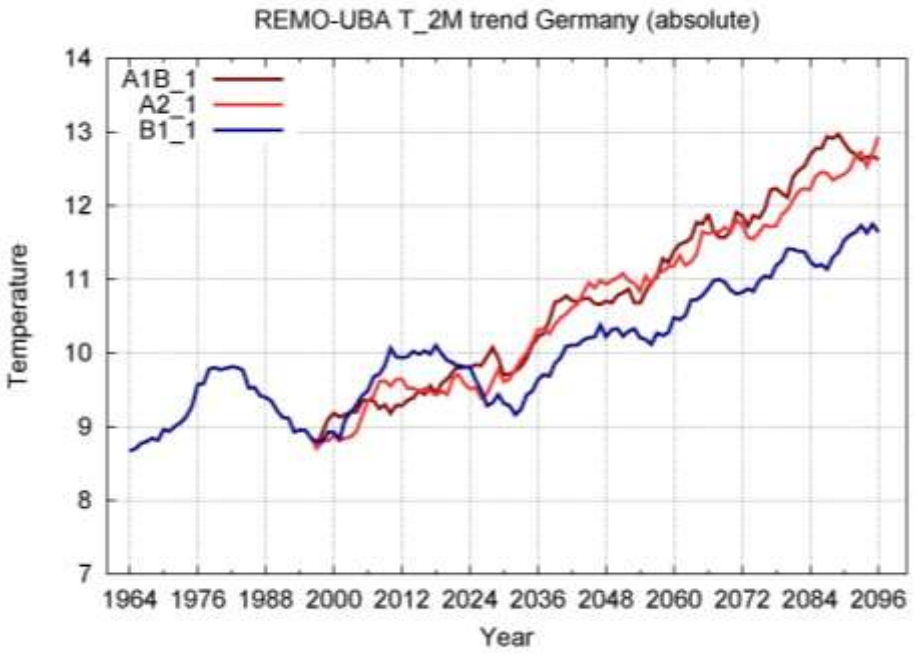
Results: Climate – temperature increase





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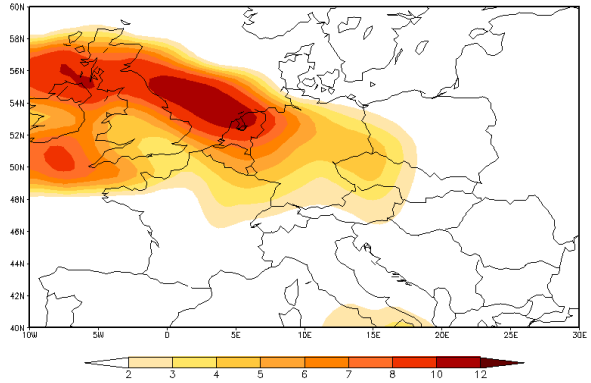

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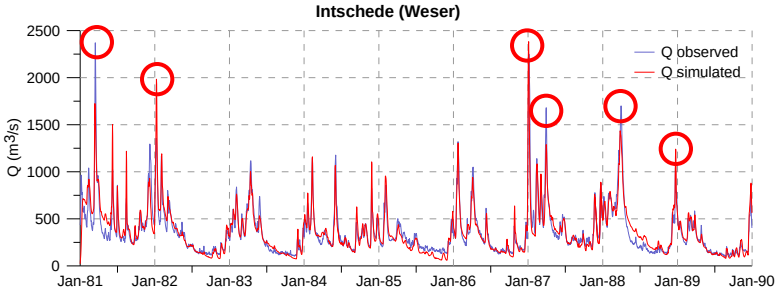
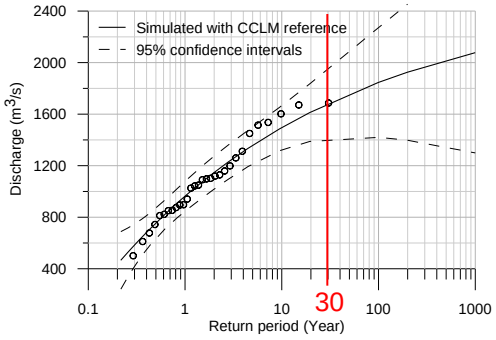


