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Changes in the discharge regimes of the Rhine River during the 21st century. Projections and scenarios of mean and low flow

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Changes in the discharge regimes of the Rhine River during the 21st century. Projections and scenarios of mean and low flow

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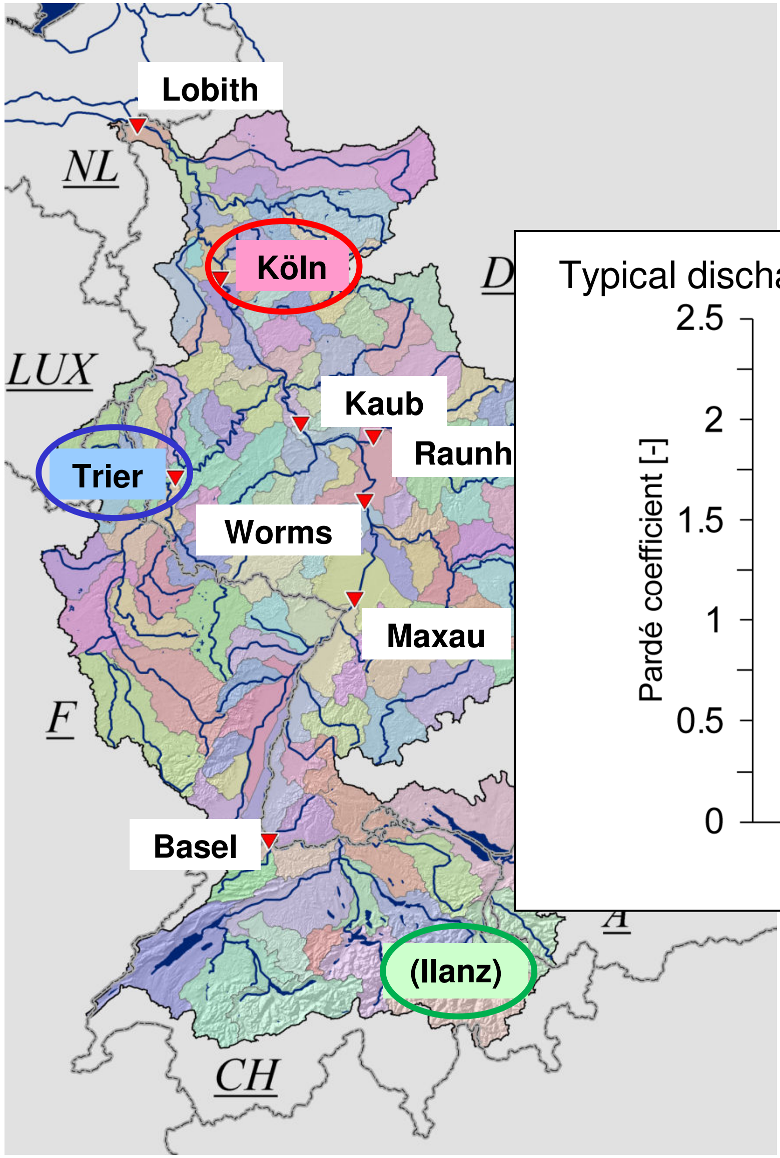
KLIWAS
Climate · Water · Navigation

Federal Ministry
of Transport, Building
and Urban Affairs

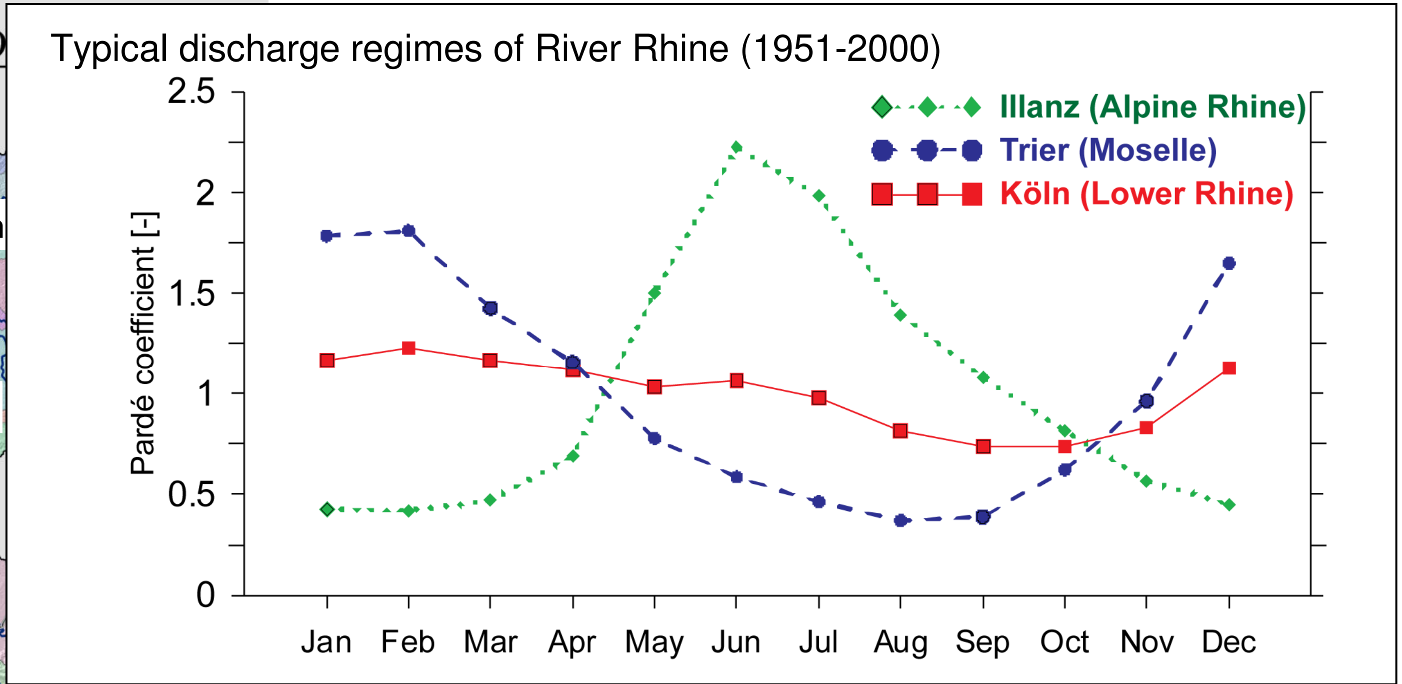
Structure of the presentation

1. Description of current discharge regimes (section 1.3)
2. Selection of model chains (section 3.1)
3. Validation of simulations (section 3.4)
4. Projections and scenarios of mean and low flow (chapters 5 and 6)
5. Summary and conclusions

Description of current discharge regimes (section 1.3)



Definition **discharge regime**: "Overall behavior of river runoff with regard to the multi-annual average seasonal cycle, and the characteristic developments of the extreme high and low water situations."

