Precipitation frequency and intensity under global warming scenarios

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- Global and local warming
- Precipitation frequency and intensity
- Climatic scales & downscaling
- Expanded downscaling
- Precipitation scenarios
- Conclusions

P I K

Global and local warming

Two *independent* effects of warming can be distinguished

- global: enhanced moisture from oceanic evaporation (remote effect)
- local: larger water holding capacity of the air

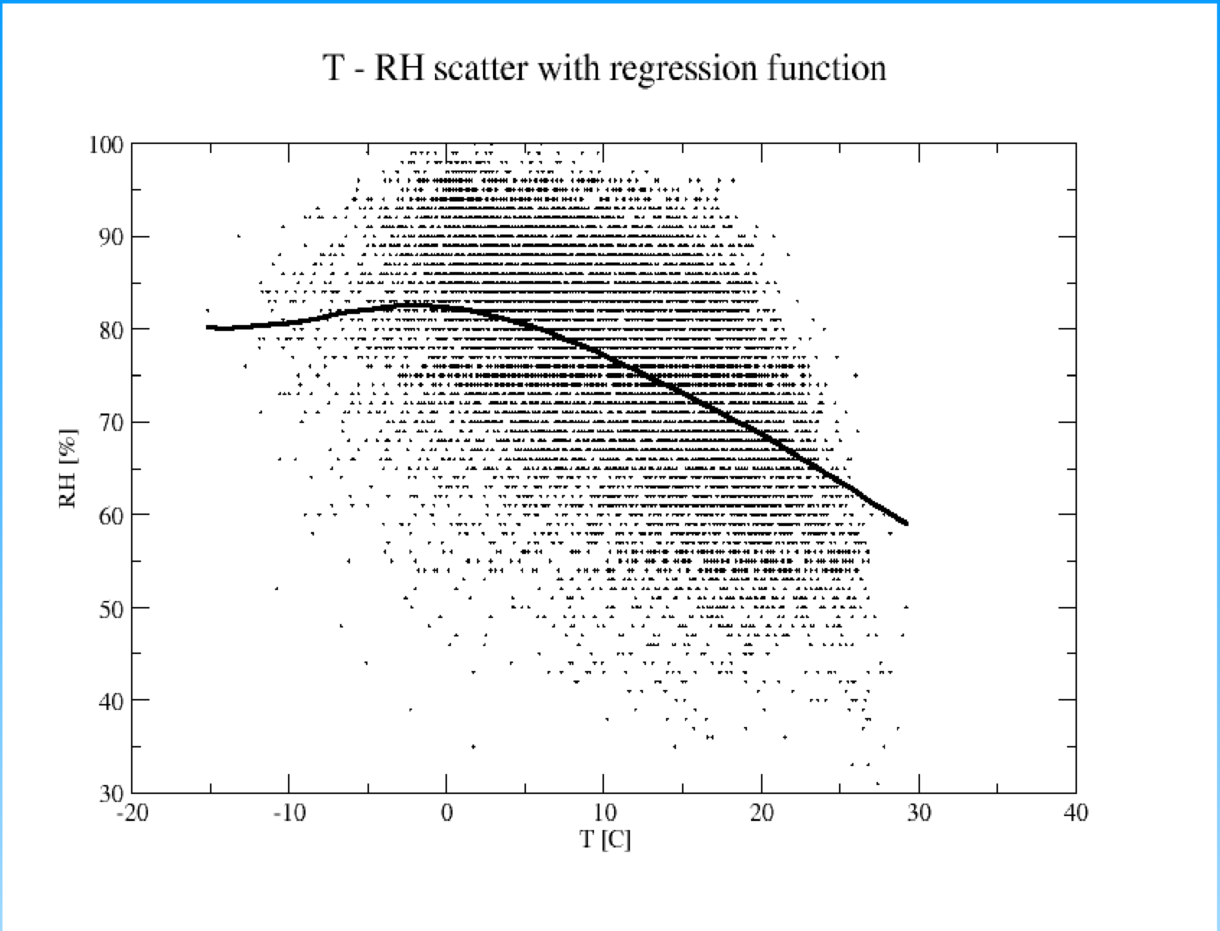
What is their combined effect on precipitation?

local warming

- comprises all the observational statistics between local temperature and moisture variables
- includes no remote effects from advection of increased moisture
- is an artificial concept
- that attempts to clarify the effect of global warming on local precipitation

daily variables

- m_P - precipitation sum
- f_P - precipitation frequency
- I_P - precipitation intensity (sum per wet day)
- T - temperature
- RH - relative humidity



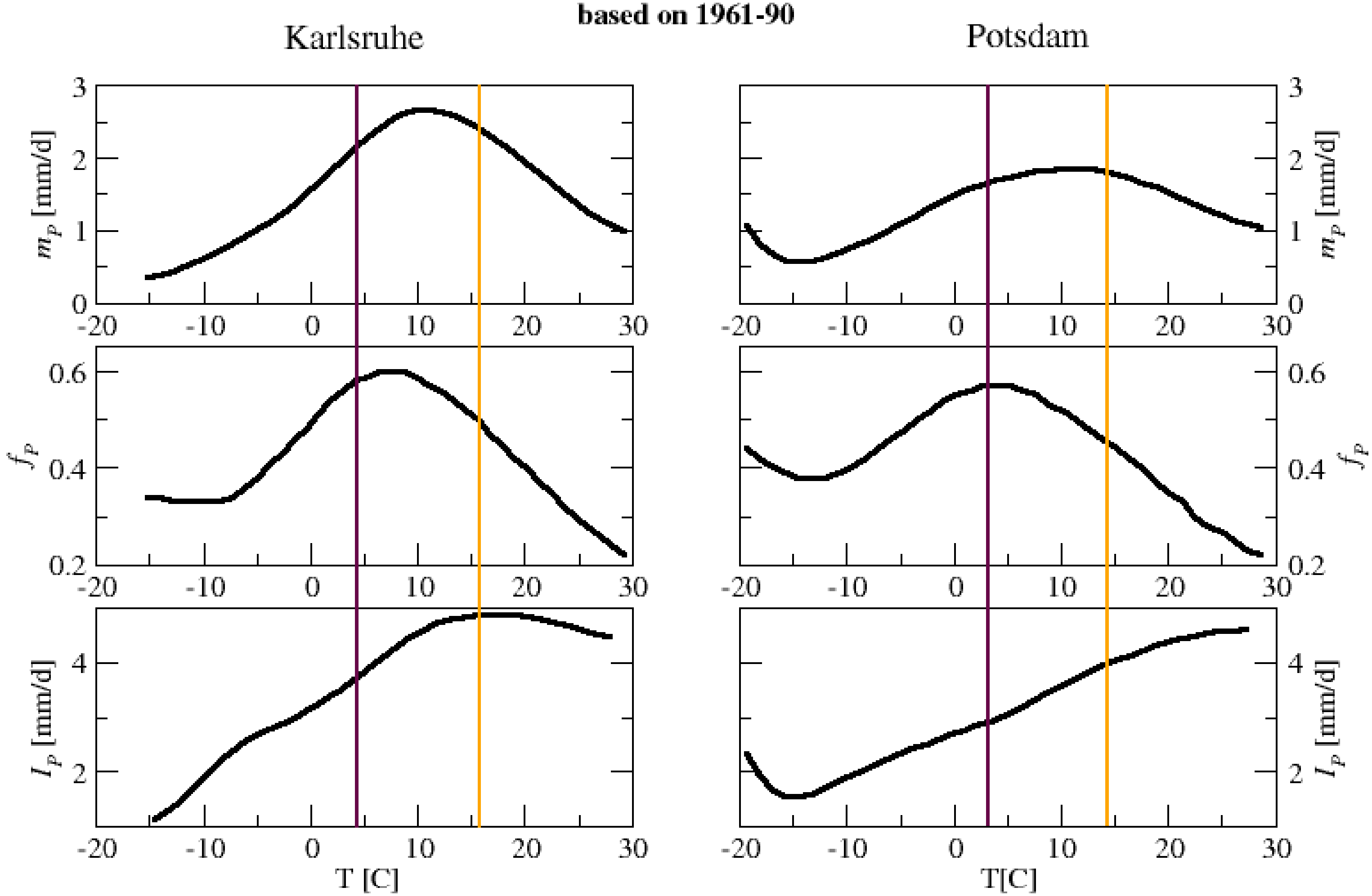
regression function Φ of two random varables X and Y