Calculation of extreme value distributions



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$q = runoff$

$u = threshold$

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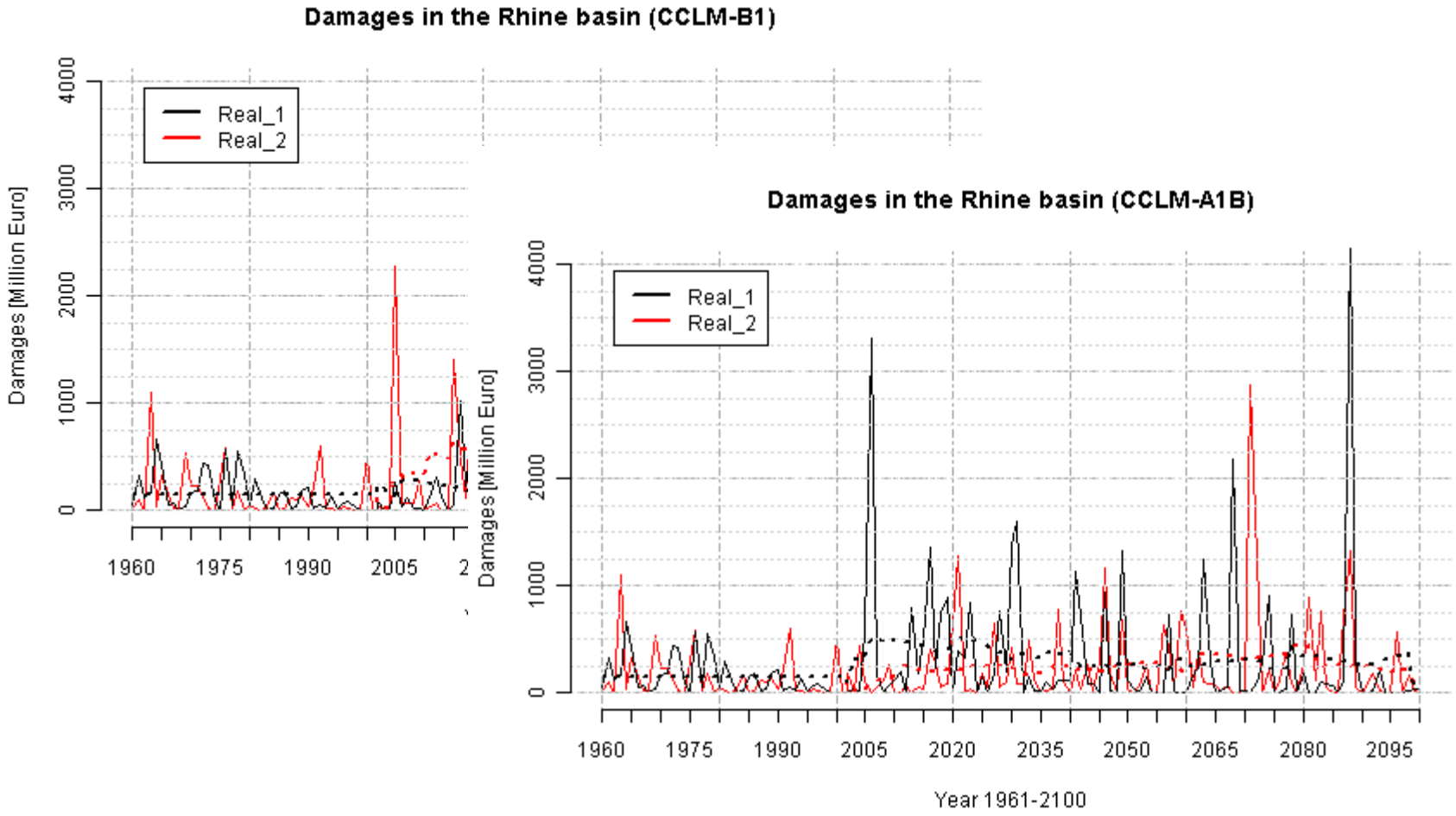
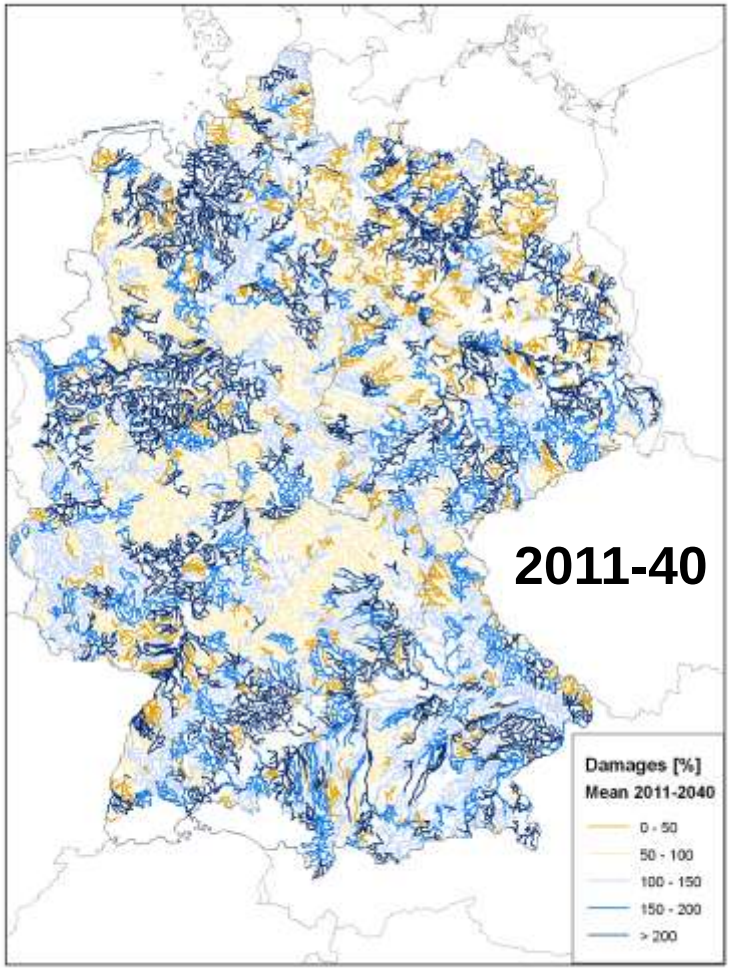
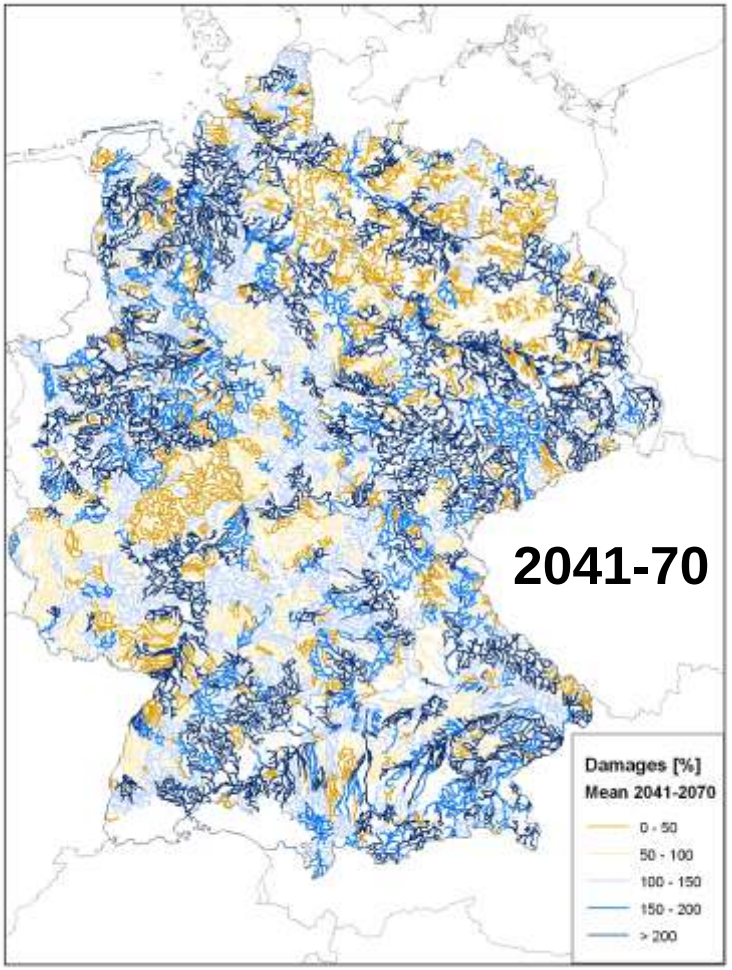
Results: Flood damages in the Rhine basin under climate change



