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Changes in the hydro-meteorological regimes of the Rhine River basin based on bias corrected RCM simulations

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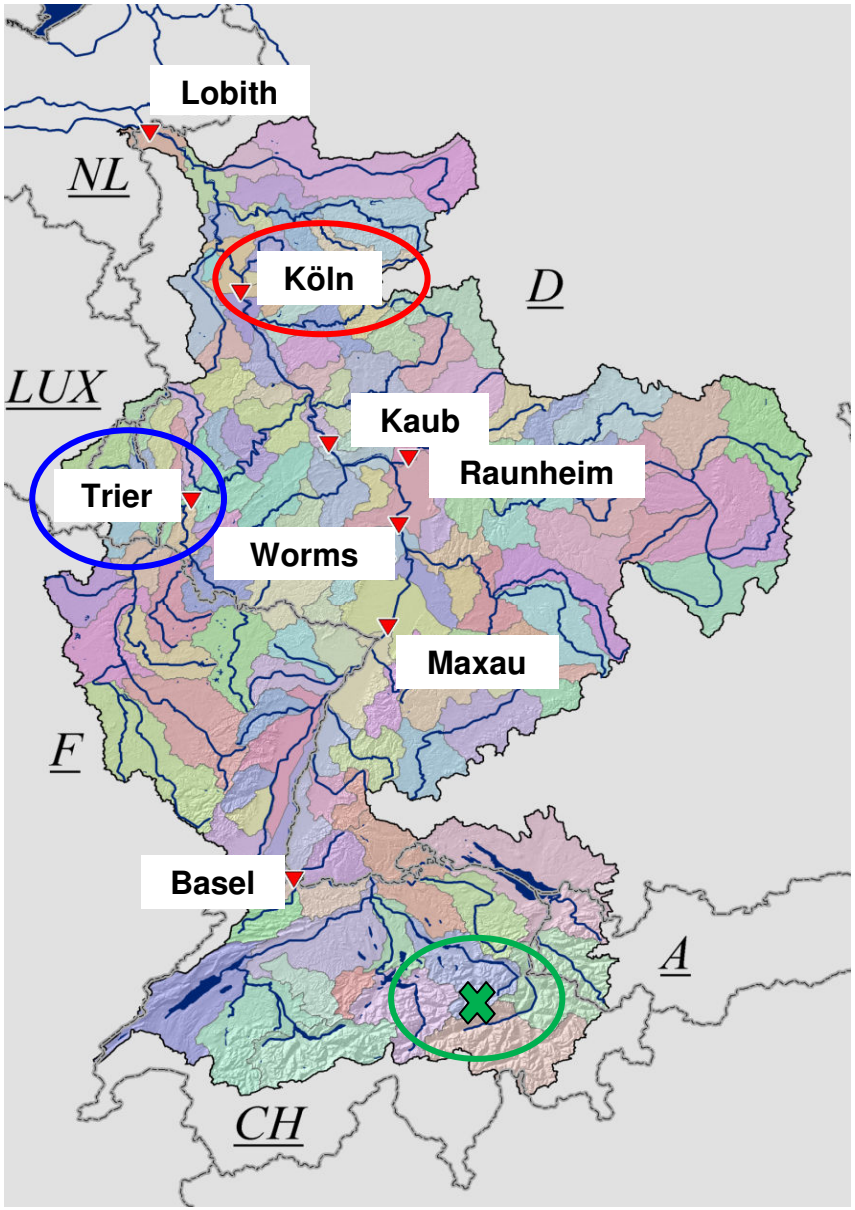
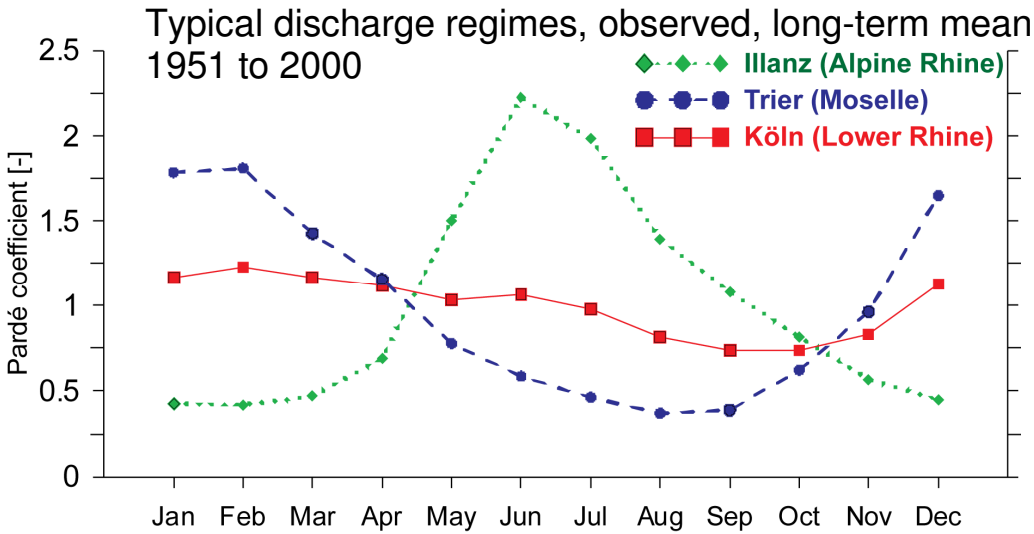
Outline of the presentation

- Introduction
- The modelling chain
- Future hydro-meteorological changes
- Time series resampling (= KNMI weather generator)
- Bias correction
- Summary and conclusions

Introduction

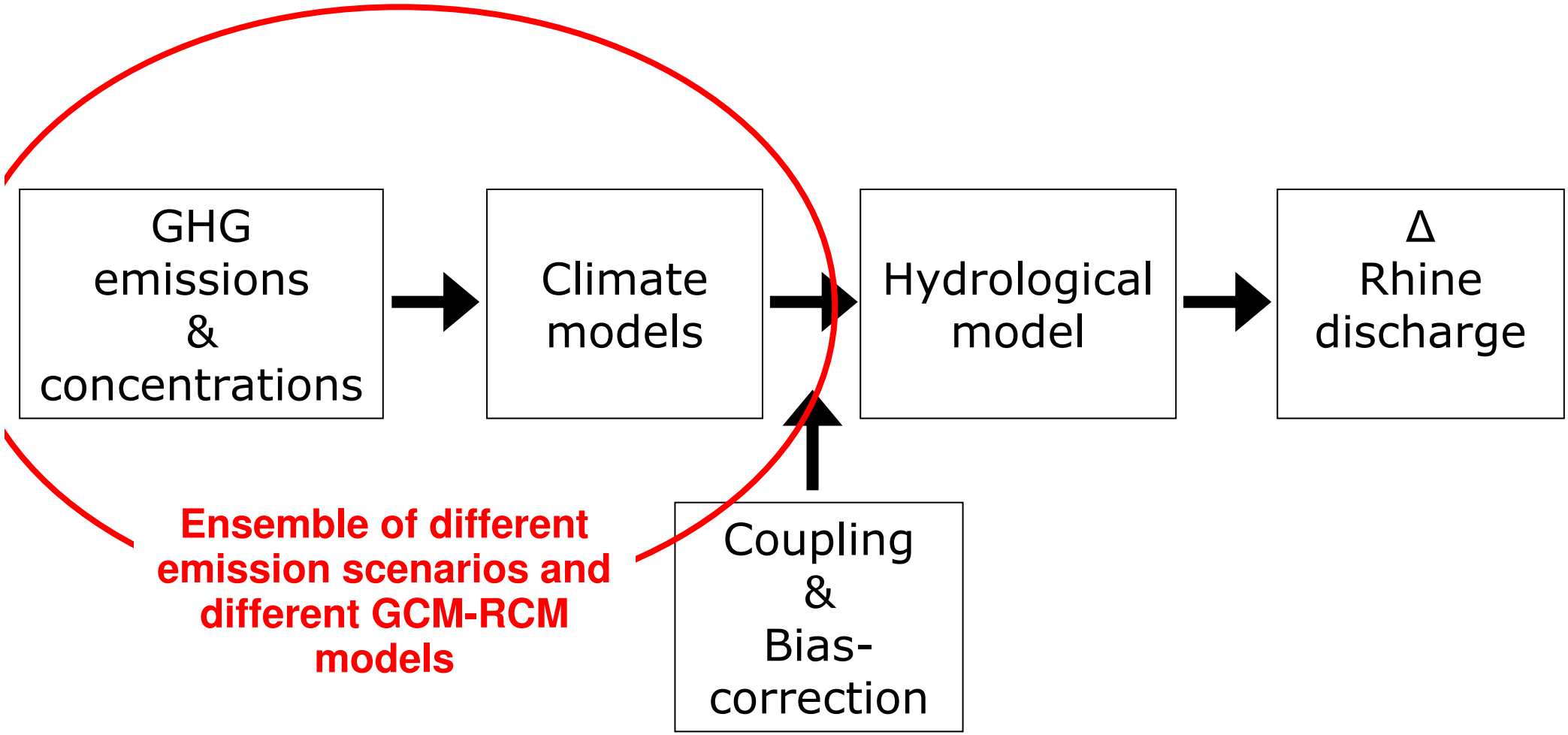
Study area and setup of hydrological model HBV134