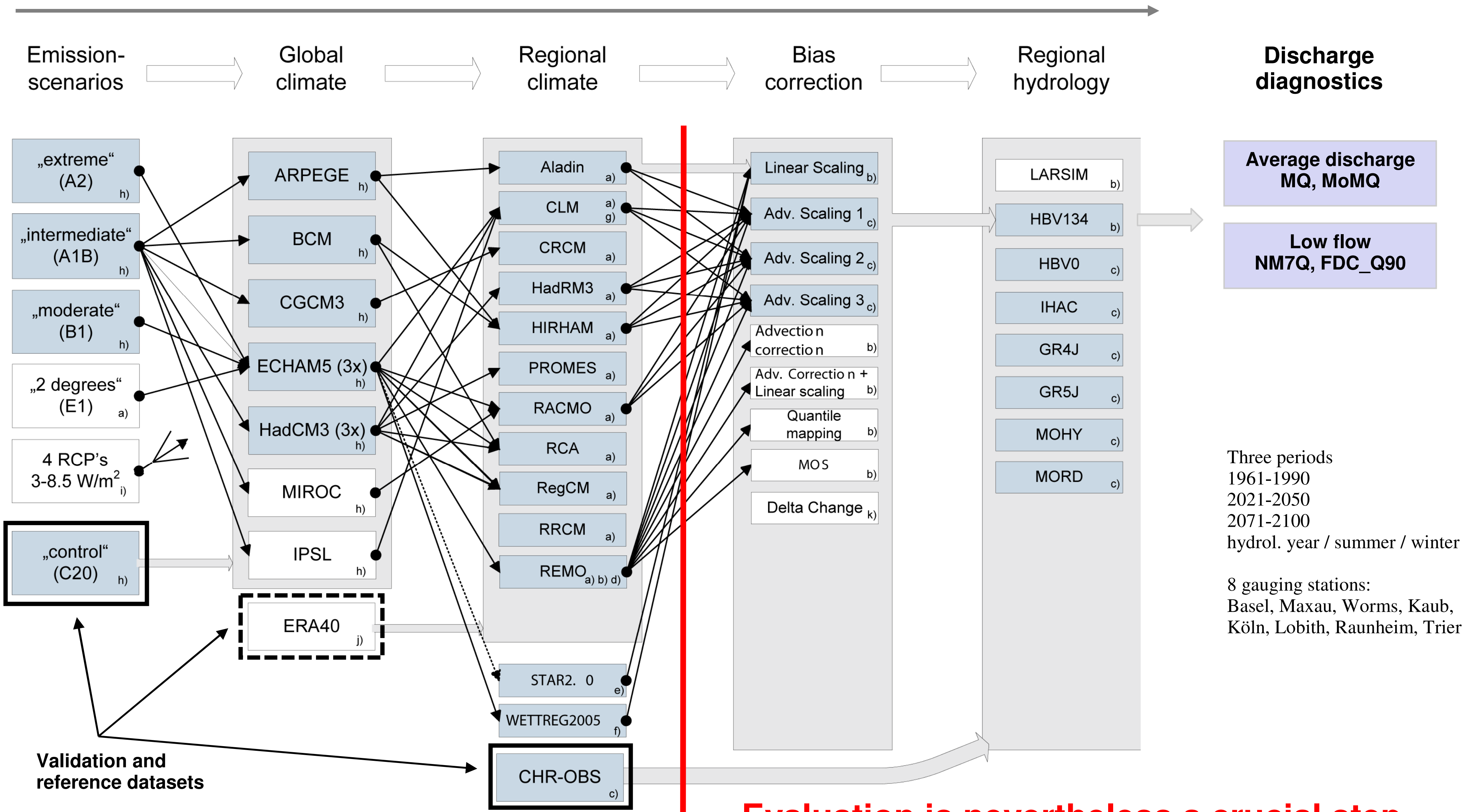


- Nival (Alps; e.g. Ilanz)
- Pluvial (Mid-mountain ranges; e.g. Trier)
- “Combined” (e.g. Köln)

Selection of model chains (section 3.1)

Selection of model chains (section 3.1)

Multi-Model approach is a key concept for uncertainty assessment.



Evaluation is nevertheless a crucial step.

Selection of model chains (section 3.1)

Chapter	Set	Presence	Near future	Far future
Section 2.1.3 (inventory) Section 3.2 (evaluation)	**Total runs**	**26**	**37**	**31**
	Couplings	16	22	16
	GHG-Forcing	1	3	3
	GCM	5	5	5
	RCM	11	11	7
	sRDS	1	2	1
	BC	0	0	0

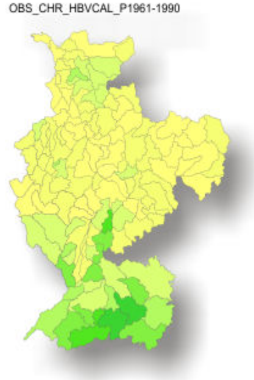
Step 1: Spatial structure Annual means → Step 2: Temporal structure Monthly statistics → Step 3: Outlier identification → Step 4: Selection of model chains

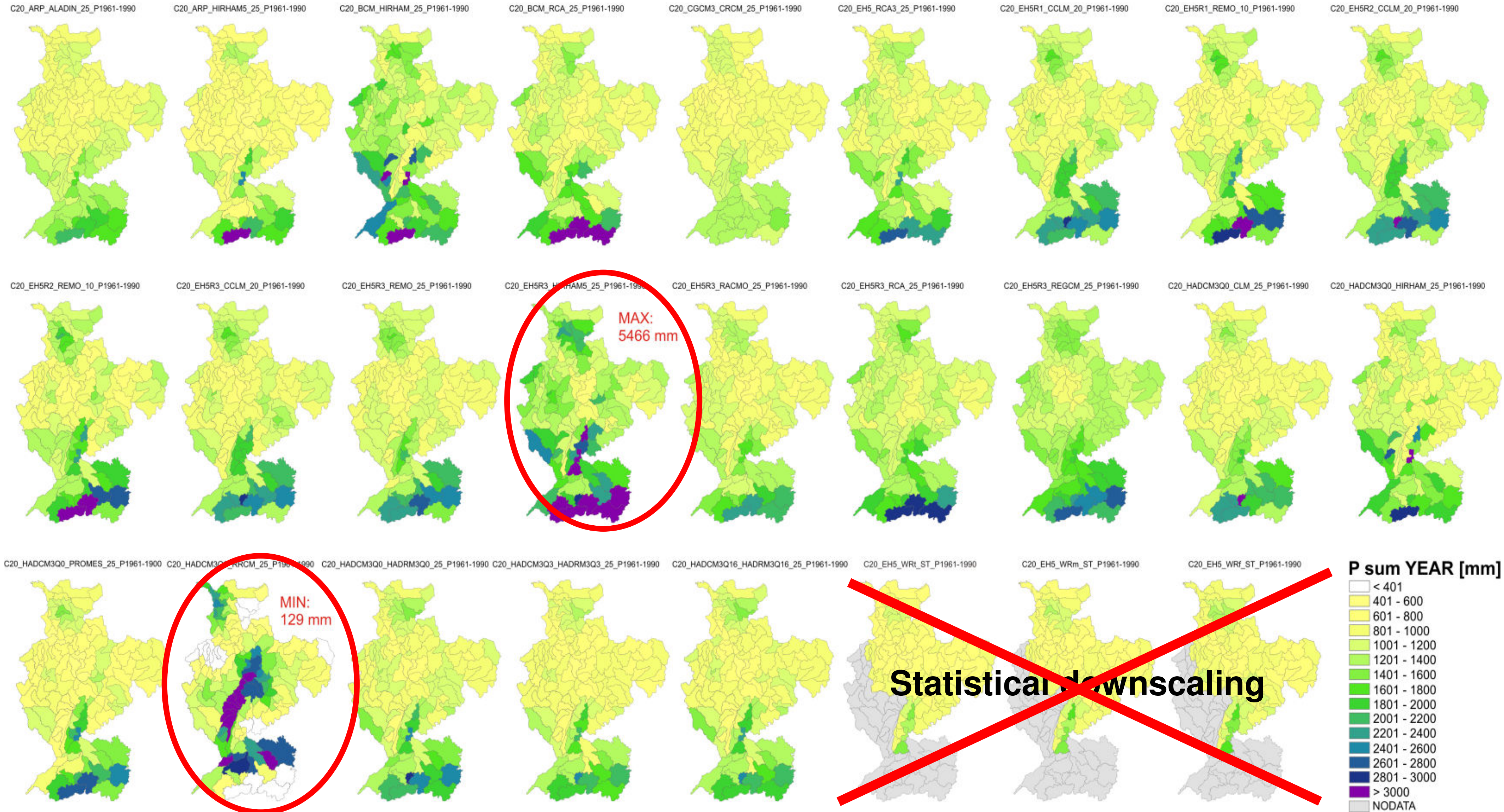
Selection of model chains: Spatial structure