Source of damage functions: German Insurance Association (GDV), modelled at PIK

Maps of the flood-related damages under scenario conditions





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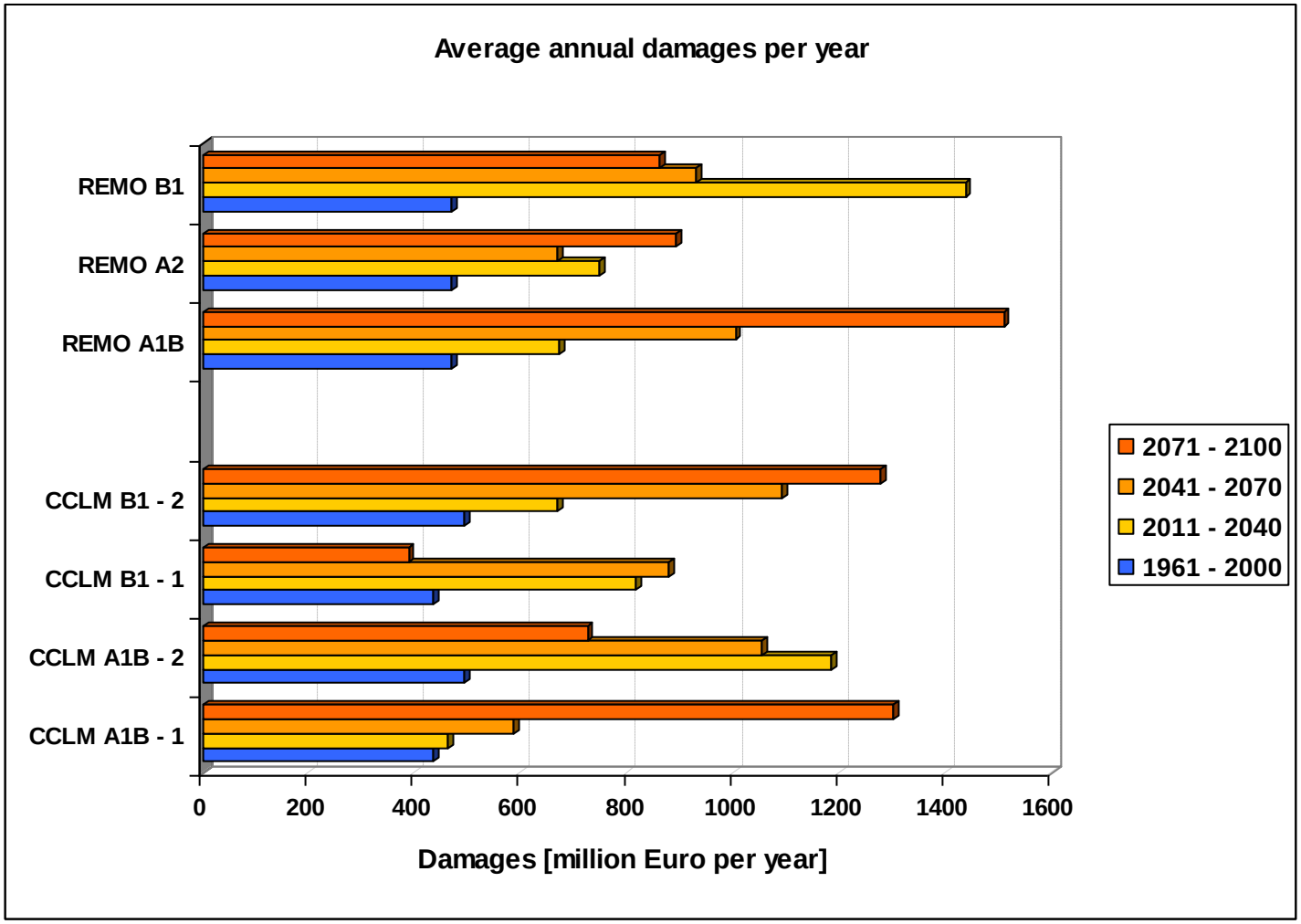
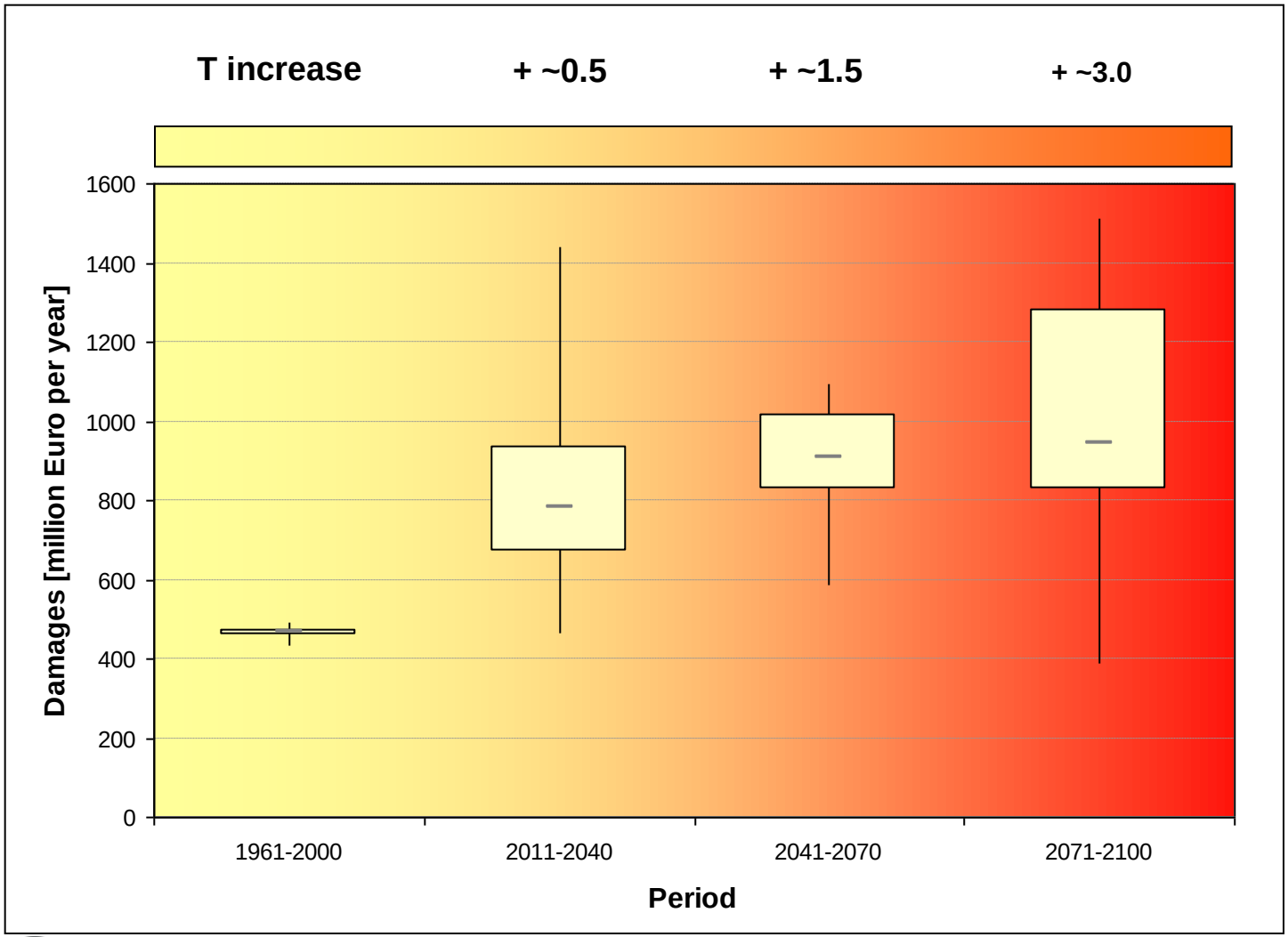
Damages per climate model, scenario and realization