- HBV hydrological model for discharge projections
- Version: HBV-96, jointly implemented by BfG and RWS-WD to Rhine River catchment
- Semi-distributed, 134 model catchments (HBV134); daily time-step
- Inputs: precipitation, air temperature, potential evapotranspiration
- Limitations (excerpt):
  - Hydrometeorological reference datasets
  - Linear description of base flow
  - No lake retention, not too sensitive
  - Flood routing, no hydraulic model, no overtopping of dikes → only with HQx

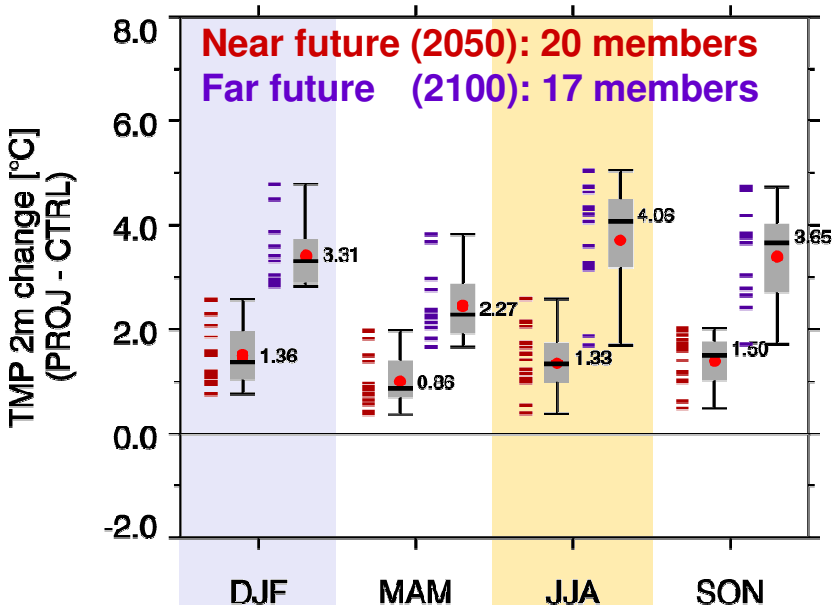
The modeling chain
Mean and low discharges