Mean annual Precipitation

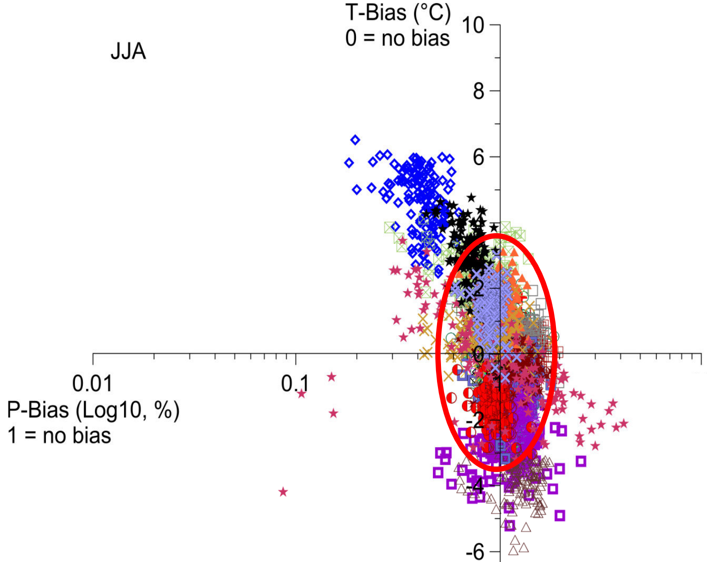
Unit: mm
26 **control simulations**
Period: 1961-1990
134 Subbasins of River Rhine (HBV)
GCM-Forcing: C20
No bias correction

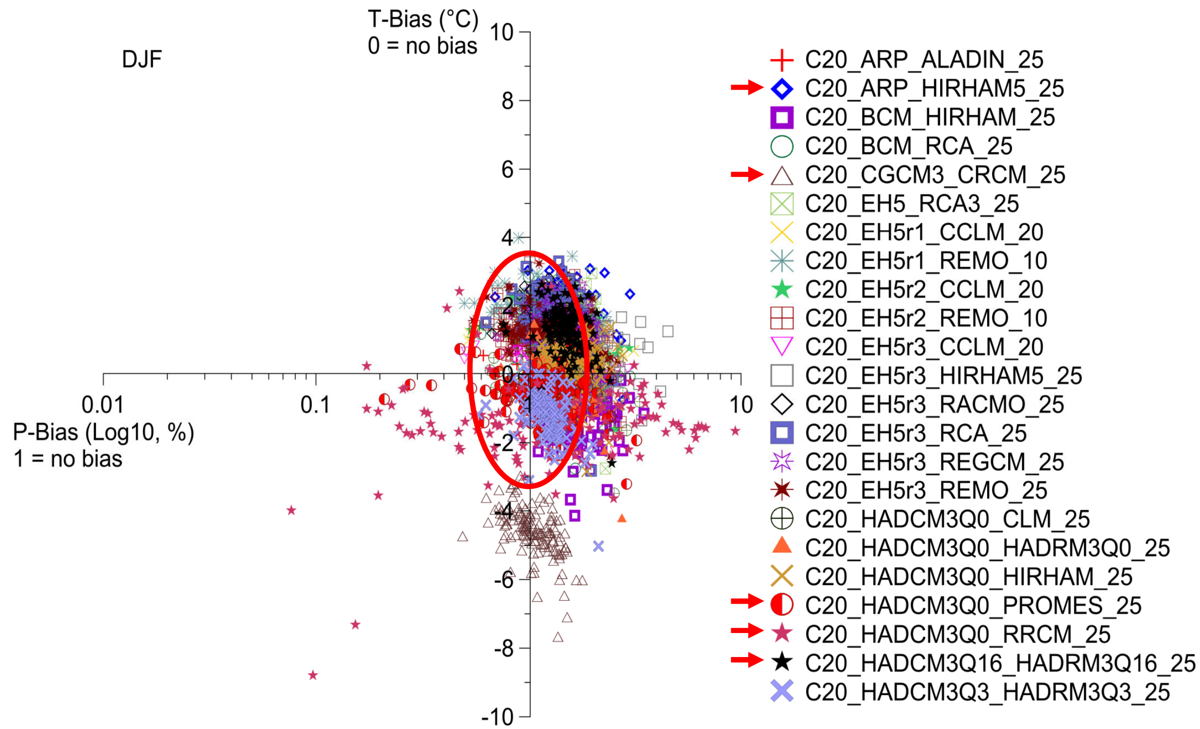
Reference:





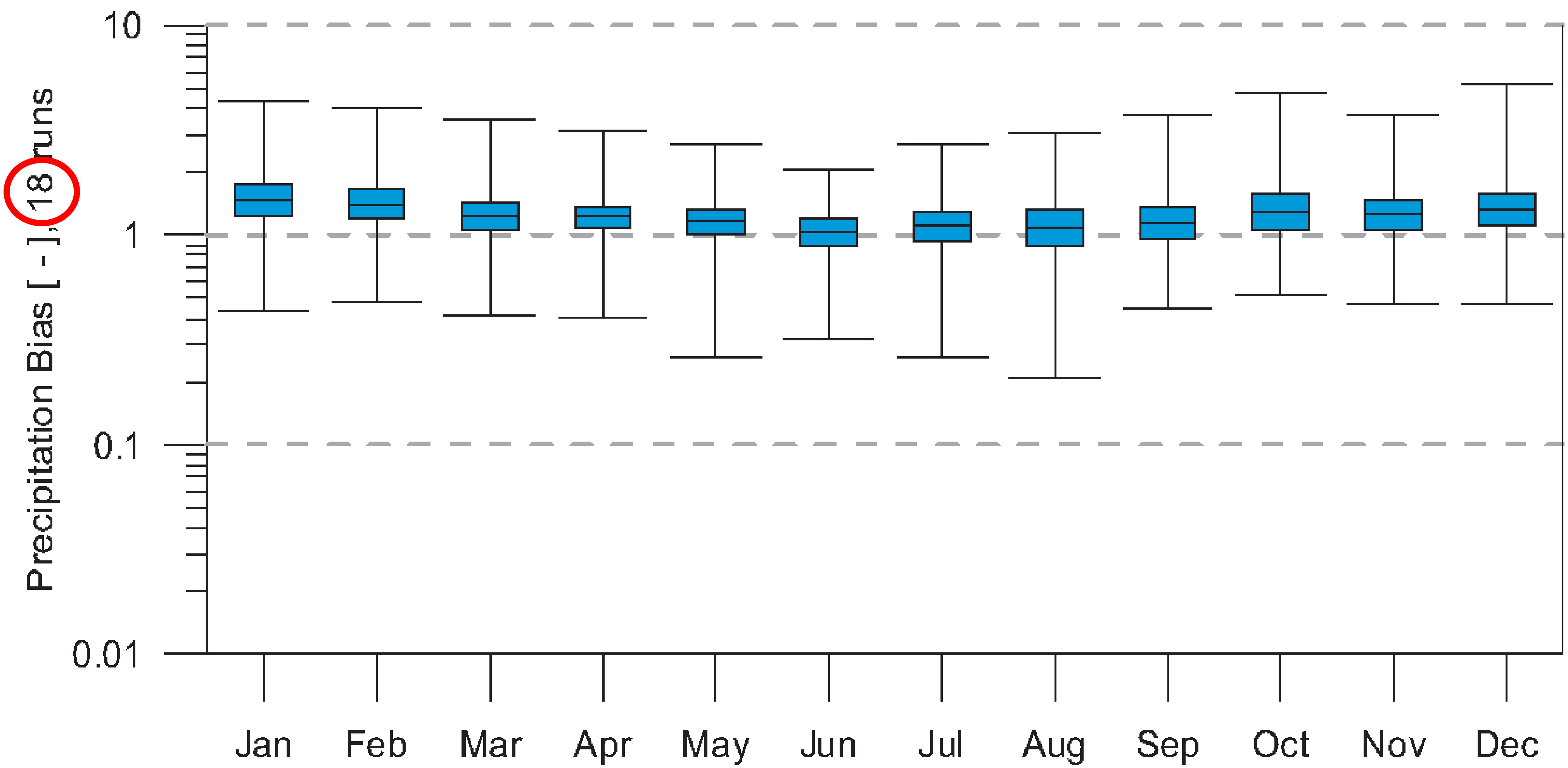
Selection of model chains: Outlier identification (section 3.1)





Mean seasonal bias of temperature and precipitation for 134 Subcatchments of River Rhine based on 23 RCM runs.
Reference data: CHR_OBS
Evaluaton period: 1961-1990

Selection of model chains (section 3.1)



Selection of model chains (section 3.1)

Step 1: Spatial structure Annual means → Step 2: Temporal structure Monthly statistics → Step 3: Outlier identification → Step 4: Selection of model chains

Chapter	Set	Presence	Near future	Far future
Chapter 5 (mean flow)	**Total runs**	**18**	**20**	**17**
	Different Couplings	13	16	13
	GHG-Forcing	1	3	3
	GCM	4	4	2
	RCM	8	8	7
	sRDS	0	0	0
	BC	1	1	1
Chapter 6 (low flow)	**Total runs**	**18**	**20**	**17**
	Different Couplings	13	16	13
	GHG-Forcing	1	3	3
	GCM	4	4	2
	RCM	8	8	7
				0
				1

→ Step 5: Bias correction: Linear Scaling → Step 6: Hydrological modelling: HBV134 → Step 7: Diagnostics: MQ, MoMQ, NM7Q, FDC_Q90

Selection of model chains
(section 3.1)

Conclusions (1)

→ Not all climate model runs are suitable for this study.