Source of damage functions: German Insurance Association (GDV), modelled at PIK

Average annual damages per period



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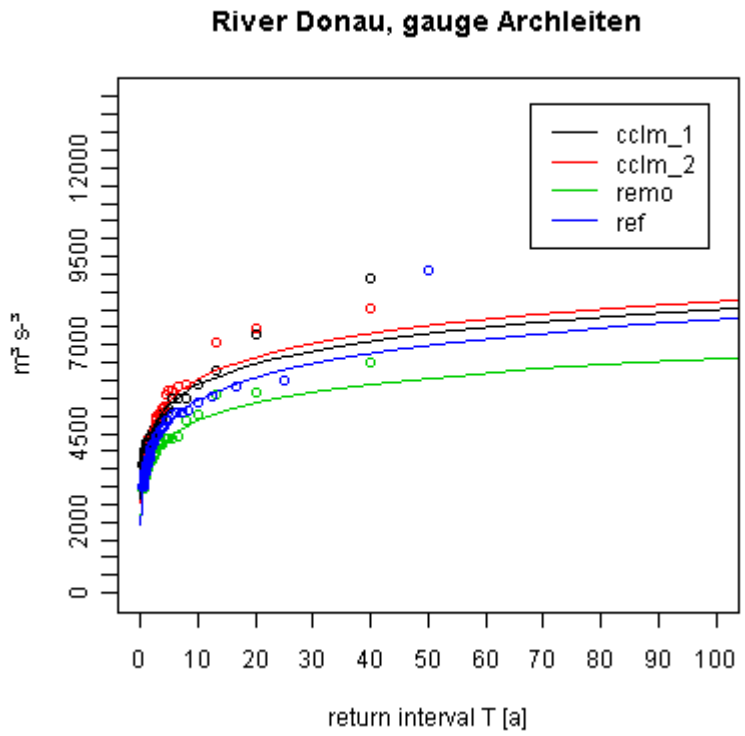
Conclusions

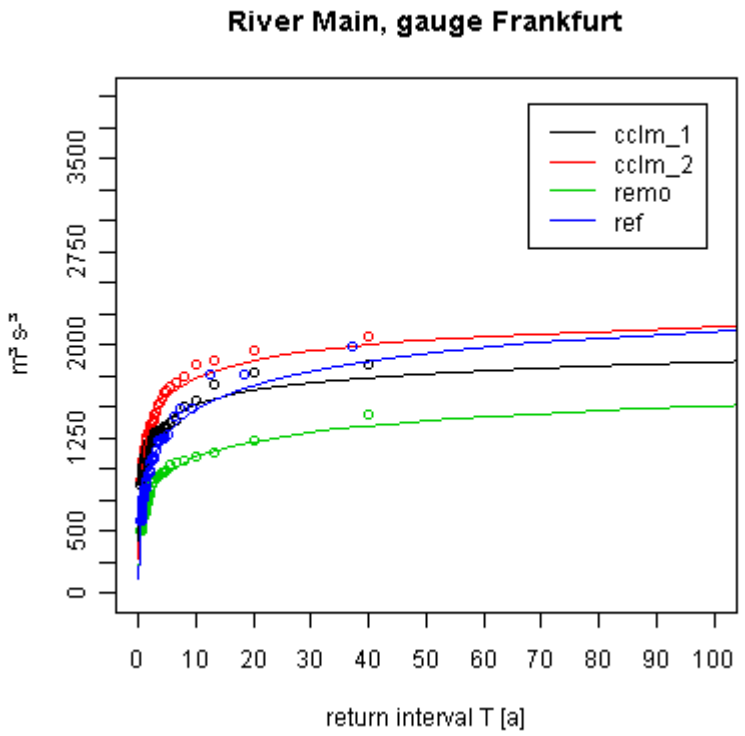
- All scenarios project higher damages in future
- Increase about 100 %
- Results have high uncertainty
- Understanding of climate change has to be improved
- Hydrology is very sensitive to changes in climate
- Unexpected events may happen, never observed before