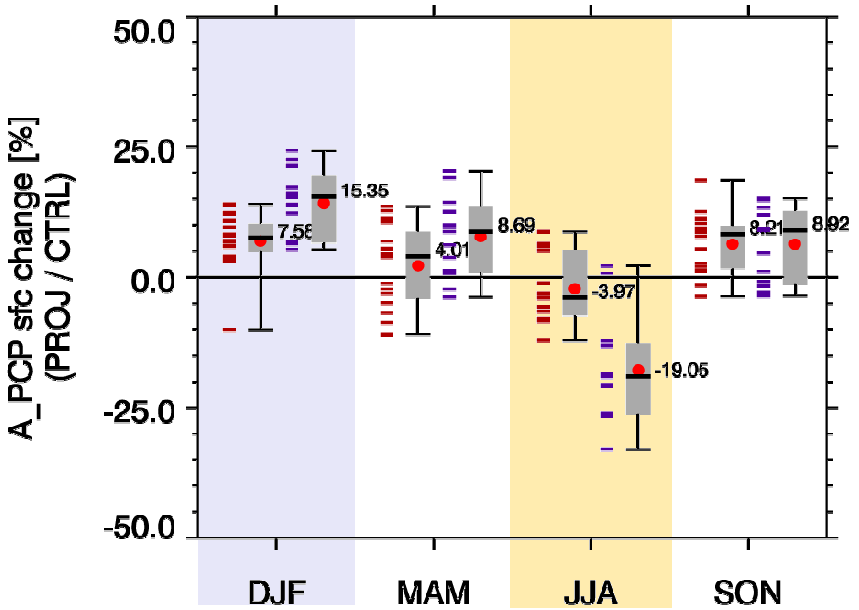
Future hydro-meteorological changes

Mean temperature and precipitation, basin-wide

Air temperature changes, 30-yr seasonal means



Precipitation changes, 30-yr seasonal means

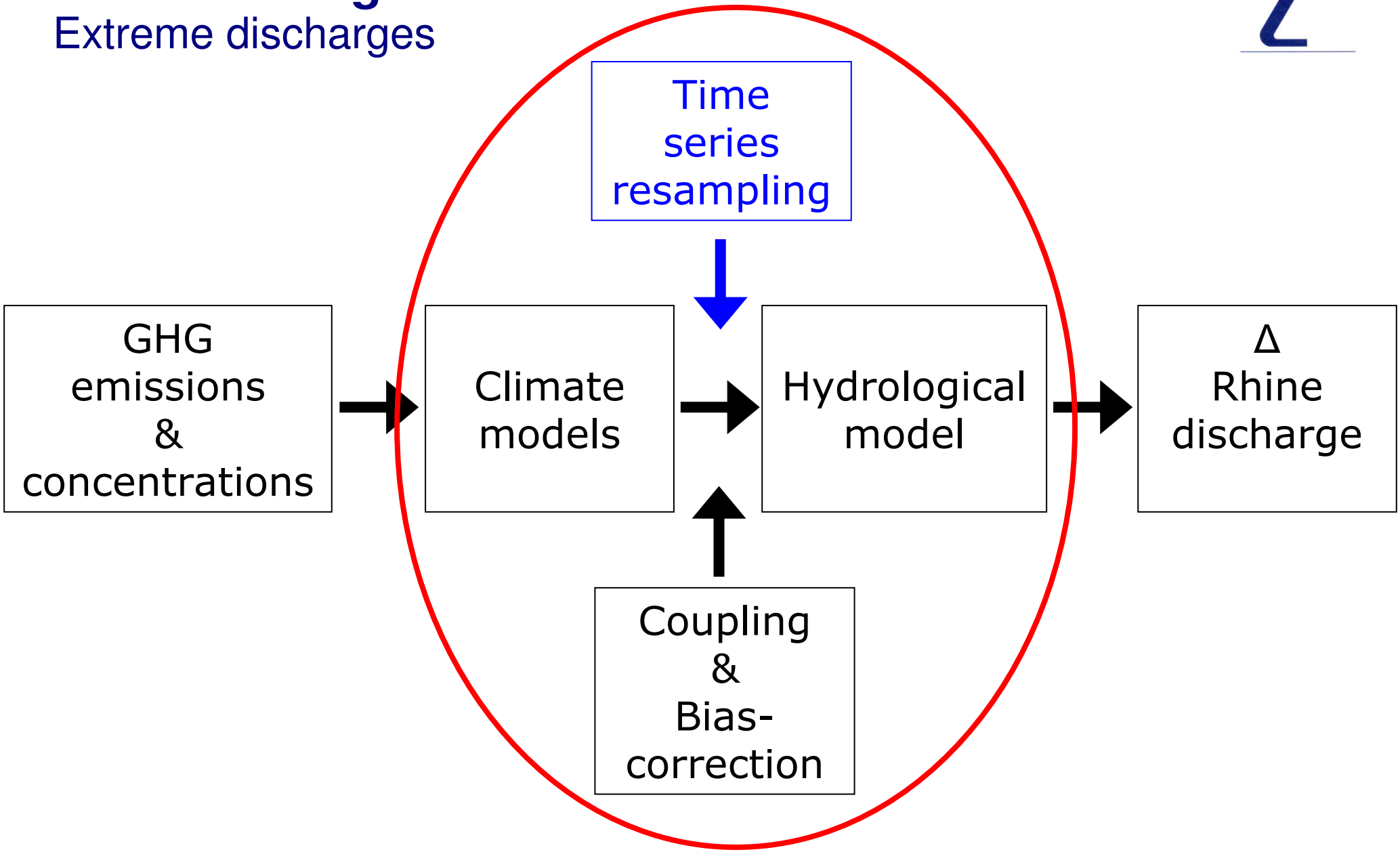


- **DJF: 0.5 °C to 2.5 °C near future; 2.5 °C to 5.0 °C far future**
- **JJA: 0.0 °C to 2.0 °C near future; 2.5 °C to 5.0 °C far future**
- **All seasons: increase of temperature, all spatial domains (slightly higher in South); more clearly defined in winter**

- **DJF: increase of precipitation; 0 - 15% near future; up to 25% far future**
- **JJA: decrease of 10% to 30% far future**
- **MAM/JJA/SON: no clear tendency near future**
- **Spatially uniform in-/decrease in near future; larger heterogeneity in South in far future**

The modeling chain

Extreme discharges



The modelling chain
Extreme discharges

Climate model (GCM-RCM)
30 year time slice

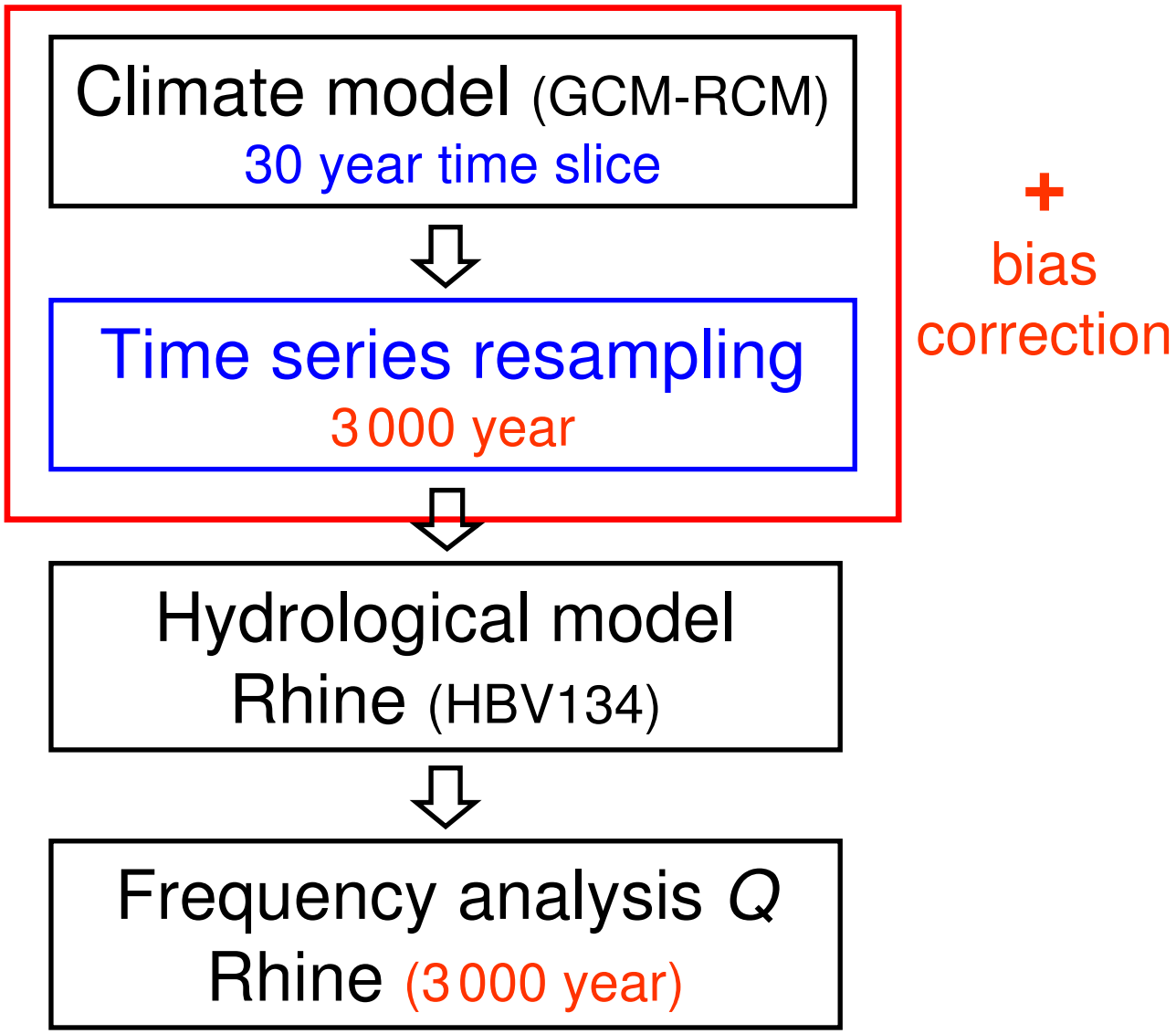
⇩

Hydrological model
Rhine (HBV134)

⇩

Frequency analysis *Q*
Rhine (30 year)

The modelling chain
Extreme discharges



Time series resampling
The principle (1)

Historical/RCM series

5	1	0	2	20	10	0	5	30	0

amount (mm)

Resampling with replacement

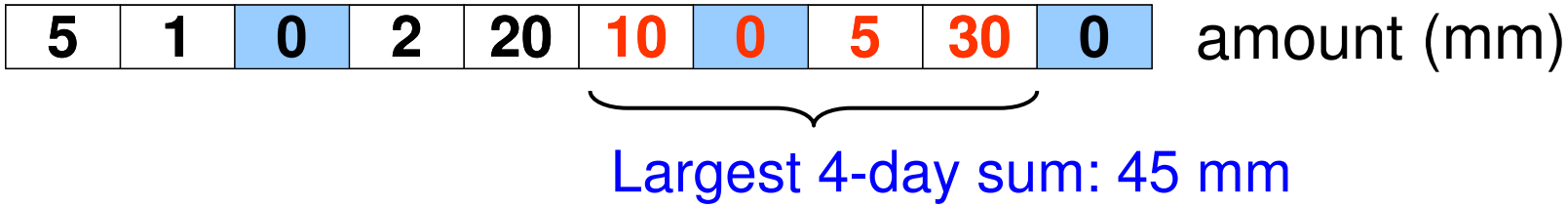
Simulated series

0	5	1	20	10	30	10	0	0	0	...	