- Incomplete spatial coverage prohibits from using current statistical downscaling approaches.
- 5 runs show extreme biases in relevant hydrometeorological fields.

→ Skipping the most biased members from the ensemble leads to a reduction of the overall bias by half.

→ For the remaining runs bias correction is still necessary.

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Validation of simulations (section 3.4)

Validation of simulations (section 3.4)

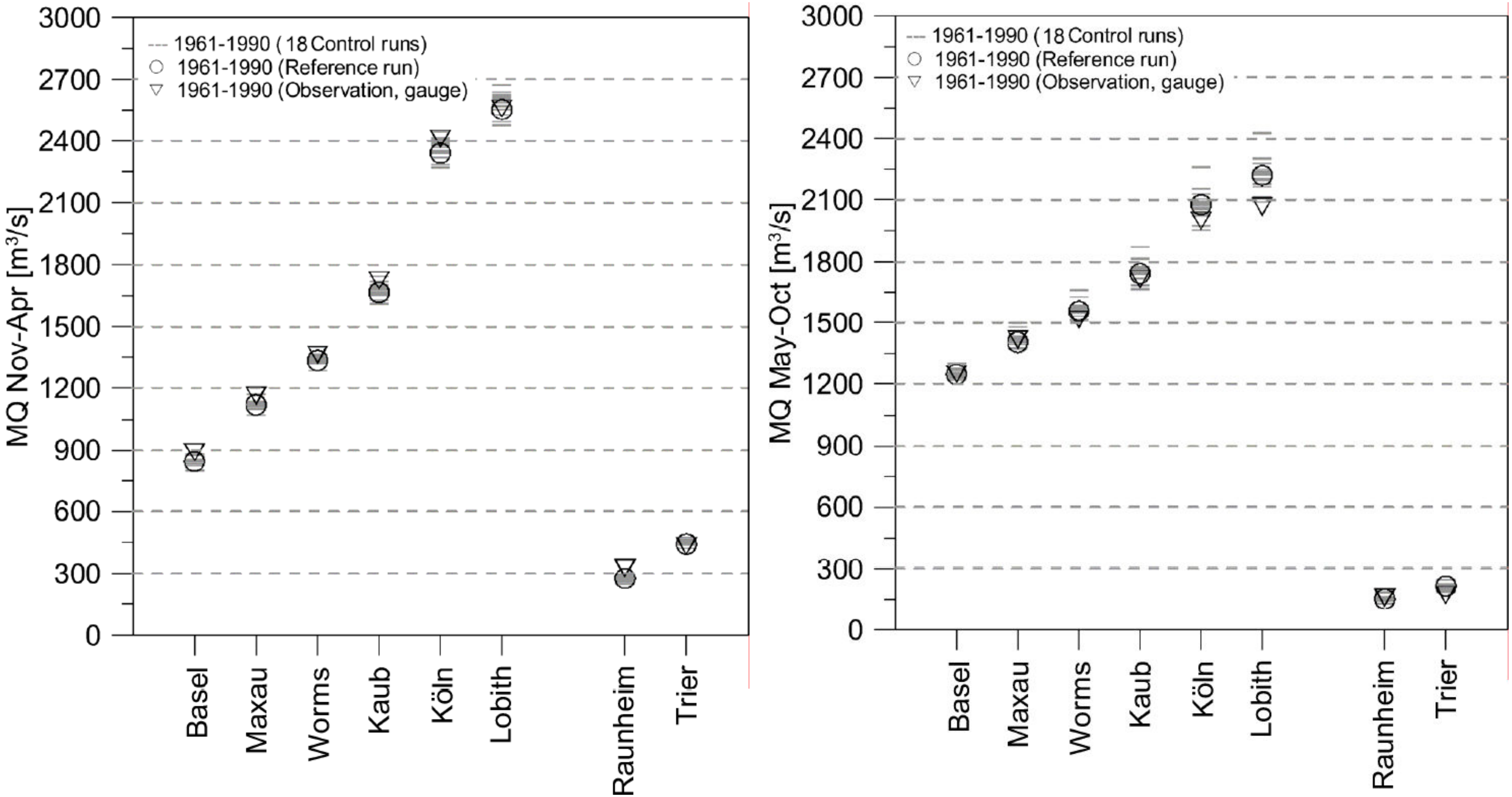
1. Validation of the hydrological model

   → comparison of observed discharges and reference simulations (i.e. HBV134 simulations driven by observed hydrometeorological data)

2. Validation of the full model chain

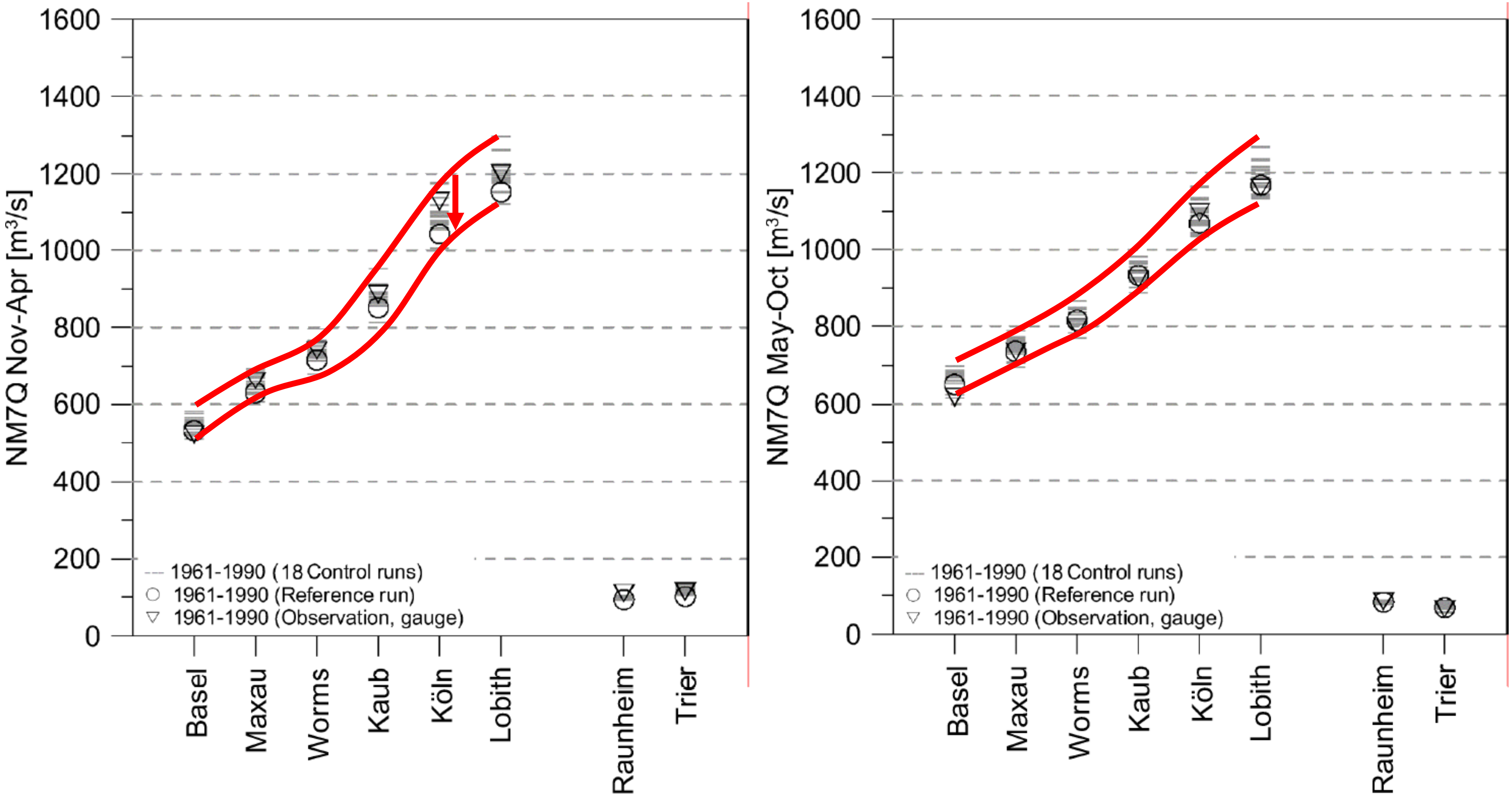
   → comparison of observed discharges and control simulations (i.e. HBV134 simulations driven by RCM data of 20th century)