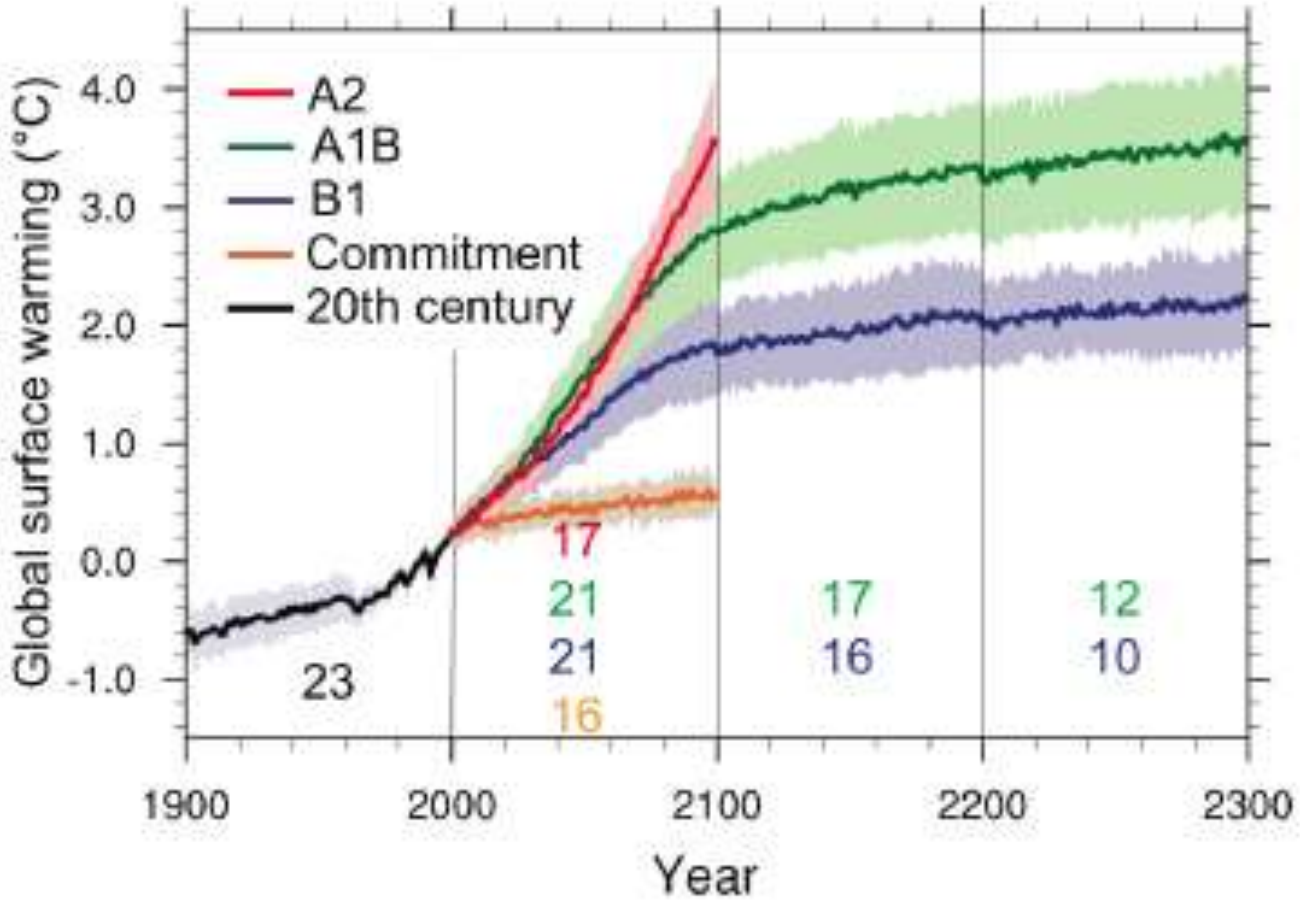
Thank you very much!