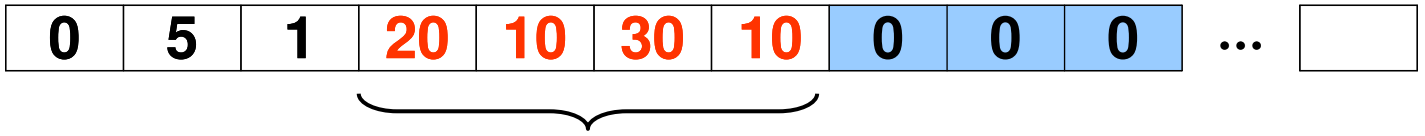
Simulated series
>>
Historical/RCM series

Time series resampling
The principle (2)

Historical/RCM series



Simulated series



Time series resampling
The principle (3)

But…

Resampling *conditional* on the previous day to reproduce ***persistence*** of simulated series:

Nearest-neighbour resampling

Time series resampling
The principle (4)

Historical/RCM series

5	1	0	2	20	10	0	5	30	0

amount (mm)

Nearest-neighbour resampling = *conditional* resampling

Simulated series

0	5	1	20	10	30	10	0	0	0	...	

Time series resampling
Multivariate resampling

Resampling of ***multiple variables simultaneously*** in stead of one single variable:

- Different locations (in an area)
- Different meteorological variables (*Precipitation*, *Temperature*, *Evaporation*)

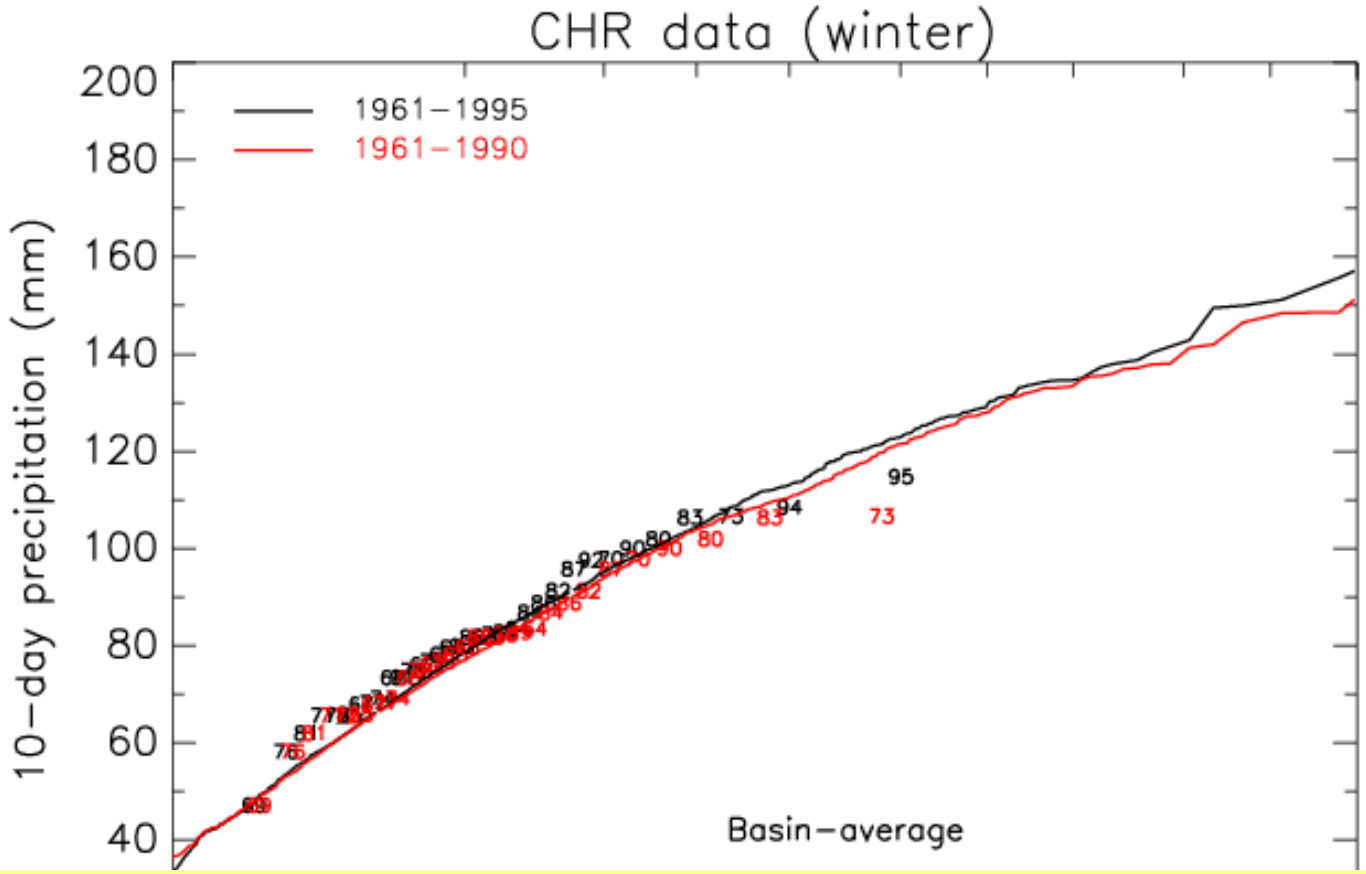
Time series resampling
Resampling of CHR_OBS data

Multivariate application for the Rhine basin:

- Daily *Precip.* and *Temp.* for 134 Rhine sub-basins
- Period: 1961 – 1990
- Period: 1961 – 1995 (full period CHR_OBS data)
- 3000 years simulated

- Annual maxima of 10-day *Precip.* in hydrological winter (Oct-Mar)

Time series resampling
Annual maxima in winter (Oct-Mar)



In conclusion

- Resampling not sensitive to including 1961-1995 which contains the two most extreme historical years
- Most extreme simulated events about 30% larger than historical maximum (basin wide 10-day precip. in hydrological winter)

Bias correction
Objectives

- Bias correction for temperature needed but not very sensitive
- Bias correction for extreme discharges more demanding than for mean discharges
- Bias correction should fulfil the following characteristics:
  1. Bias in mean precipitation effectively corrected
  2. Bias in extreme (multi-day) precipitation effectively corrected
  3. Bias correction should not alter (enhance of reduce) the climate change signal (in the mean and the extremes)
  4. Bias correction should be robust (i.e. work for any climate model, location and time of the year)