Validation of simulations (section 3.4): MQ (Multi-annual mean seasonal discharge)



Hydrological Model: HBV134_BFG
Model chains: C20_*GCM_RCM*_EPW_LS_HBV134_MQ

Validation of simulations (section 3.4): NM7Q (Multi-annual mean of lowest 7 day mean discharge per season)



Hydrological Model: HBV134_BFG
Model chains: C20_*GCM_RCM*_EPW_LS_HBV134_NM7Q

Validation of simulations (section 3.4)

Conclusions (2)

→ Hydrological model (HBV134_BFG)

- reasonable results for multi-annual means of mean and low flow (MQ, NM7Q)
- small underestimation of Winter low flow (NM7Q) and FDC_Q90 (not shown)

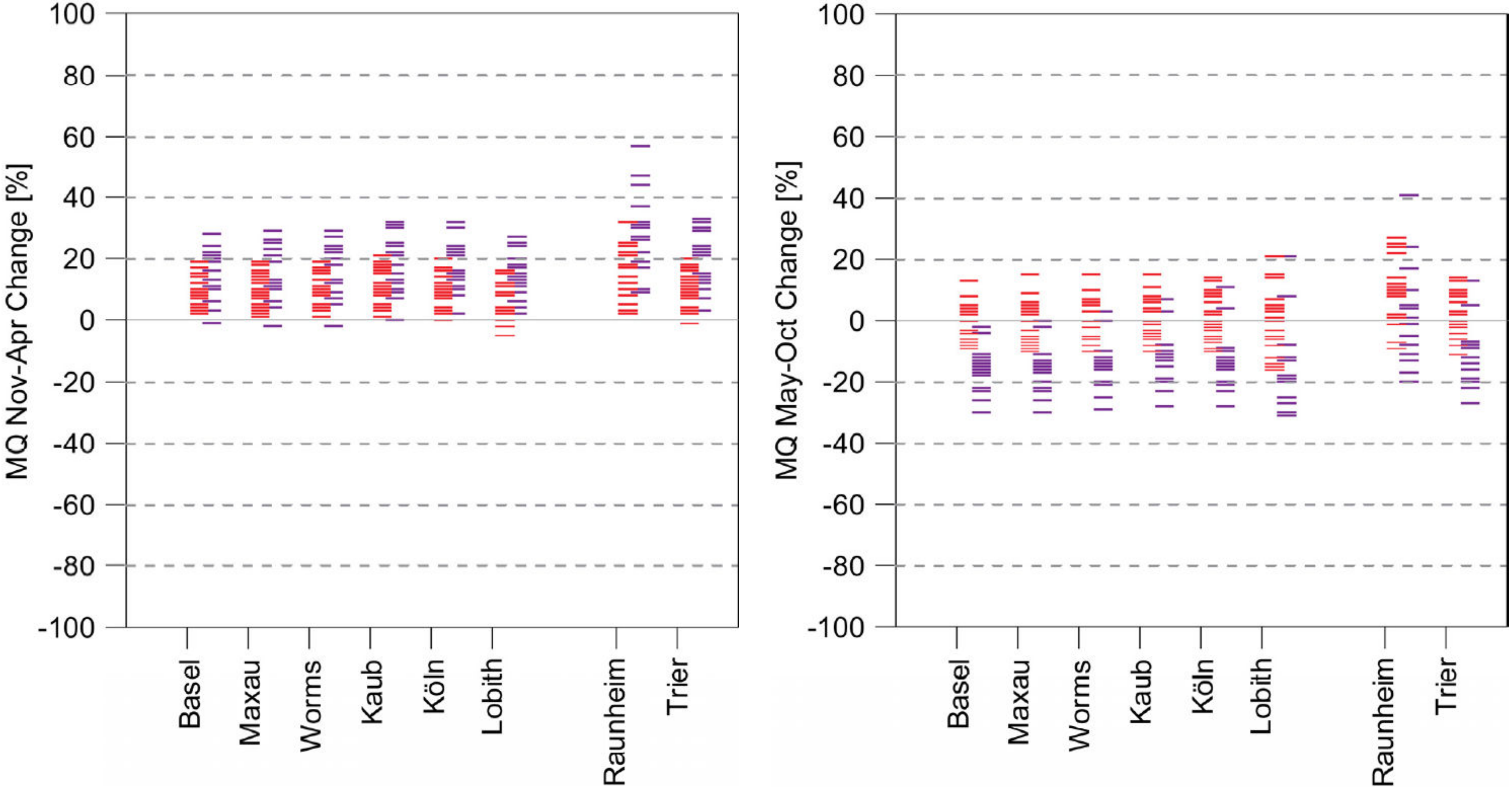
→ Full model chain (C20_*GCM_RCM*_EPW_LS_HBV134)

- reasonable results for multi-annual means of mean and low flow
- spread of low flow estimates increases slightly downstream of gauge Kaub

Projections and scenarios of mean and low flow (chapters 5 and 6)

Definition of scenarios from an ensemble of projections (section 2.5)

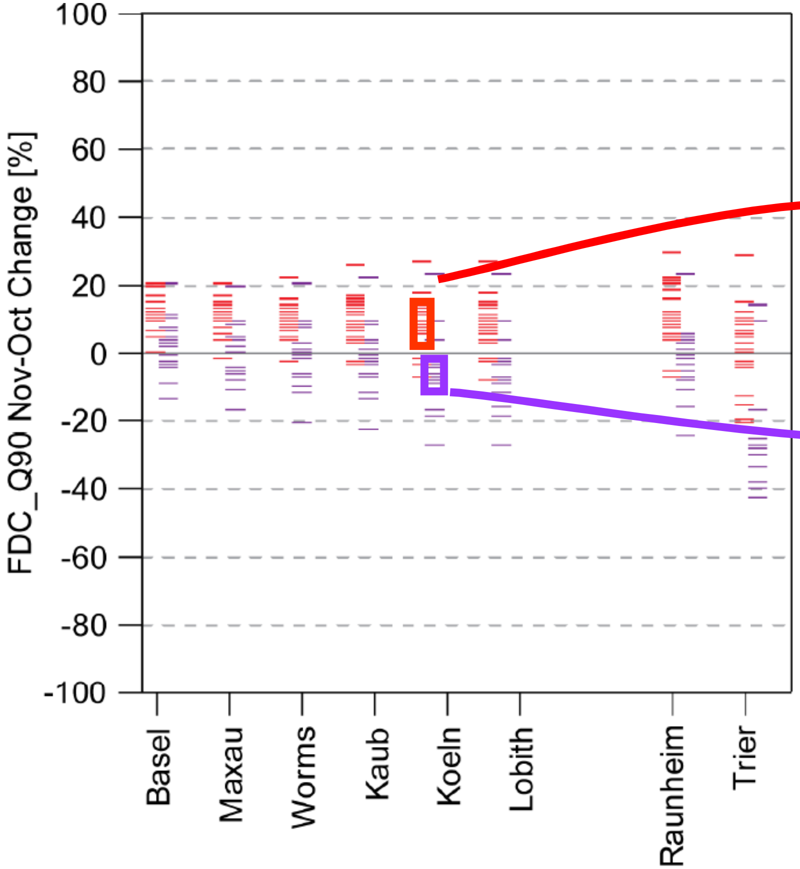
→ Large bandwidth, but clusters



— change in near future (2021 to 2050) based on 20 projections
— change in far future (2071 to 2100) based on 17 projections
with respect to control period (1961-1990)

Definition of scenarios from ensemble of projections (section 2.5)