Especially to the German Insurance Association for providing the damage data

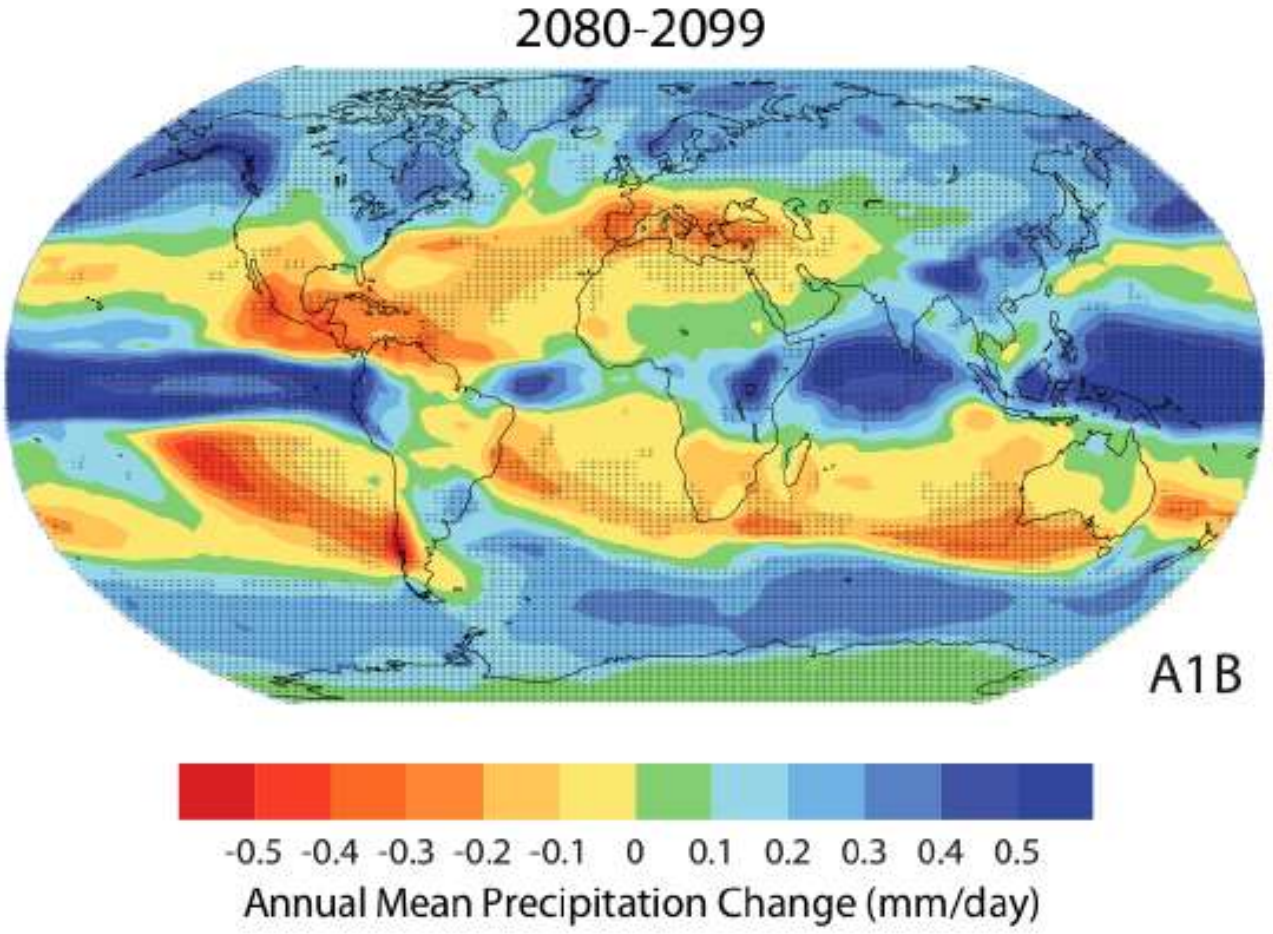
Bias control: Comparison flood statistics *with oberved climate as input and with simulated climate as input* for the reference period 1961 - 2000



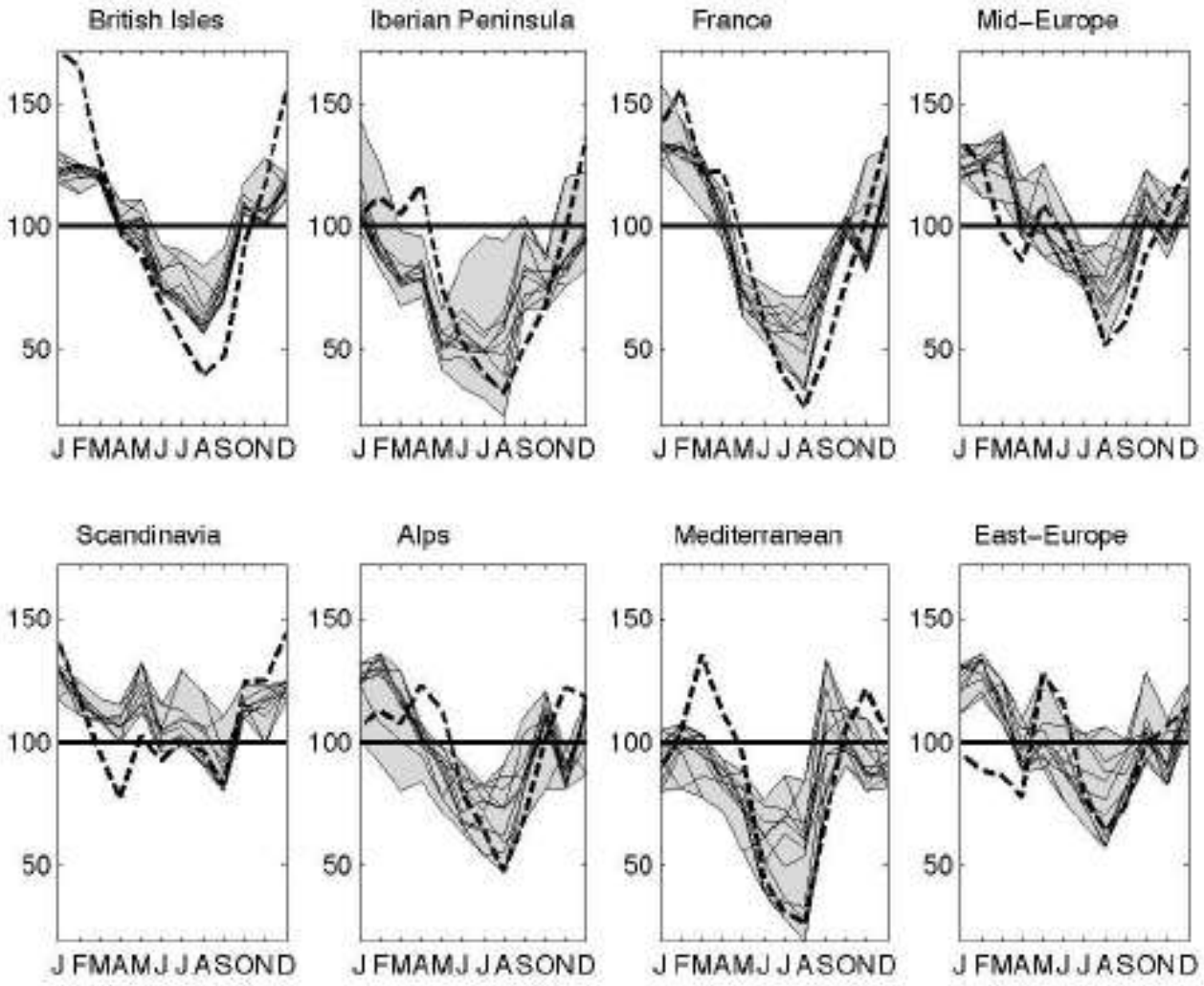



A2
A1B
B1
Commitment
20th century
Global surface warming (°C)
4.0
3.0
2.0
1.0
0.0
-1.0
23
17
21
21
16
17
16
12
10
1900
2000
2100
2200
2300
Year