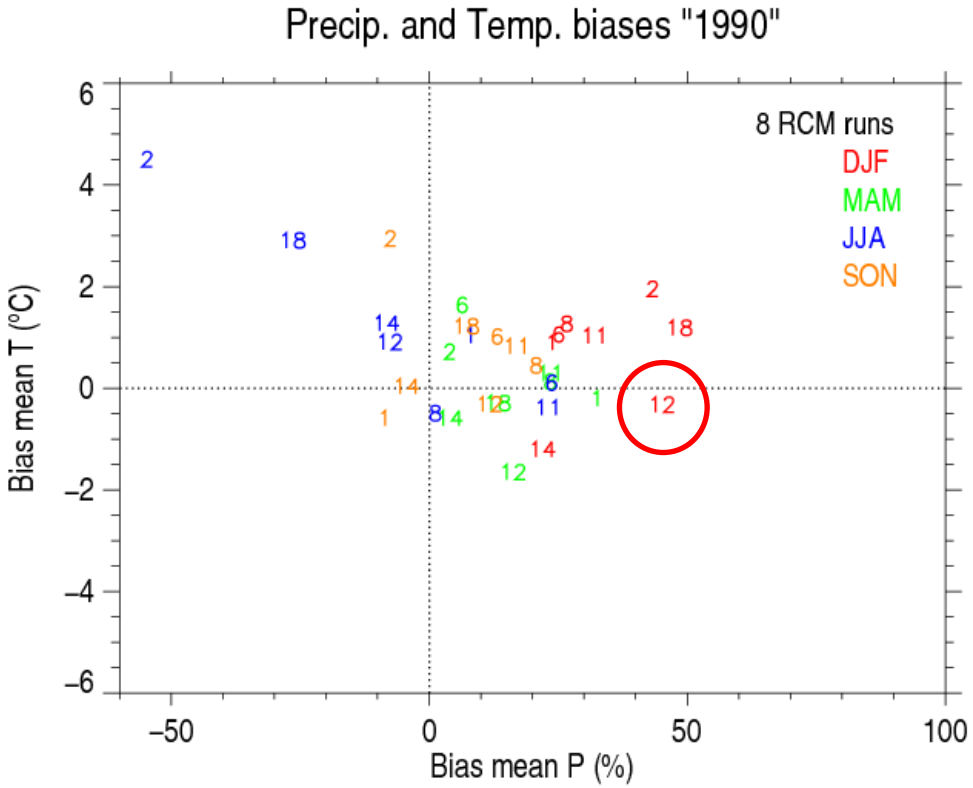
Bias correction

4 available correction methods for precipitation

- Linear correction (LS)
  $P^* = aP$
- 3 Non-linear correction (AS)
  $P^* = aP^b$
- For each subsub-basin (134) and calendar month (12) or
  for each subsub-basin (134) and 5-day intervals per calendar year (73) using a 65-day moving window