- 80% of ensemble members point into same direction:
  Tendency: direction of change [increase / no tendency / decrease],
- Span as defined by 80% of ensemble members:
  Bandwidth: span of projections [%]



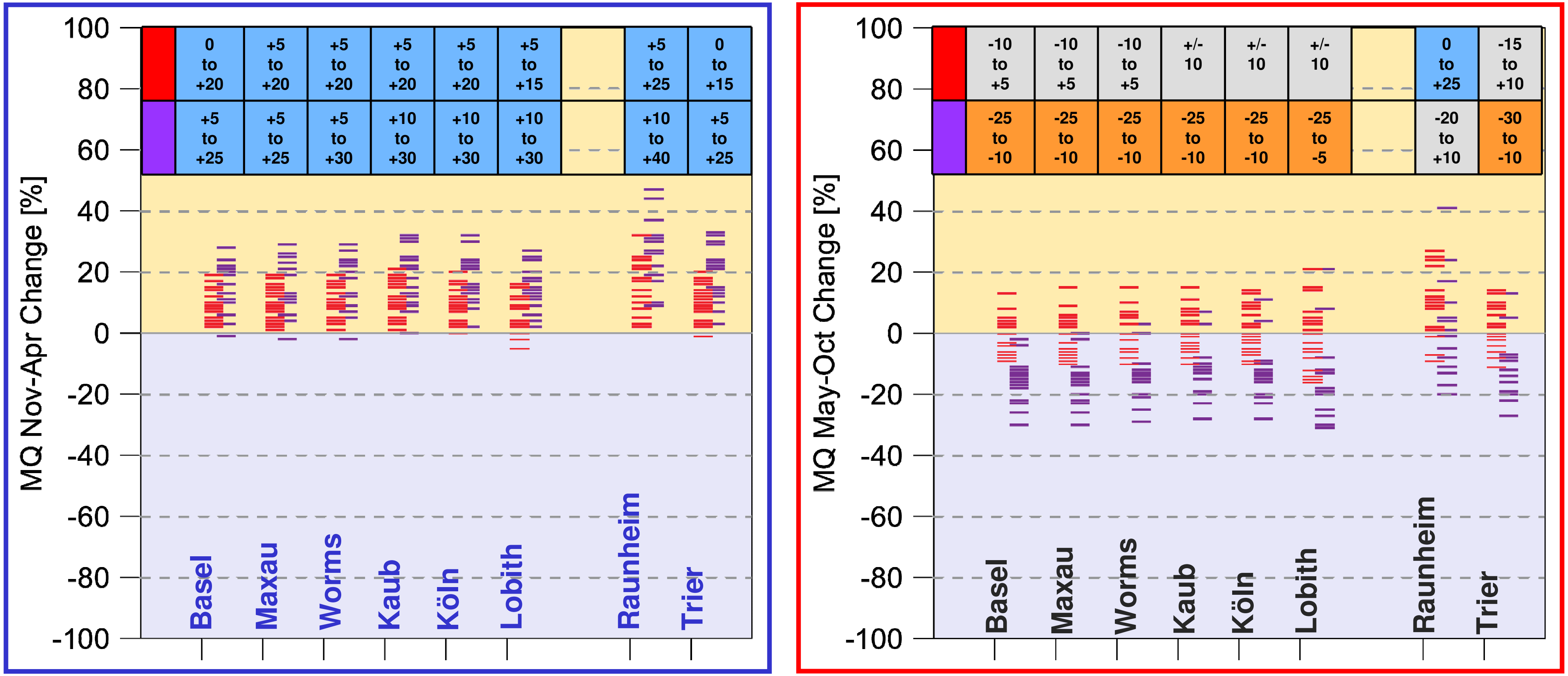
Gauging station	2021 to 2050	2071 to 2100
Basel	+5 to +15%	-5 to +15%
Maxau	+5 to +15%	+/-10
Worms	+5 to +15%	+/-10
Kaub	+5 to +15%	-10 to +5%
Köln	+5 to +15%	-10 to 0%
Lobith	+5 to +15%	-20 to 0%
Raunheim	+5 to +25%	+/-10
Trier	-5 to +15%	-40 to -25%

- full information is retained
- transparent

FDC_Q90: 90th percentile of flow duration curve / discharge value undershot at 10% of days in time-span

Projections and scenarios of **mean flow** (chapter 5)

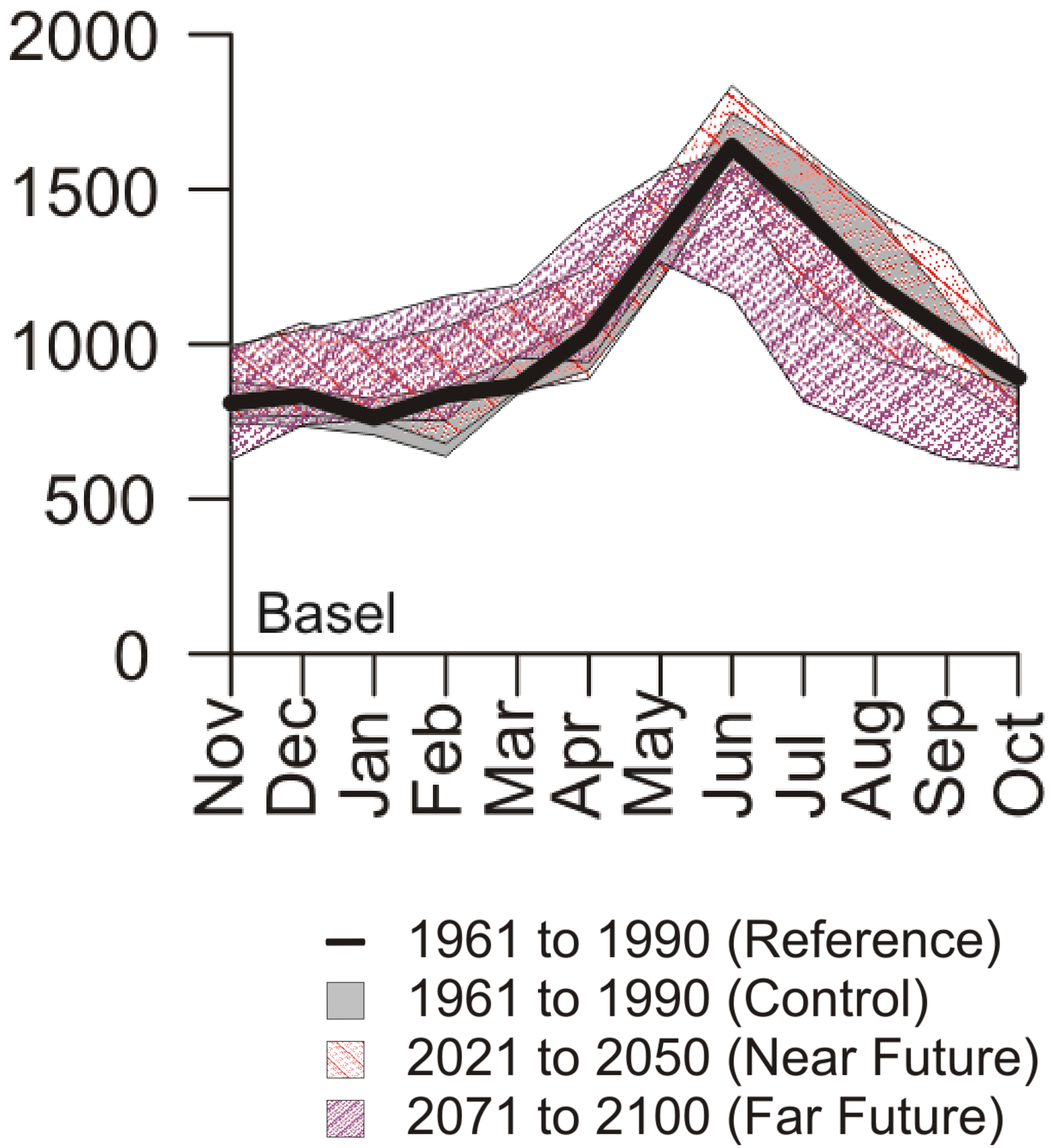
MQ (Multi-annual mean seasonal discharge)