Global change in precipitation



PRUDENCE: Signal in Precipitation 2071-2100 minus 1961-1990, A2

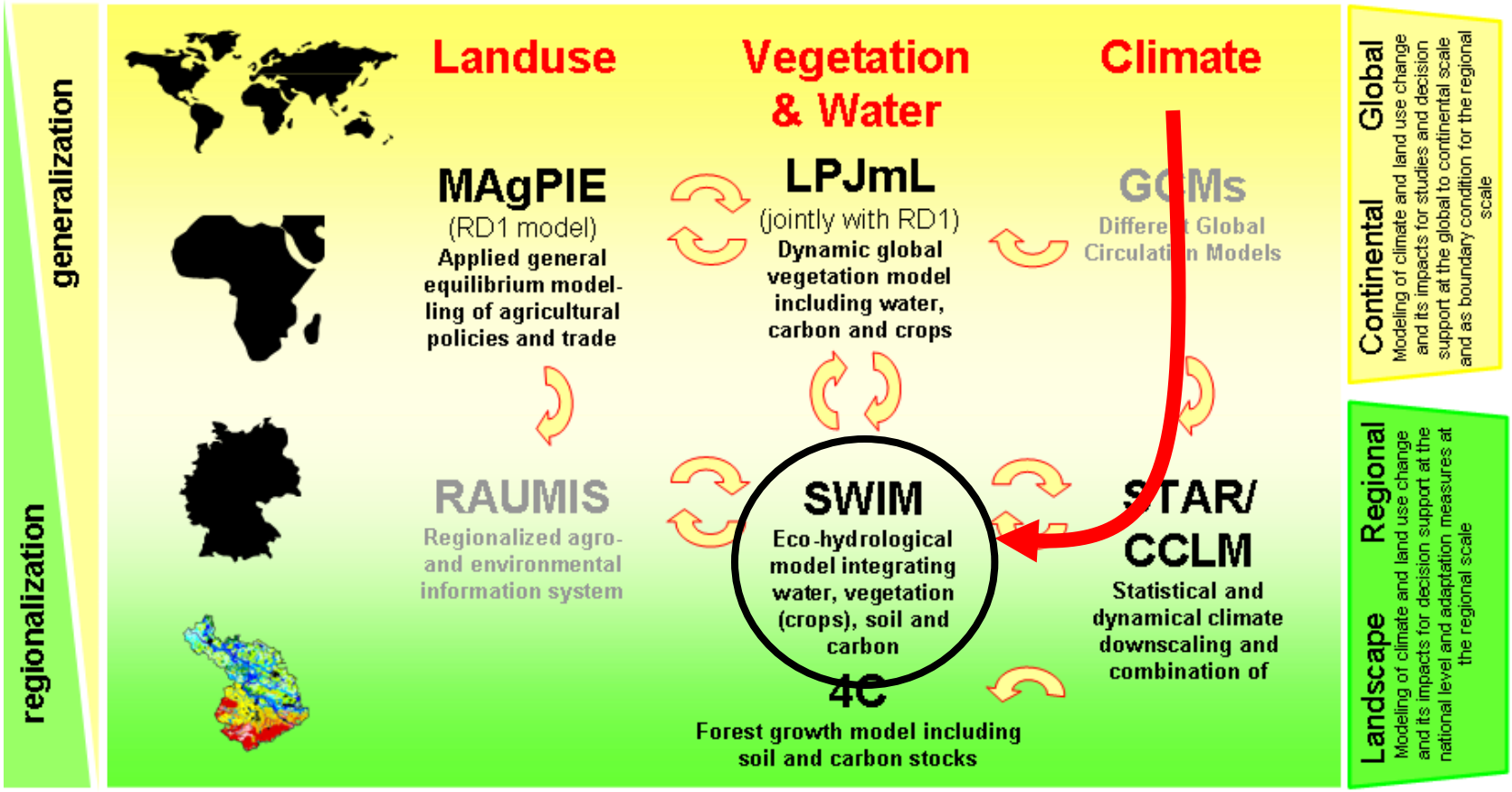


Jacop et al. 2008

Climate Impacts in a 2 3 4 Degree World

- Regional investigations worldwide

PIK Model System



Two way data transfer

One way data transfer

4C Model developed and maintained at PIK

GCM Model developed and maintained by German and international partners, interface and cooperation established