$$y = \Phi(x) = E(Y|X = x) = \int \eta f(x, \eta) d\eta$$

plot based on observed T and RH in Karlsruhe, 1961-90
(kernel regression)

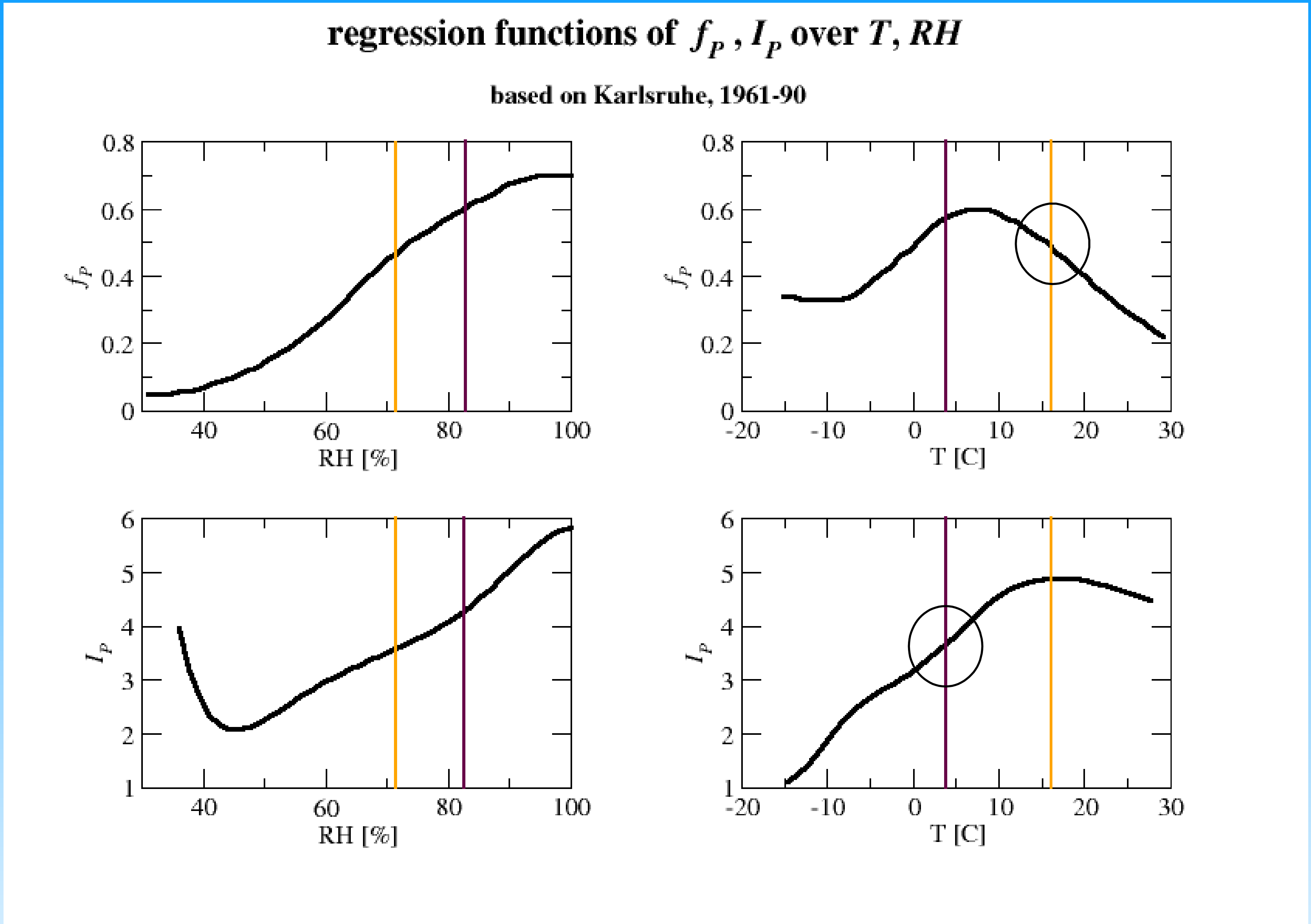
regression functions of m_P, f_P, I_P over T