- Winter: increase of mean discharge: near future (0% to +25%), far future (+5% to +40%)
- Summer: no tendency in near future; decrease of 5% to 30% in far future

— change in near future (2021 to 2050) based on 20 projections
— change in far future (2071 to 2100) based on 17 projections
with respect to control period (1961-1990)

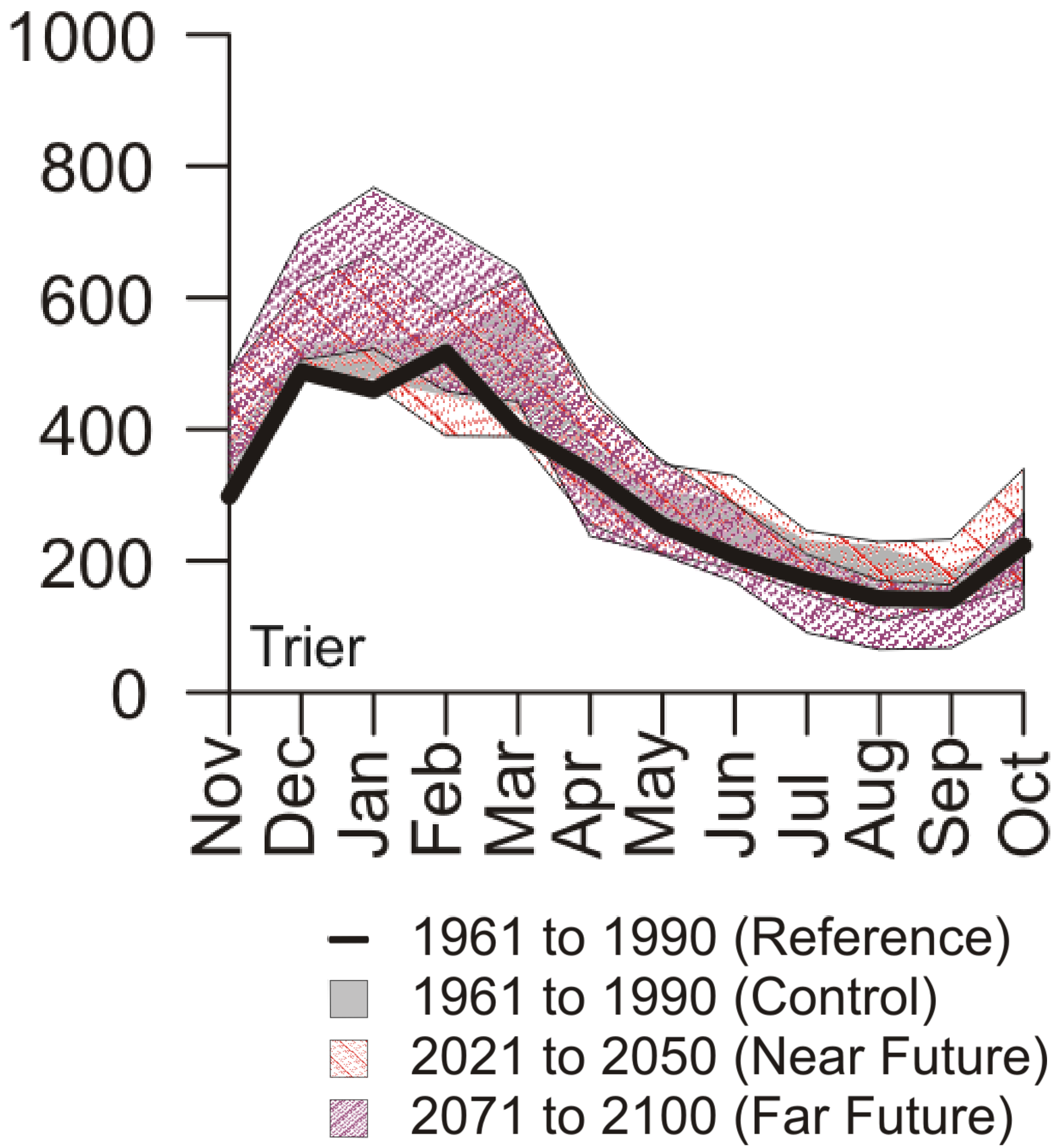
Projections and scenarios of **mean flow** (chapter 5)
Nival regime
MoMQ (Multi-annual mean monthly discharge)



- Near future: no clear change of seasonality
- Far future: Decrease of seasonality due to "Pluvialisation" of nival discharge regime (i.e. higher winter discharge due to more winter rain; lower summer discharge due to reduced melt water input)

← **18 runs**
← **20 runs**
← **17 runs**

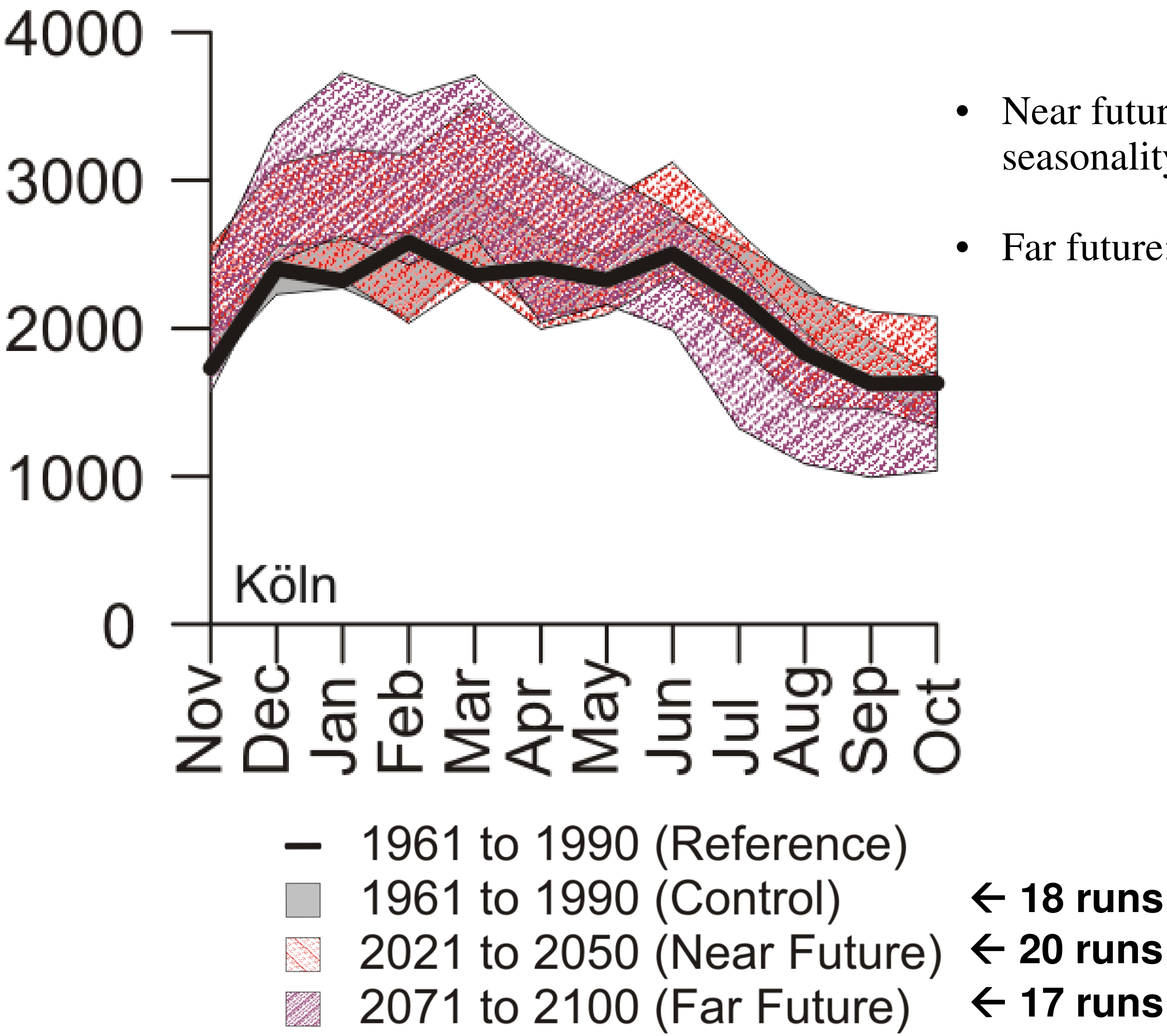
Projections and scenarios of **mean flow** (chapter 5)
Pluvial regime
MoMQ (Multi-annual mean monthly discharge)