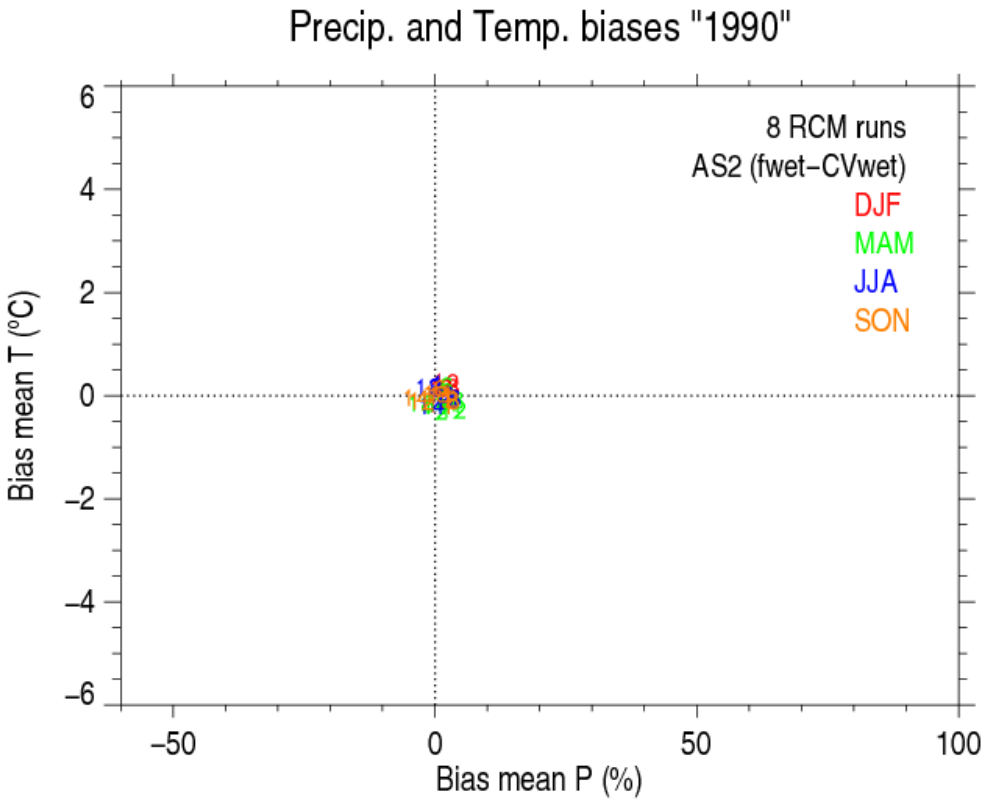
Bias correction

Results for mean precipitation and temperature



Bias T: between -2 and +4˚C

Bias P: between -50 and 50%



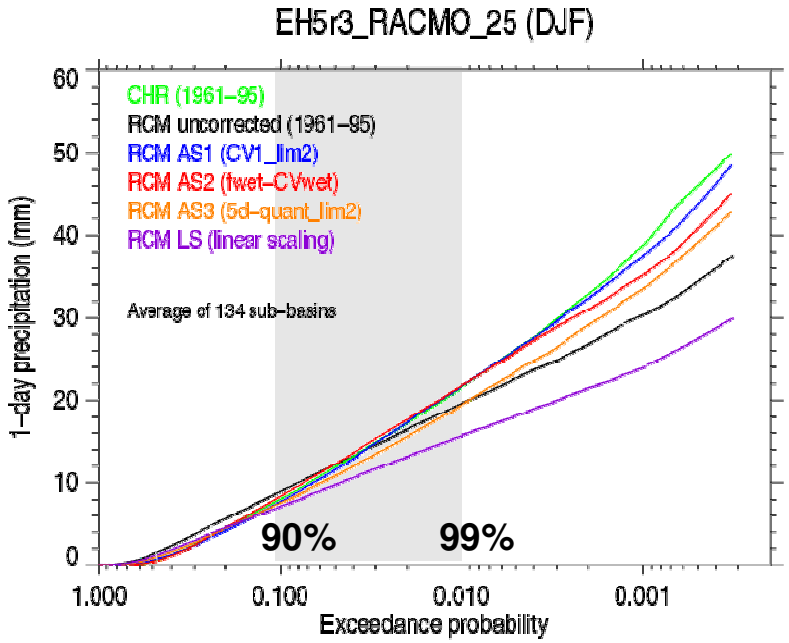
After Figure 3-8 RheinBlick2050 report

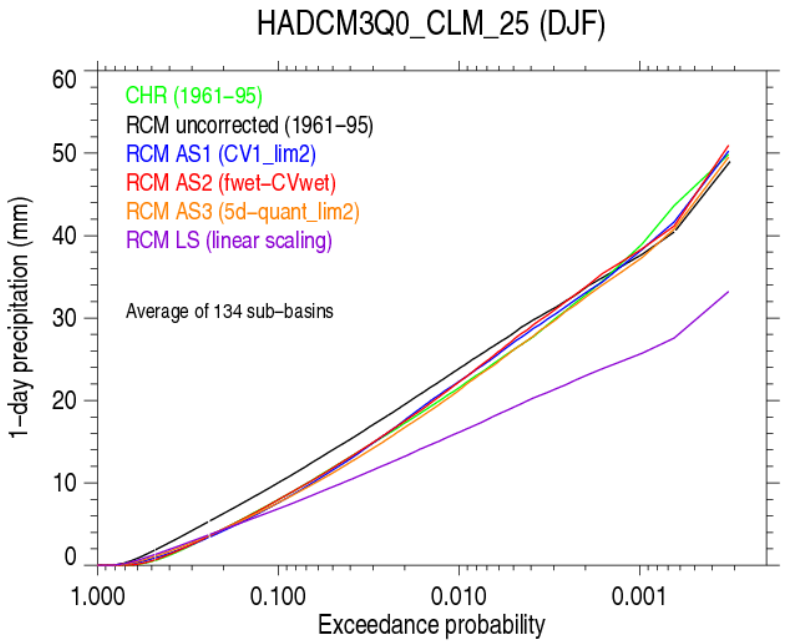
HADCM3Q0_CLM DJF Uncorrected

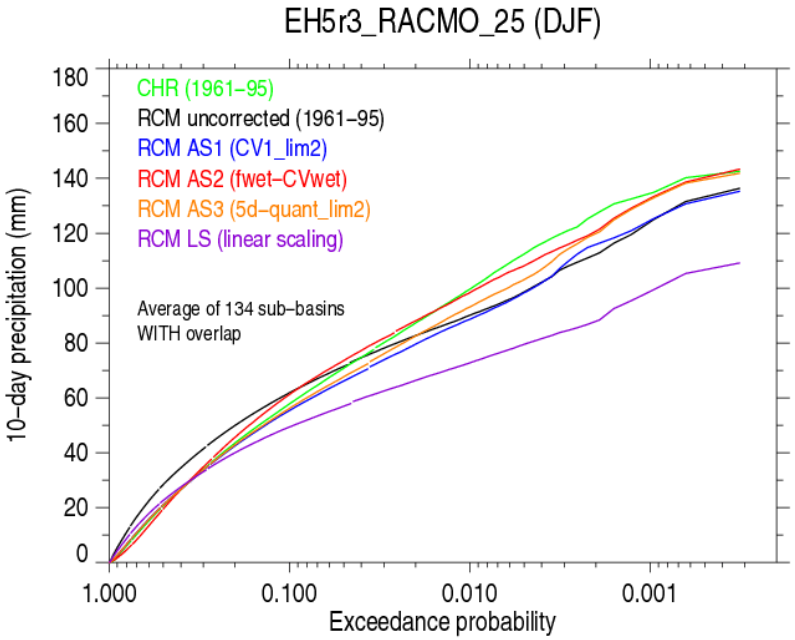
HADCM3Q0_CLM DJF AS1

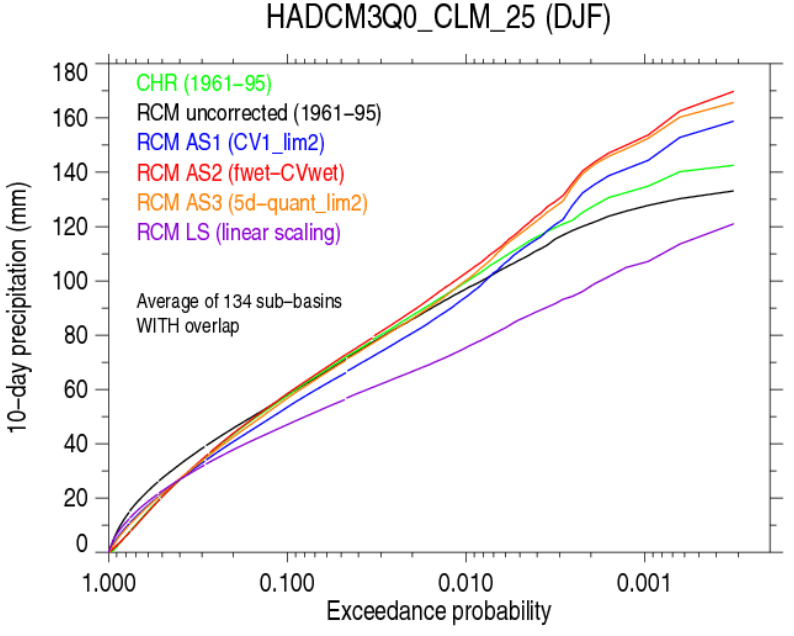
Bias correction

Results for extreme precipitation



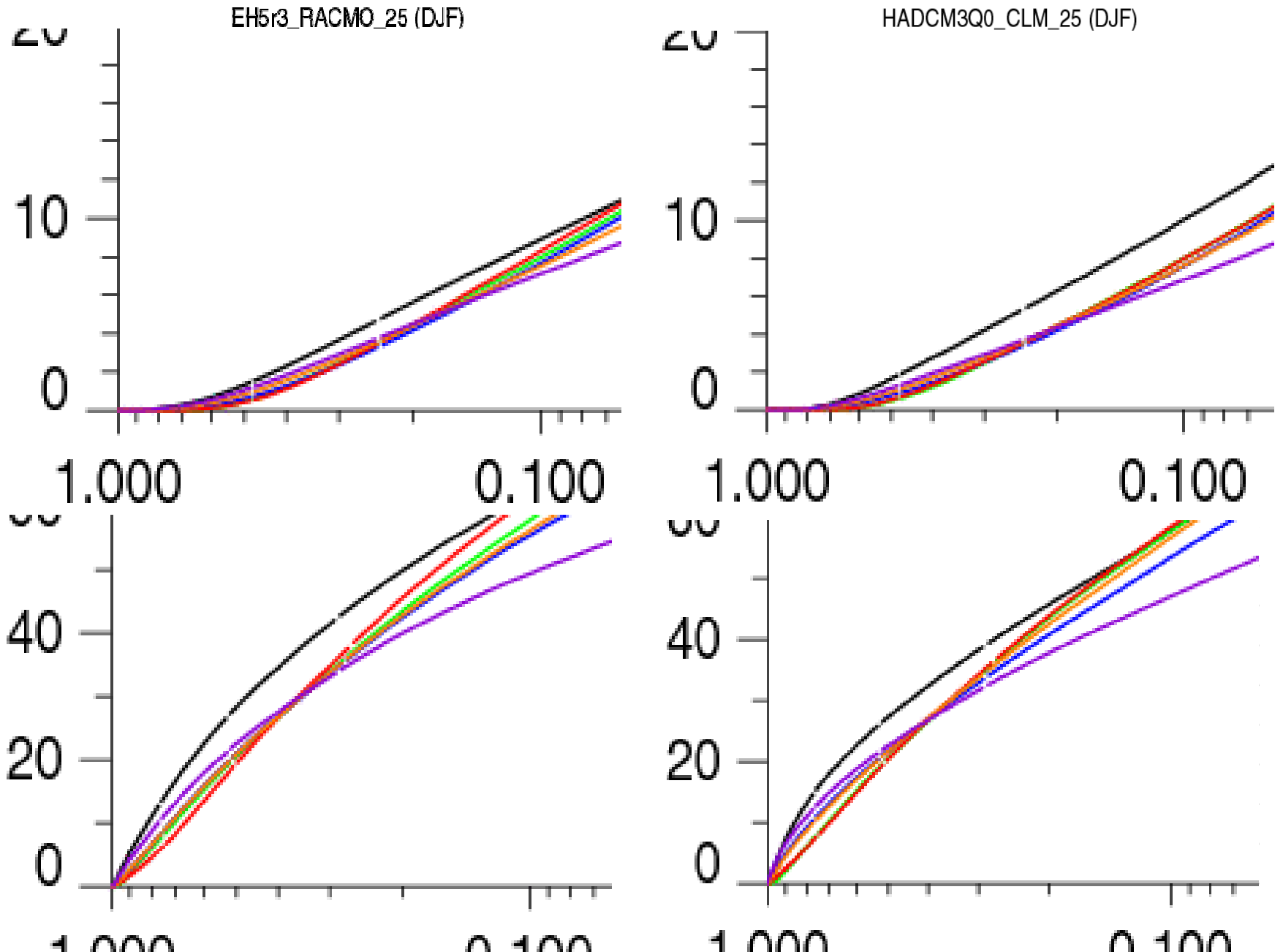






Bias correction

Results for extreme precipitation



Bias correction

Change in 10-yr return level of basin average 10-day precipitation in winter (Oct-Mar)