based on 1961-90



— winter climate

— summer climate



— winter climate

— summer climate

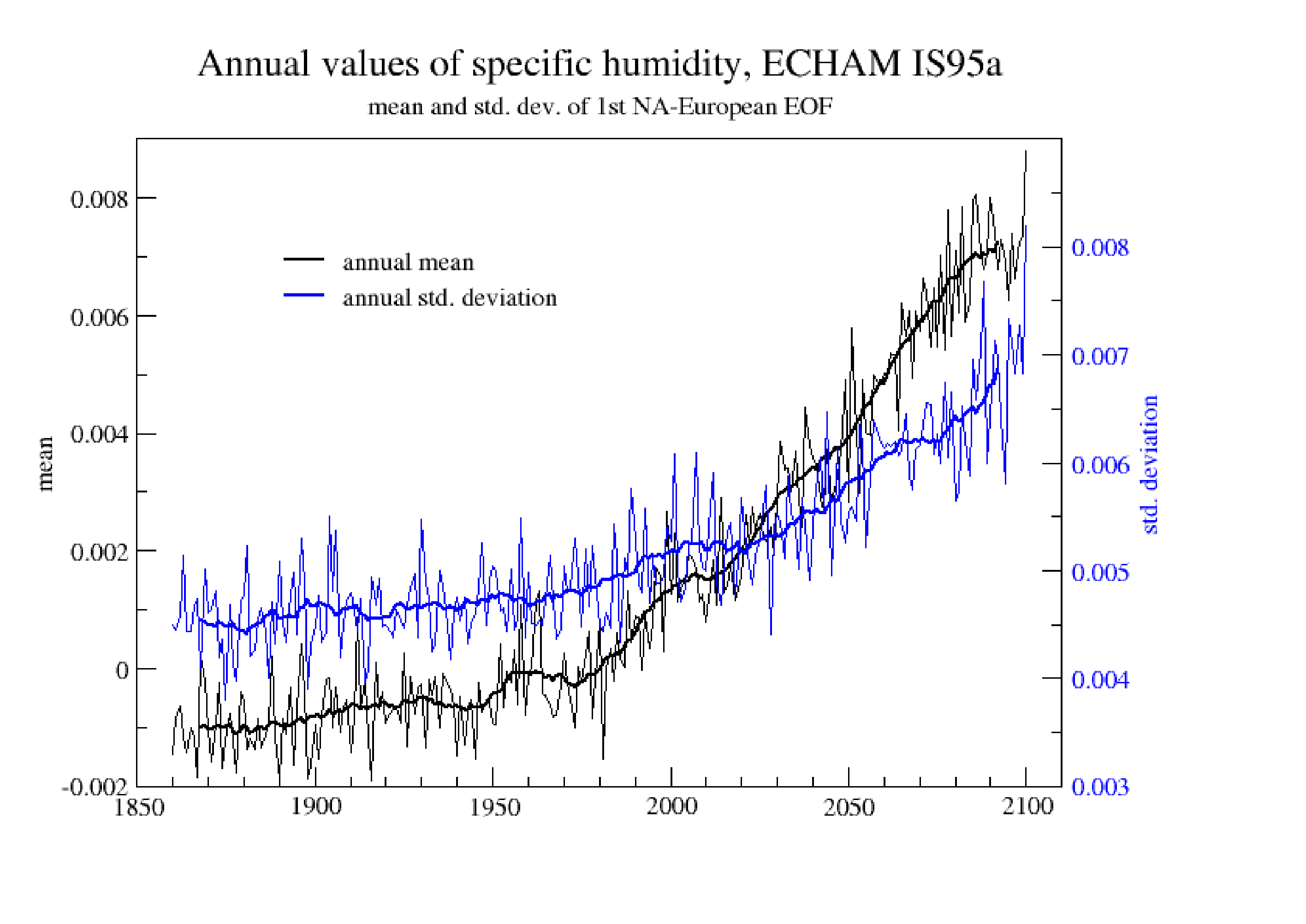
f_P and I_P under local warming (simplistic)

Karlsruhe	*winter*	*summer*
f_P	?	–
I_P	+	?

Conclusions local warming

- Local warming offers a simple (simplistic) view on precipitation climate change.
- After that, winter I_P increases and summer f_P decreases.
- Local warming is based on past statistics.
- It misses the effect of enhanced remote (oceanic) evaporation and advection of moisture under future climate conditions.
- Local warming is not global warming

global atmospheric moisture



Not only is there larger water holding capacity, but also more water

Old Europe

(seen from GCM)

```
          XX
        XXXX
      XXXXX
      XXXXX
 X      XX
  X    XX
X XX XXXXXXX
    XXXXXXXX
  XXXXXXXXXX
   XXXXXXXXX
XXXXX   XX X
XXXX       X
```

The problem of scales

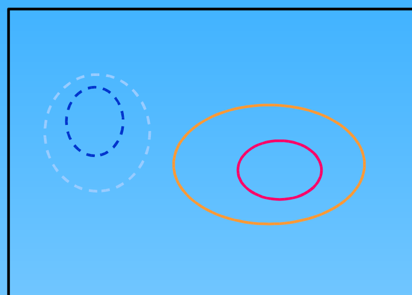
- GCMs are large-scale in space and time. They describe (at most) synoptic-scale atmospheric behavior.
- Hydrologic phenomena are small-scale. Their simulation requires (at least) daily meteorological input at the catchment scale.

downscaling

global circulation g

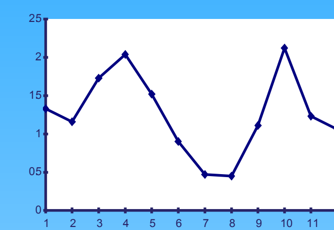
transfer function f

local weather $\mathfrak{l}$



$$\mathfrak{g} \xrightarrow{\quad f \quad} \mathfrak{l}$$

$$\mathfrak{l} = f(\mathfrak{g}) + \varepsilon$$



minimize $\langle (\mathfrak{l} - f(\mathfrak{g}))^2 \rangle$!

linear regression: $\mathbf{L} = C_{\mathfrak{lg}}(C_{\mathfrak{gg}})^{-1}$ ($C_{\mathfrak{lg}}$,... covariance) reduced model variability, $\mathbf{L}\mathbf{C}_{\mathfrak{gg}}\mathbf{L}^{\mathrm{T}}$, according to ...

$$\mathbf{L} = \mathbf{C}_{\mathfrak{lg}}(\mathbf{C}_{\mathfrak{gg}})^{-1} \qquad \Rightarrow \qquad \mathbf{L}\mathbf{C}_{\mathfrak{gg}}\mathbf{L}^{\mathrm{T}} = \mathbf{R}\mathbf{C}_{\mathfrak{ll}} < \mathbf{C}_{\mathfrak{ll}}$$

with $\mathbf{R} = \mathbf{C}_{\mathfrak{lg}}(\mathbf{C}_{\mathfrak{gg}})^{-1}\,\mathbf{C}_{\mathfrak{gl}}(\mathbf{C}_{\mathfrak{ll}})^{-1}$ canonical correlation matrix, $|\mathrm{R}| < 1$

[i.e., the eigenvectors of **R** are the canonical correlation patterns

with corresponding eigenvalues (correlations) ≤ 1.]

My Grandmothers principle:

"If uncertain, don't do anything."

- Regression inappropriate for daily precipitation.

regression

via *unconstraint* *error minimization*

$$\min \langle (\mathfrak{l} - \mathbf{L}\,\mathfrak{g})^2 \rangle$$

explicit solution: $\mathbf{L} = \mathbf{C}_{\mathfrak{l}\mathfrak{g}}(\mathbf{C}_{\mathfrak{g}\mathfrak{g}})^{-1}$

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expanded downscaling

via *constraint* *error minimization*

$$\min \langle (\mathfrak{l} - \mathbf{L}\,\mathfrak{g})^2 \rangle$$

cond. upon

$$\mathbf{L}\mathbf{C}_{\mathfrak{g}\mathfrak{g}}\mathbf{L}^{T} = \mathbf{C}_{\mathfrak{l}\mathfrak{l}}$$