PIK


P I K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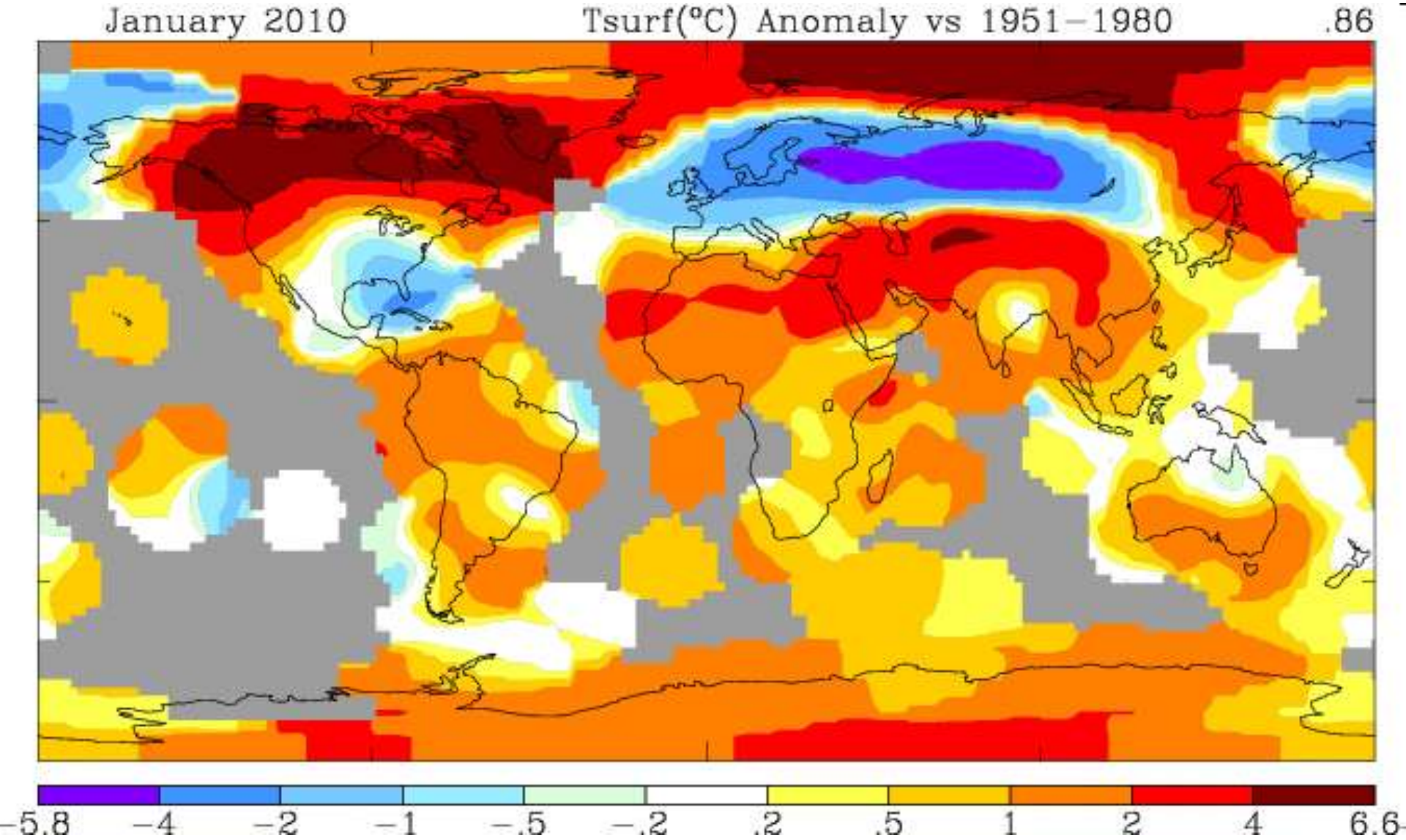
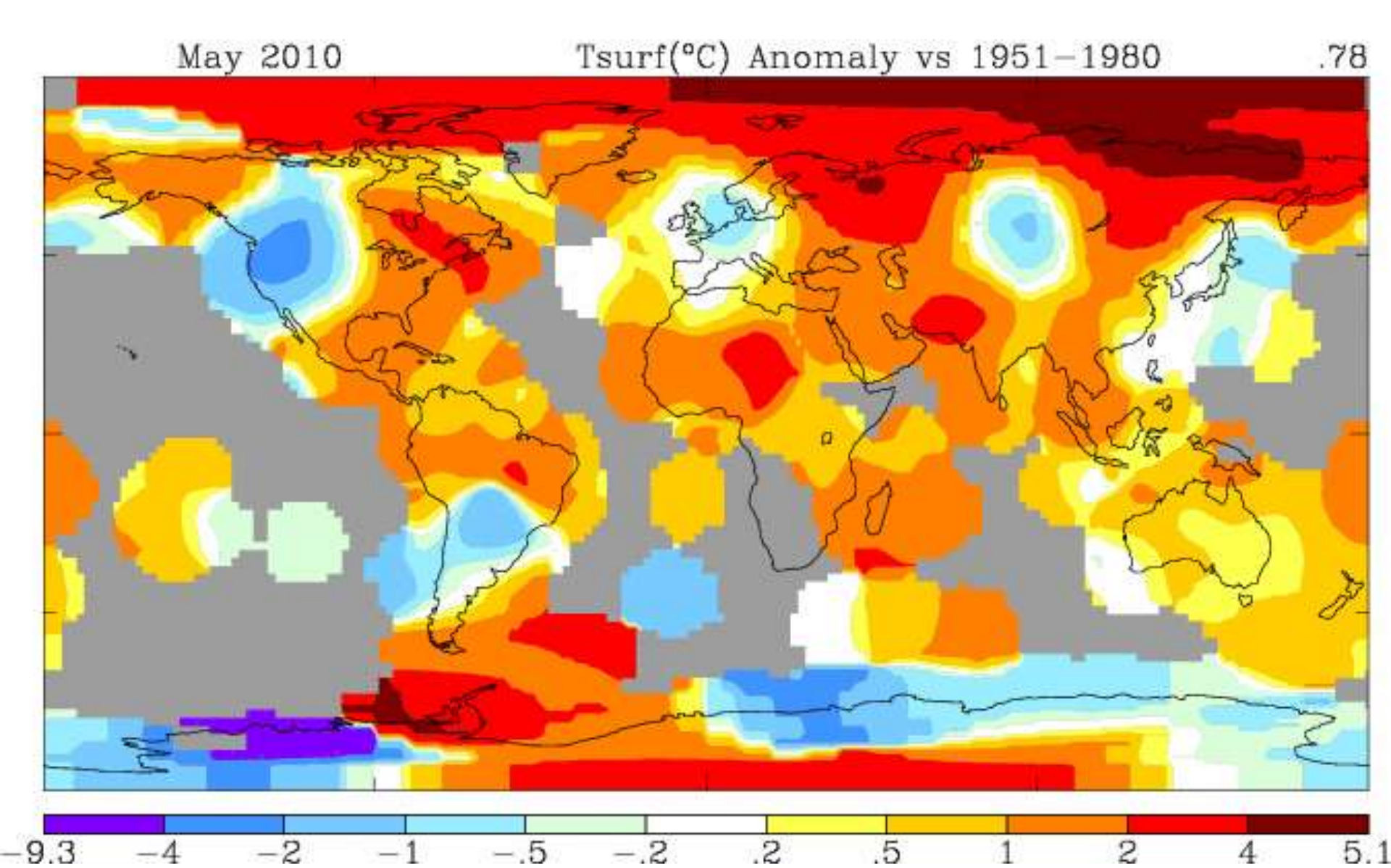


Source: http://data.giss.nasa.gov/



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