← **18 runs**
← **20 runs**
← **17 runs**

- Near future: no clear change of seasonality
- Far future: Increase of seasonality due to i.e. higher winter discharge and lower summer discharge

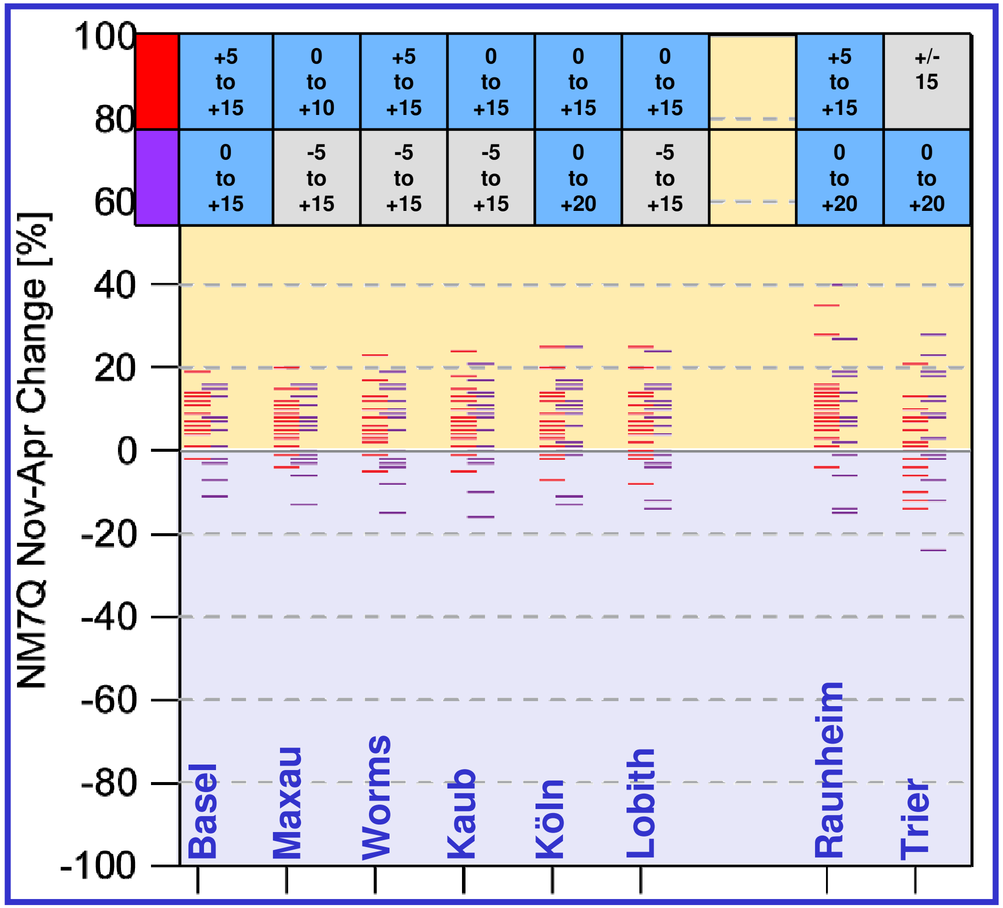
Projections and scenarios of **mean flow** (chapter 5)
“Combined” regime
MoMQ (Multi-annual mean monthly discharge)

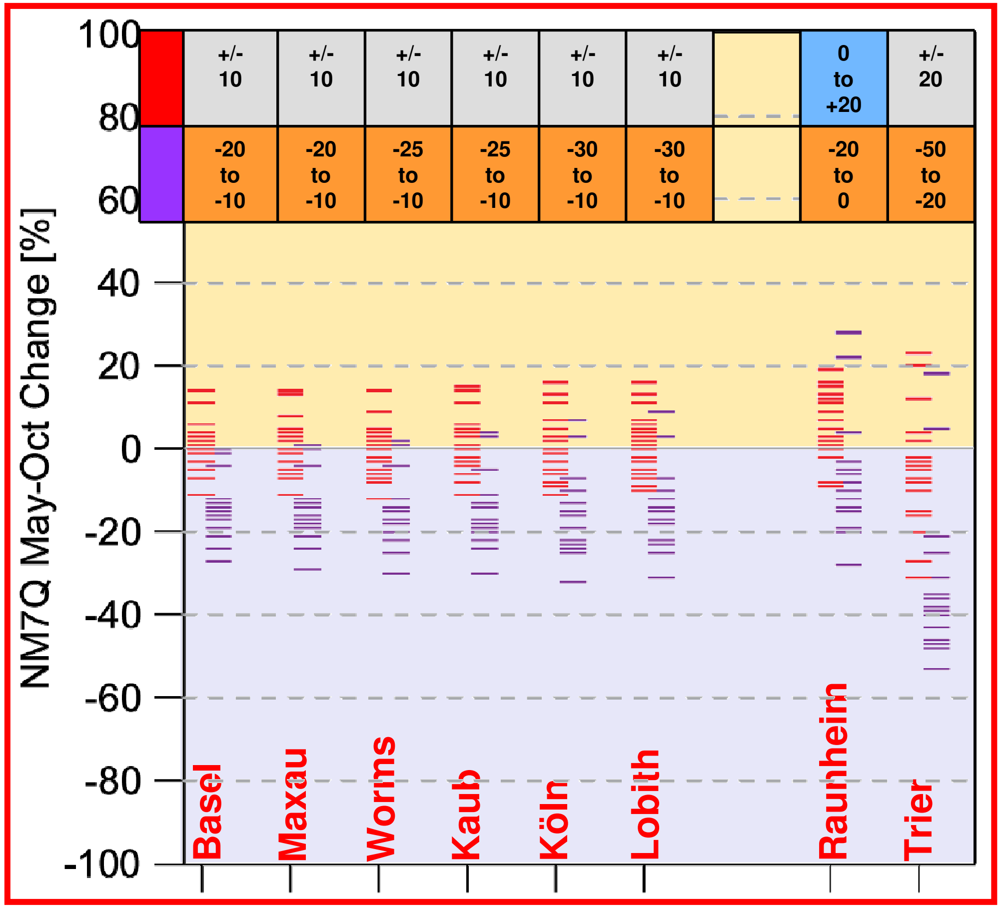


- Near future: no clear change of seasonality
- Far future: Increase of seasonality

Projections and scenarios of **low flow** (chapter 6)

NM7Q (Multi-annual mean of lowest 7 day mean discharge per season)





- Winter: increasing tendencies for near / far future (0% to 15%)
- Summer: no tendency in near future; decrease of 10% to 30% in far future

— change in near future (2021 to 2050) based on 20 projections
— change in far future (2071 to 2100) based on 17 projections
with respect to control period (1961-1990)

Summary and conclusions

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- An ensemble of 20 bias corrected projections of future climate has been selected for assessment of mean and low flow changes (2021-2050; 17 for far future).
- A simple bias correction method (linear scaling) and with a mesoscale semi-distributive hydrological model yield reasonable results for mean and low flow analyses.
- A transparent rule for definition of scenarios has been proposed.

- Winter MQ is projected to increase in near and far future (0% to +25% and +5% to +40%, respectively).
- Summer MQ shows no tendency in near future and a decrease of 5% to 30% in far future
- "Pluvialisation" of discharge regime projected for far future: Decrease of seasonality in nival regimes. Increase in pluvial/combined regimes.
- Winter NM7Q is projected to increase in near / far future (0% to 15%)
- Summer NM7Q shows no tendency in near future and decrease of 10% to 30% in far future

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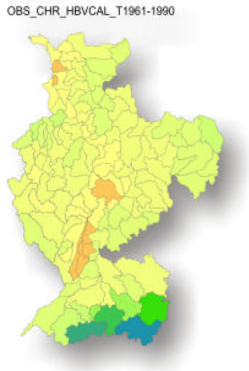
Selection of model chains: Spatial structure

Reference:



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Mean annual Temperature

Unit: °C
26 **control simulations**
Period: 1961-1990
134 Subbasins of River Rhine (HBV)
GCM-Forcing: C20
No bias correction