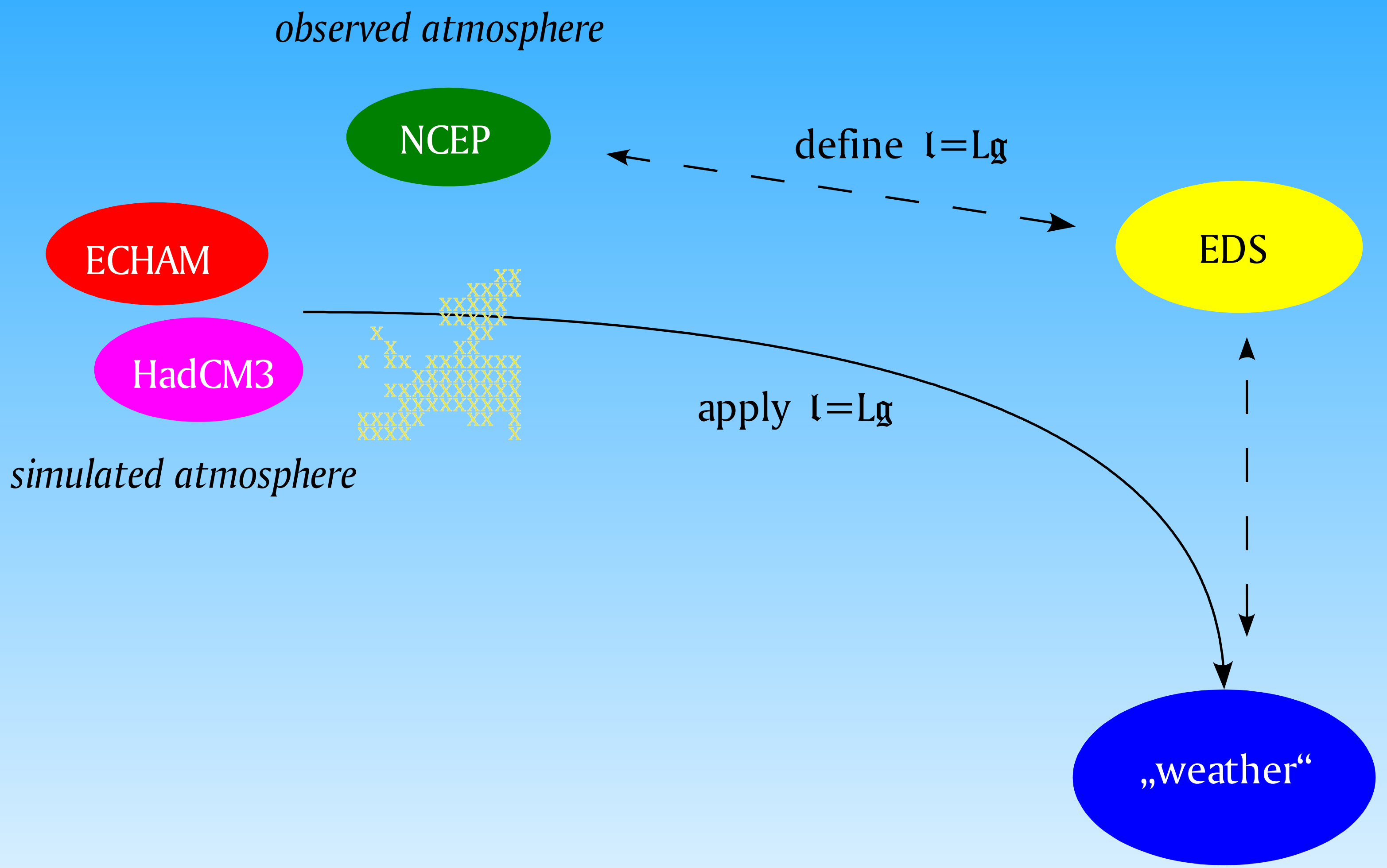
Solution **L** unique but approximative ($\Rightarrow$ nonlinear optimization)

Expanded downscaling is the unique optimum linear model (in the l. sq. sense) that preserves local covariance.

When driven by observed global fields it simulates realistic local variability on the daily scale.

When driven by changed global fields, e.g. in a climate scenario, the local variability might change accordingly.

How to proceed



European EDS applications

- **EUROTAS - EUR**opean river flood **O**ccurence and **T**otal risk **A**ssessment **S**ystem
- **DFNK** - German research network natural disasters
- **SHYDEX** - Scenarios of hydrologic extremes (DFG project)

Global circulation

North Atlantic/European sector:

- 500 hPa geopotential height
- 850 hPa temperature
- 700 hPa specific humidity

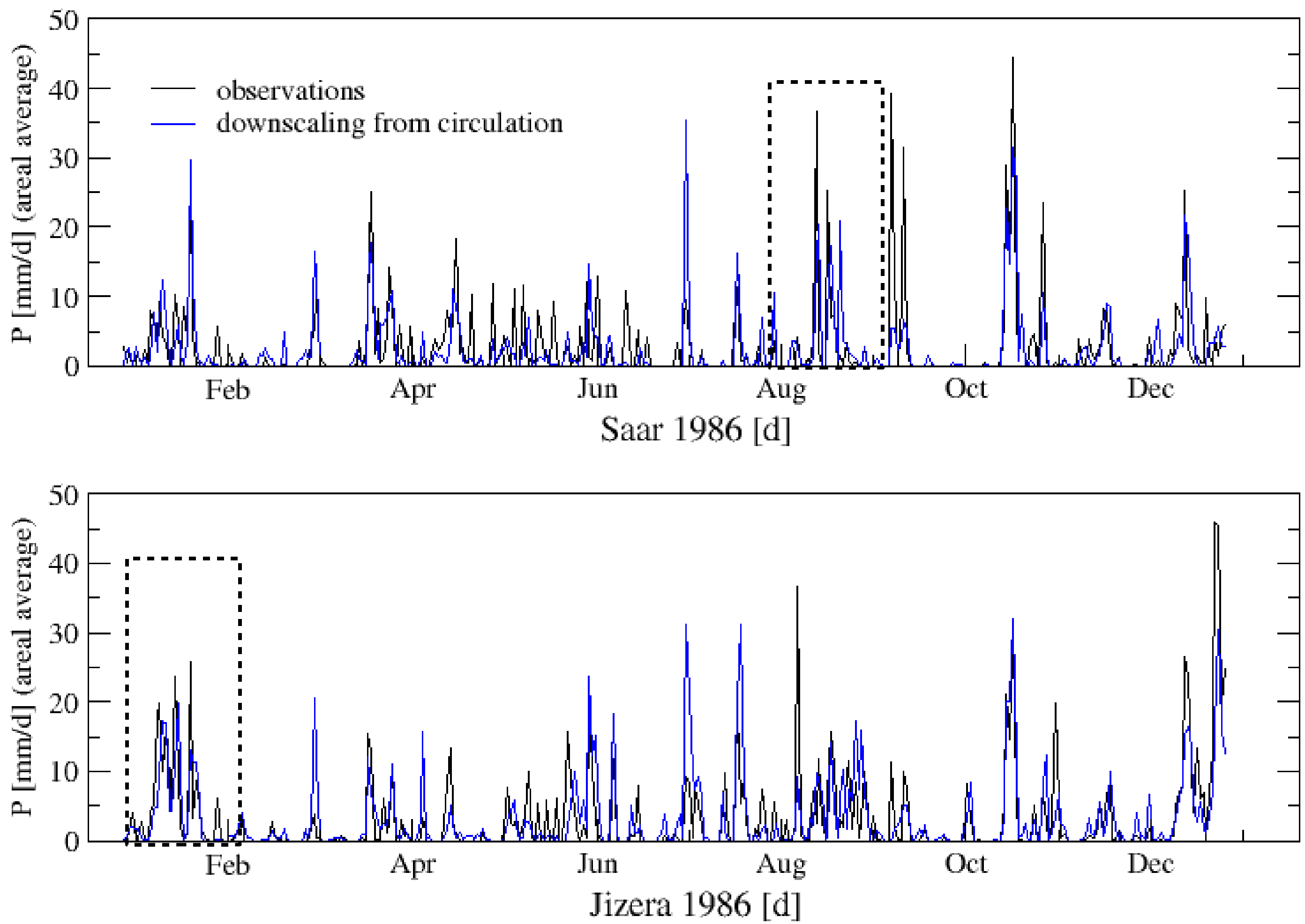
Circulation types (daily):