Change ≡ 2071 to 2100 minus 1961 to 1990

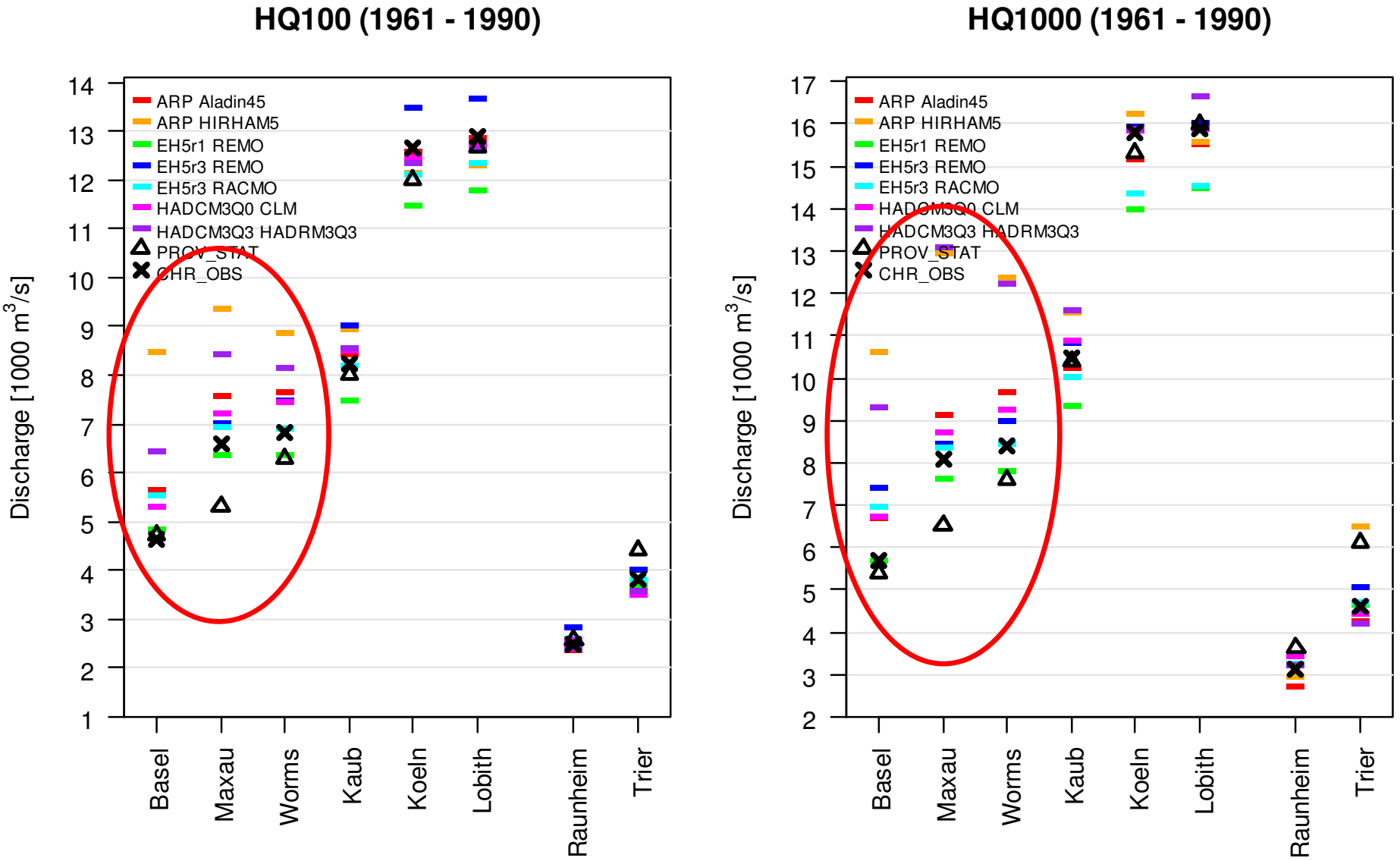
GCM_RCM	ΔP (%)	No bias correction	AS1 CV1_lim2	AS2 f_{wet}_CV_{wet}	AS3 5d-quant_lim2
EH5r3_REMO	13.2	14.5	22.1	18.5	23.8
EH5r3_RACMO	18.9	19.1	27.9	19.9	29.6
HADCM3Q0_CLM	2.8	2.9	6.5	5.5	8.2
HADCM3Q16_HADRM3Q16	4.4	4.2	6.4	4.6	8.4

After Table 3-4 RheinBlick2050 report

In conclusion

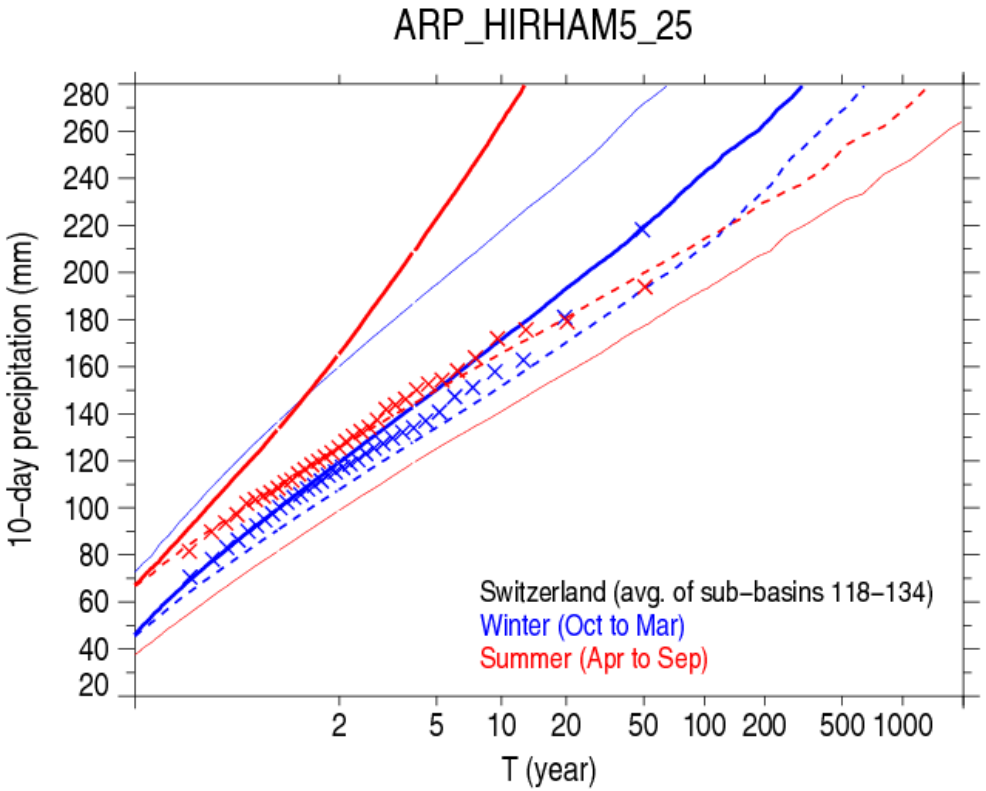
- AS2 is the best non-linear bias correction method for our purpose and therefore applied to the 3000-year resampled RCM series