- ***observed:***
  - ANA - 30 years global NCEP reanalyses 1961-90 (EDS calibration);
- ***simulated*** from ECHAM4/OPYC3 (DKRZ Hamburg):
  - CTL - 300 years control run;
  - SCA - 240 years IS95a♦ simulation (1860-2100, 2061-2090 in various plots).
- ***simulated*** from HadCM3 (Hadley Centre, U.K.):
  - HDL - 140 years IS95a simulation

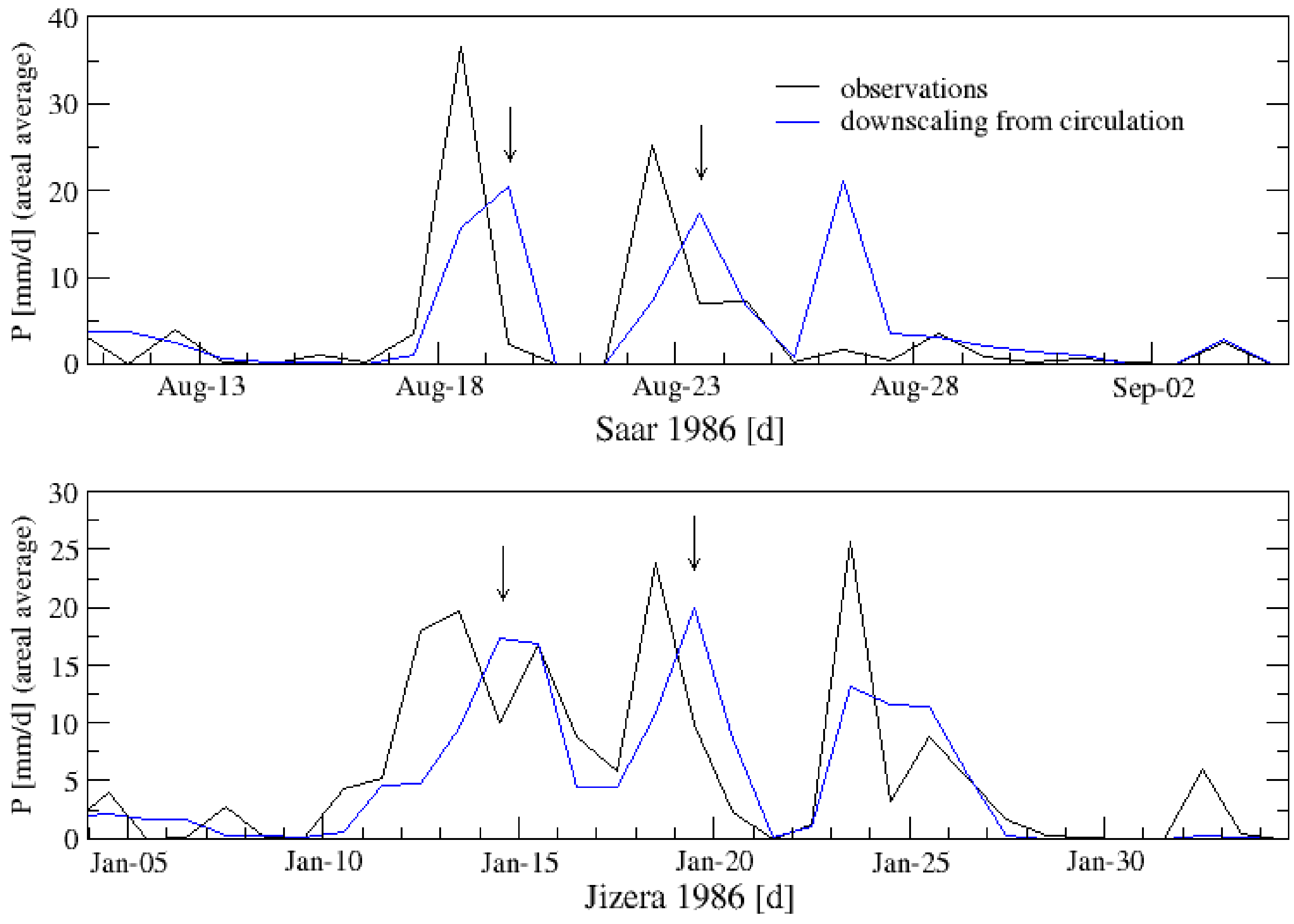
♦ IS95a: *IPCC emission scenario "business as usual"*

EDS validation

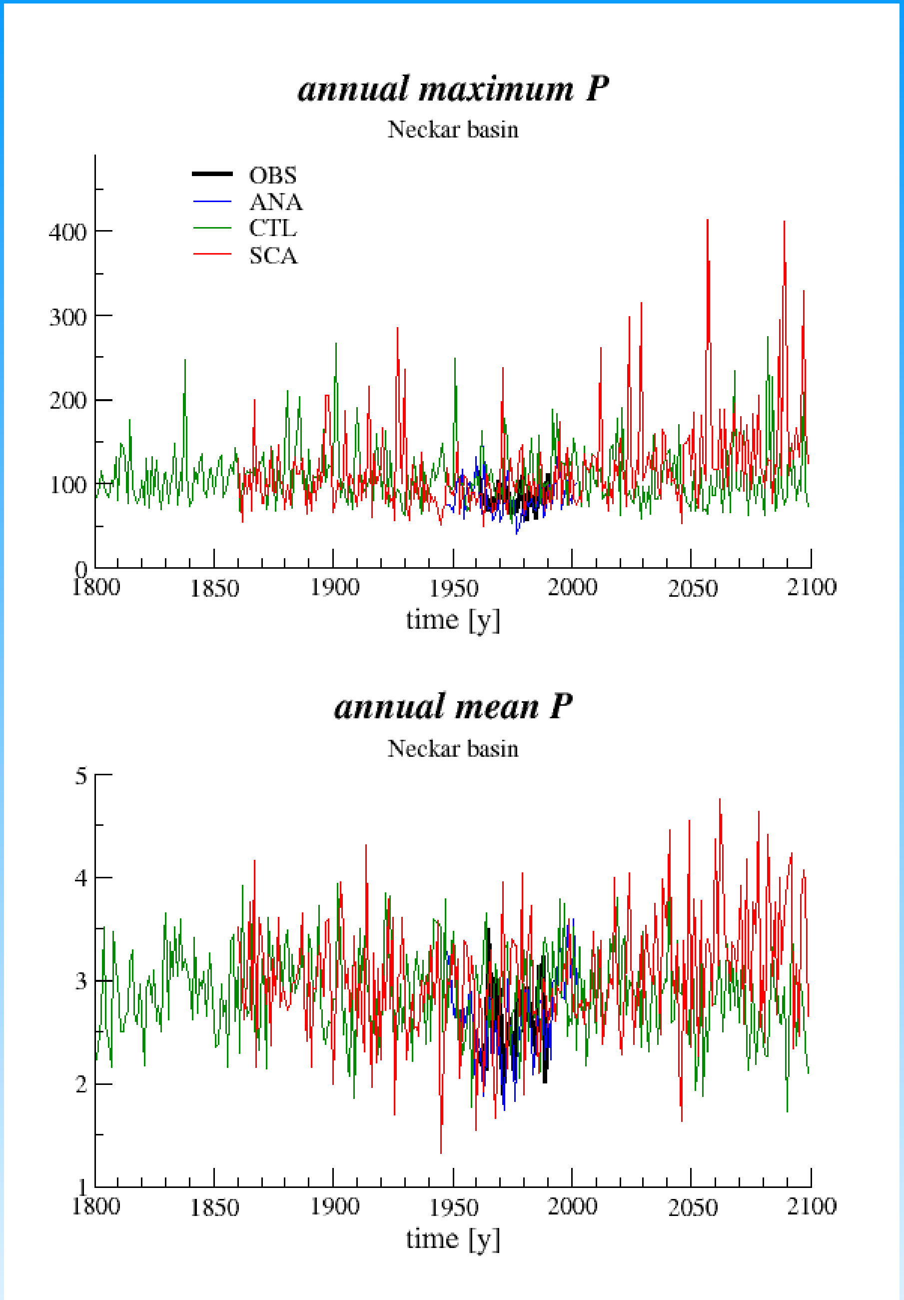
for Saar basin (Germany) and Jizera basin (Cechia)



closeup of former figure



events are often simulated with a slight temporal aberration (arrows)



Variability of mean realistic, scale of annual maximum too strong for CTL and SCA (maybe not).

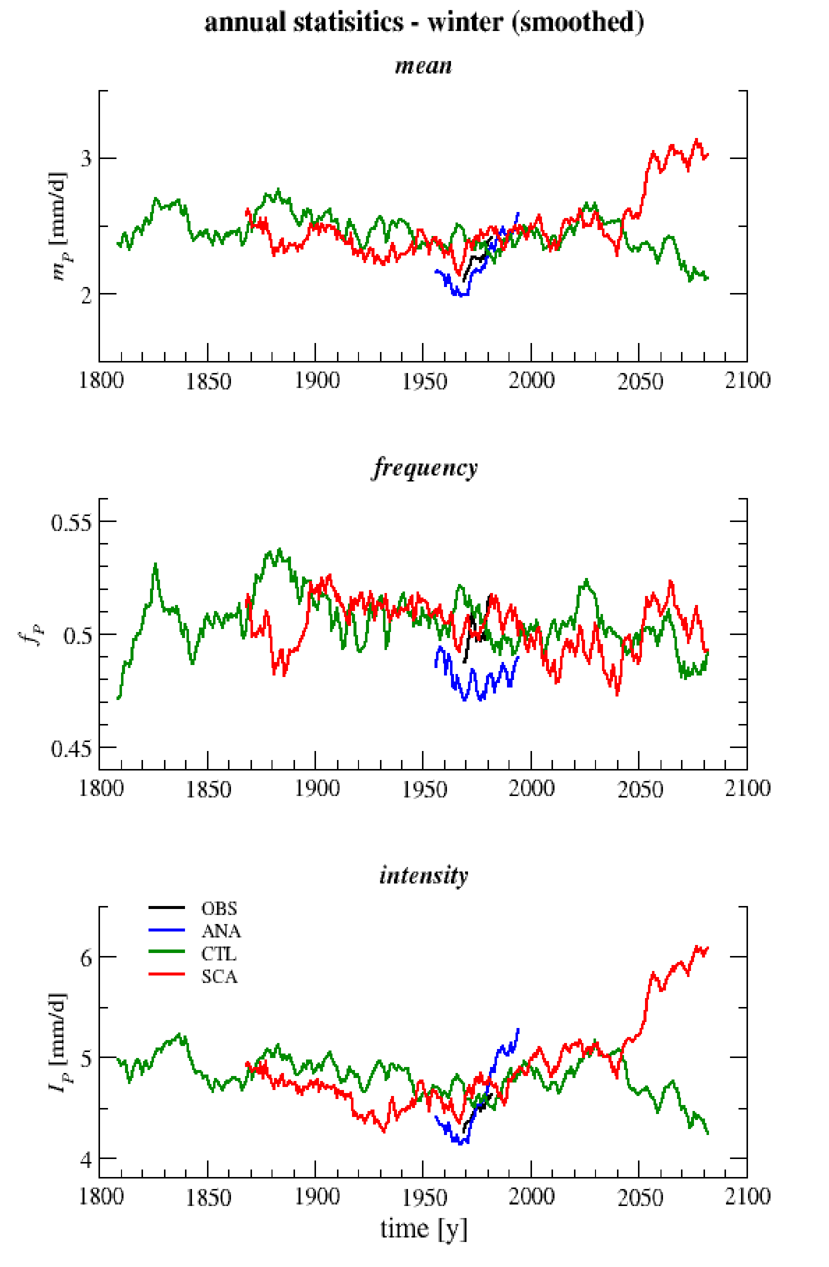
Control simulation suggests strong natural fluctuations.

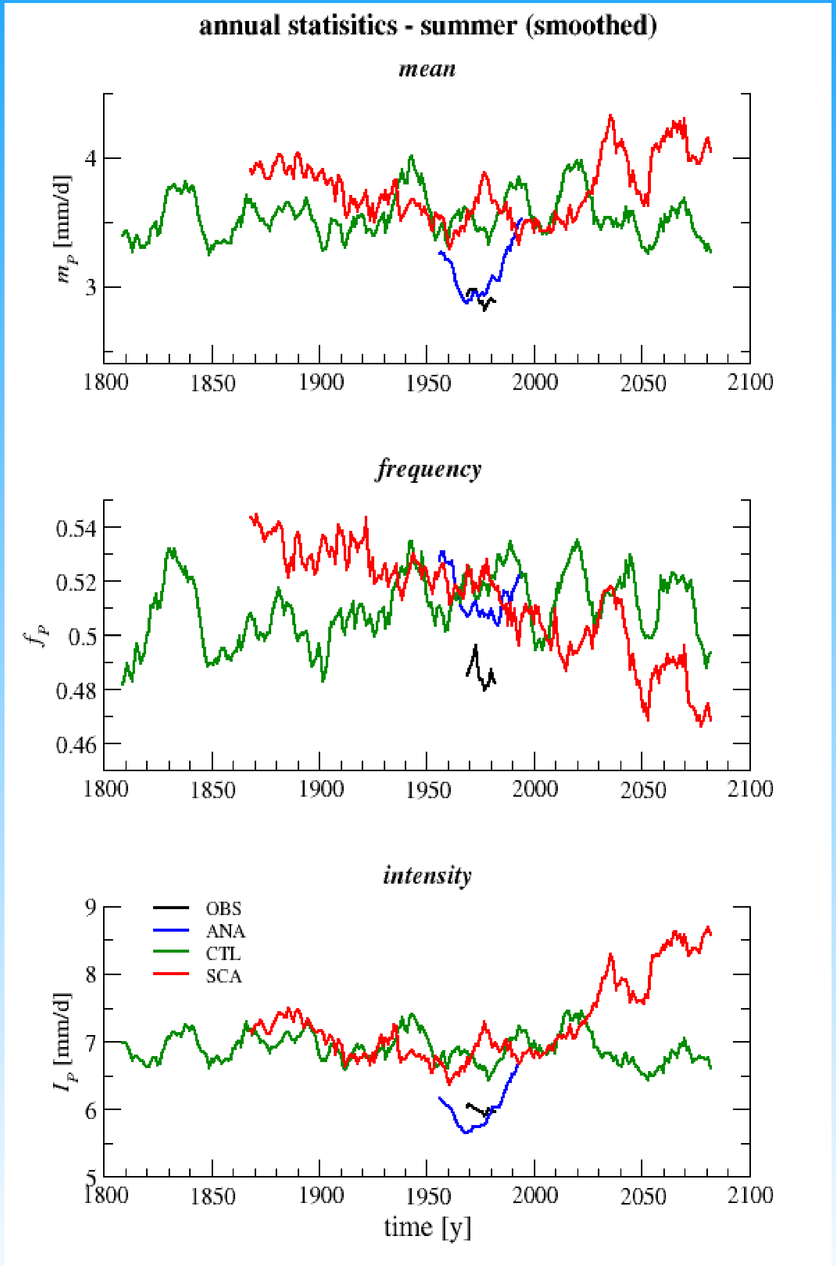
Increase for mean and maximum under global warming scenario.