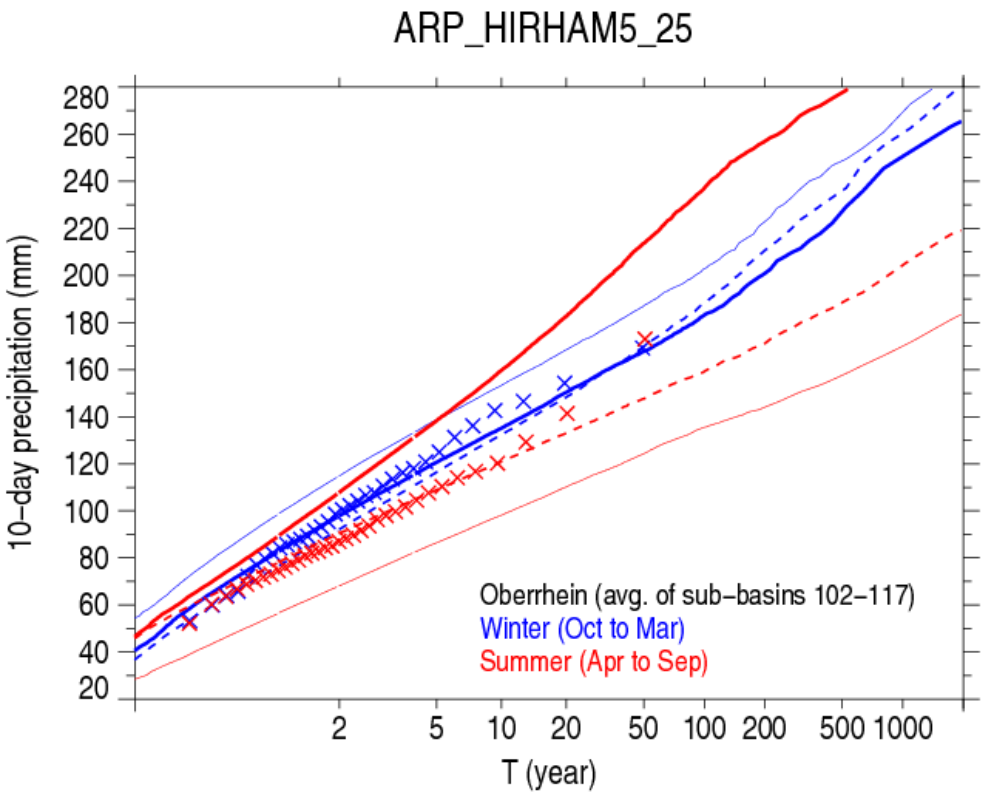
Bias correction
Robustness: a problem



After Figure 3-26 and 3-27 RheinBlick2050 report

Bias correction
Robustness: a problem





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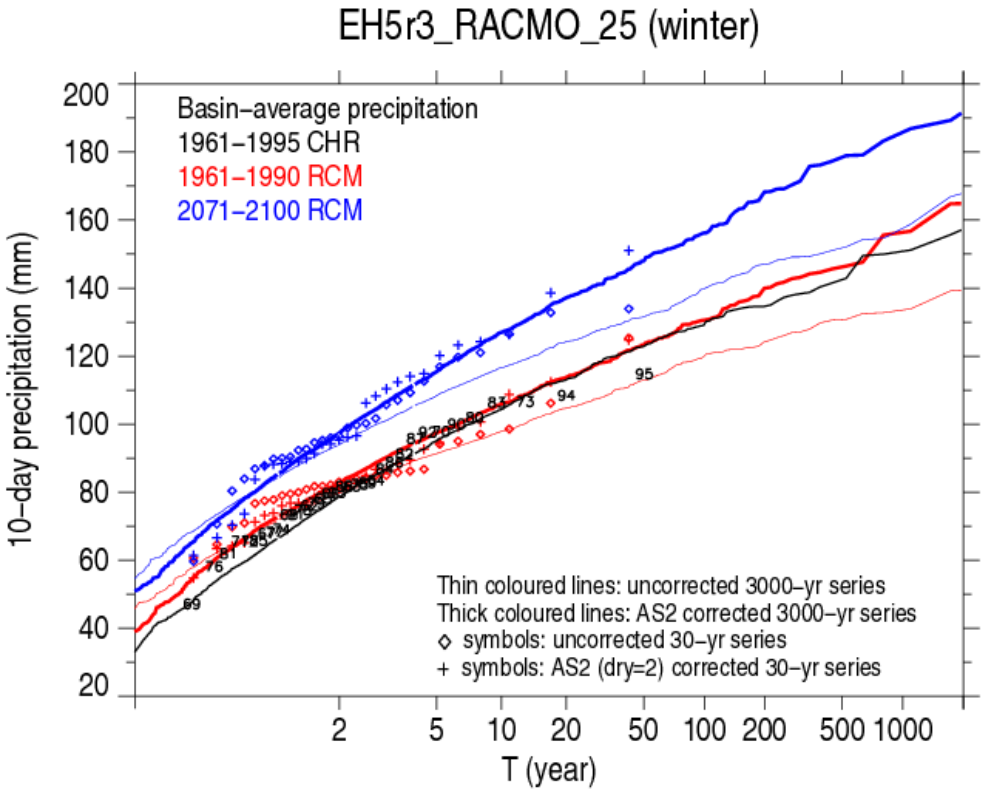
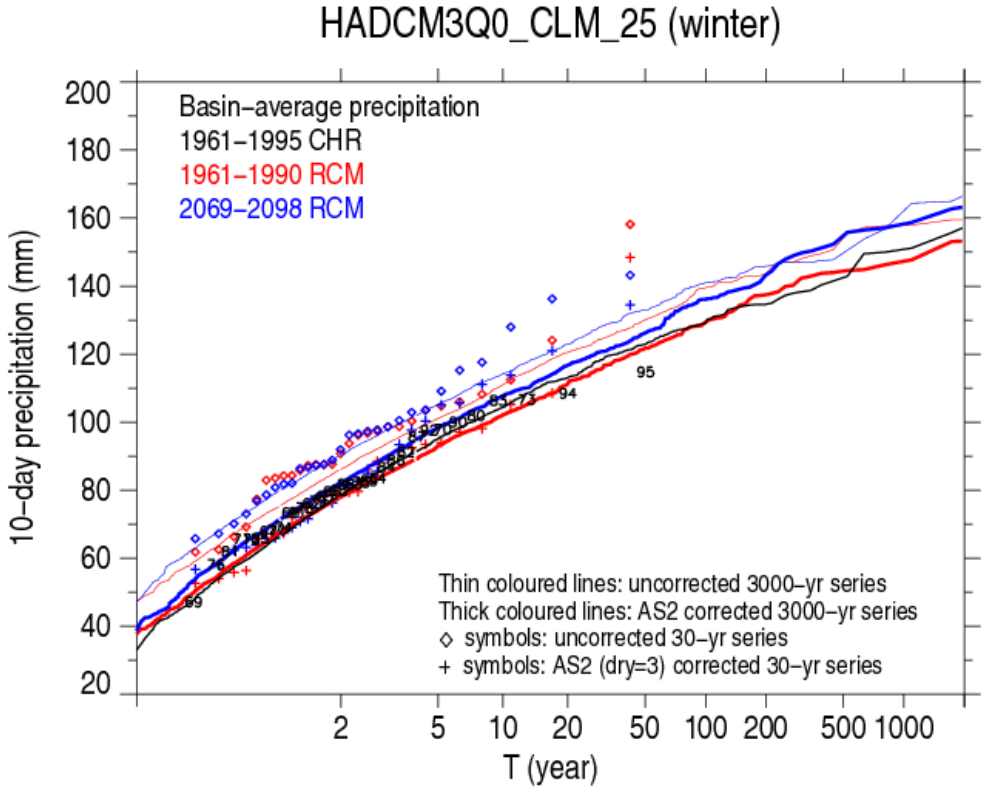
In conclusion

- AS2 bias correction method does not properly work for biases in summer precipitation in Switzerland and Oberrhein area
- Limited confidence in high flow projections for Basel, Maxau and Worms

Bias correction
combined with time series resampling





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In conclusion

- Resampled and bias corrected RCM series (for control climate) correspond well resampled CHR_OBS series
- The climate change signal in the bias corrected RCM series is comparable to that in the uncorrected series

Summary and conclusions

- In the GCM_RCM ensemble there is a distinct climate change signal in mean temperature and precipitation in particular for the far future
- Time series resampling seems to work satisfactorily both for CHR_OBS and GCM_RCM series
- AS2 bias correction best preserves climate change signal of extreme multi-day precipitation quantiles
- However, AS2 bias correction fails to correct for biases in summer precipitation in Switserland and the Oberrhein area
- Therefore, limited confidence in high flow projections for Basel, Maxau and Worms and no conclusions drawn for these stations (in Chapter 7)
- Bias correction (in particular for HQx) needs further attention and remains a subject for further research.