OBS: local observations;
ANA: downsacaled analyses;

CTL: downscaled GCM control
SCA: downscaled GCM scenario

m_p, f_p and I_p climate simulations (Neckar basin)





Extreme value analysis

- estimation of return periods limited by model calibration period of 30 years
- partition of 300 year control run into 10 30-year sections
- using 2061-2090 from the scenario

Result:

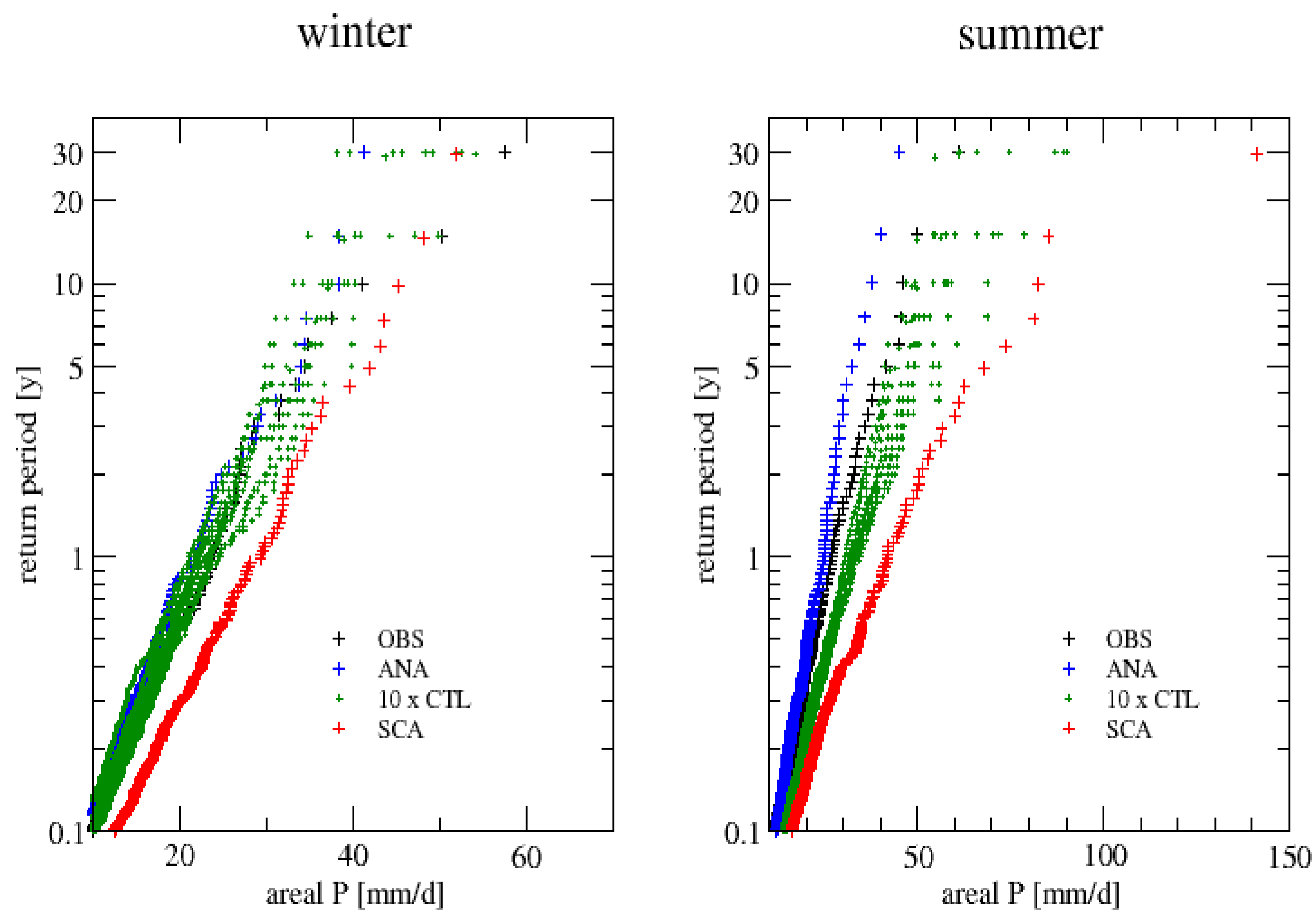
present: **OBS** + **ANA** + 10×**CTL** (12 *cdf*'s)

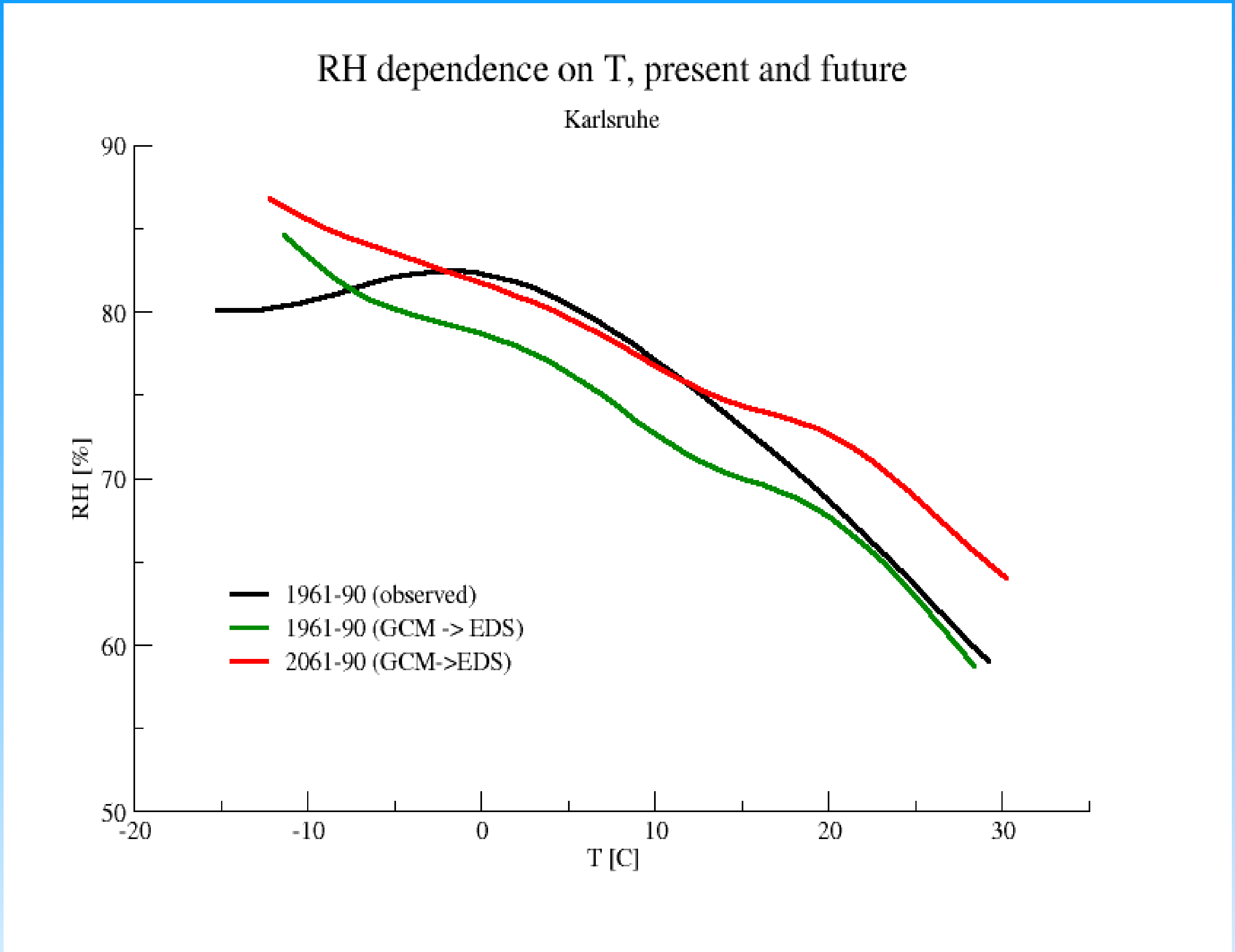
future: **SCA** (1 *cdf*)

cdf: cumulative distribution function

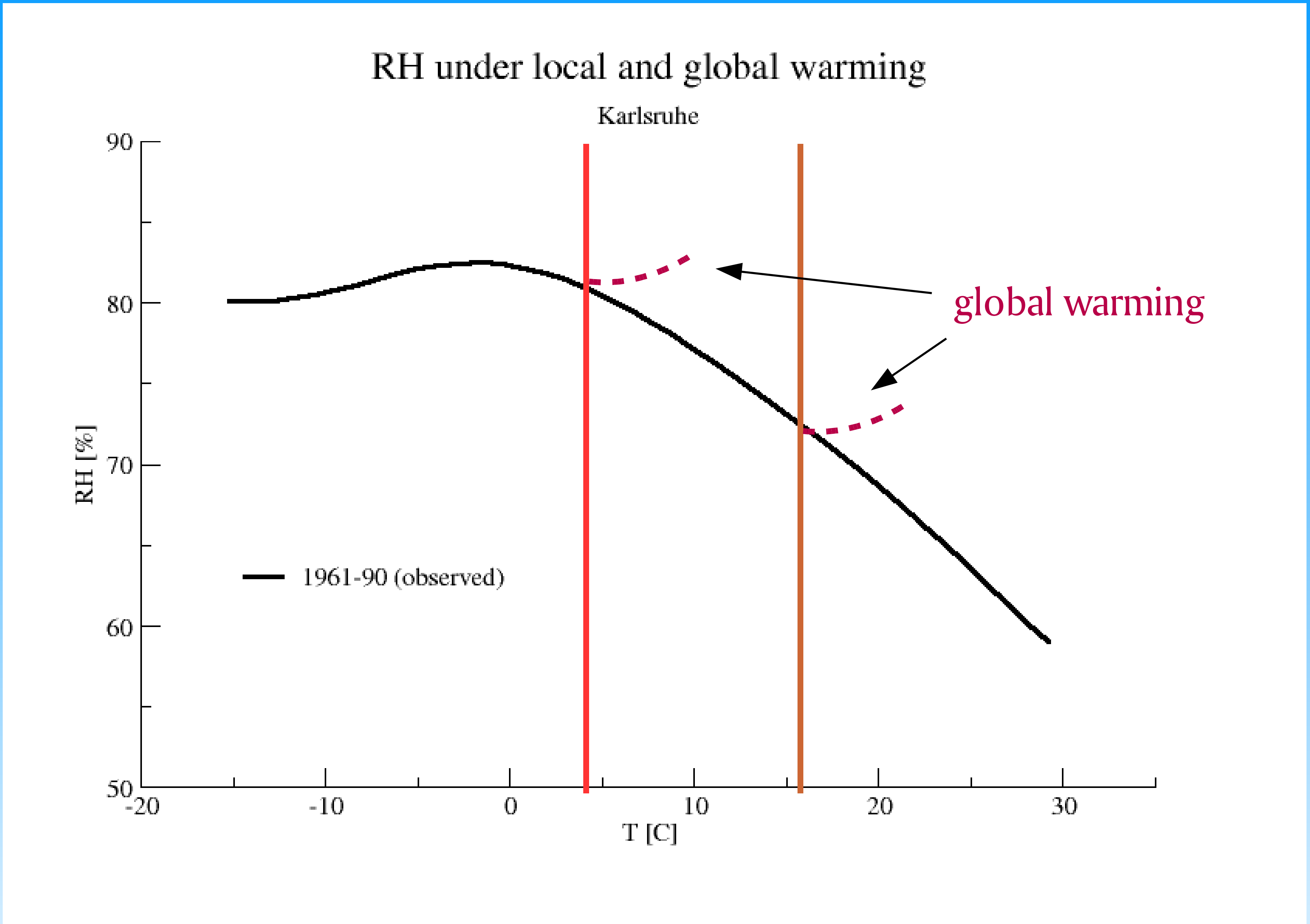
Extreme value analysis

Neckar basin





RH dependence on T, present and future
Karlsruhe
RH [%]
90
80
70
60
50
-20
-10
0
10
20
30
T [C]
1961-90 (observed)
1961-90 (GCM -> EDS)
2061-90 (GCM->EDS)



— winter climate
— summer climate

Conclusions for the Rhine

- EDS reliably reproduces observed local precipitation clusters from observed global circulation fields…
- The local P-climate downscaled from GCMs
  - partly suffers from incorrect GCM climate.
  - reveals immense "natural" (CTL generated) variability.
  - shows an increase of winter and summer I_P.
  - shows a decrease of summer f_P.
- The net effect on f_P and I_P is determined by the locally characteristic regression on T.
  - For winter I_P, both global and local warming act for larger I_P.
  - For summer f_P, local warming probably dominates, leading to a decrease in f_P.
- This supports and adds important detail to the current wisdom that stems from climate models and is reported by the IPCC.

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          XX
        XXXX
      XXXXX
      XXXXX
 X      XX
  X    XX
X XX XXXXXXX
    XXXXXXXX
  XXXXXXXXXX
   XXXXXXXXX
XXXXX   XX X
XXXX       X
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