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Uncertainties in climate change projections – impact of model selection and methods

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Methodology

Observed historical climate

Hydrological Model

Observed flow

Simulated flow

Fitted hydrological model

Catchments in different Ecoregions in Germany

Treene:

477km²

4-80mASL

13 $Ls^{-1}km^{-2}$

Kinzig

925km²

104-624mASL

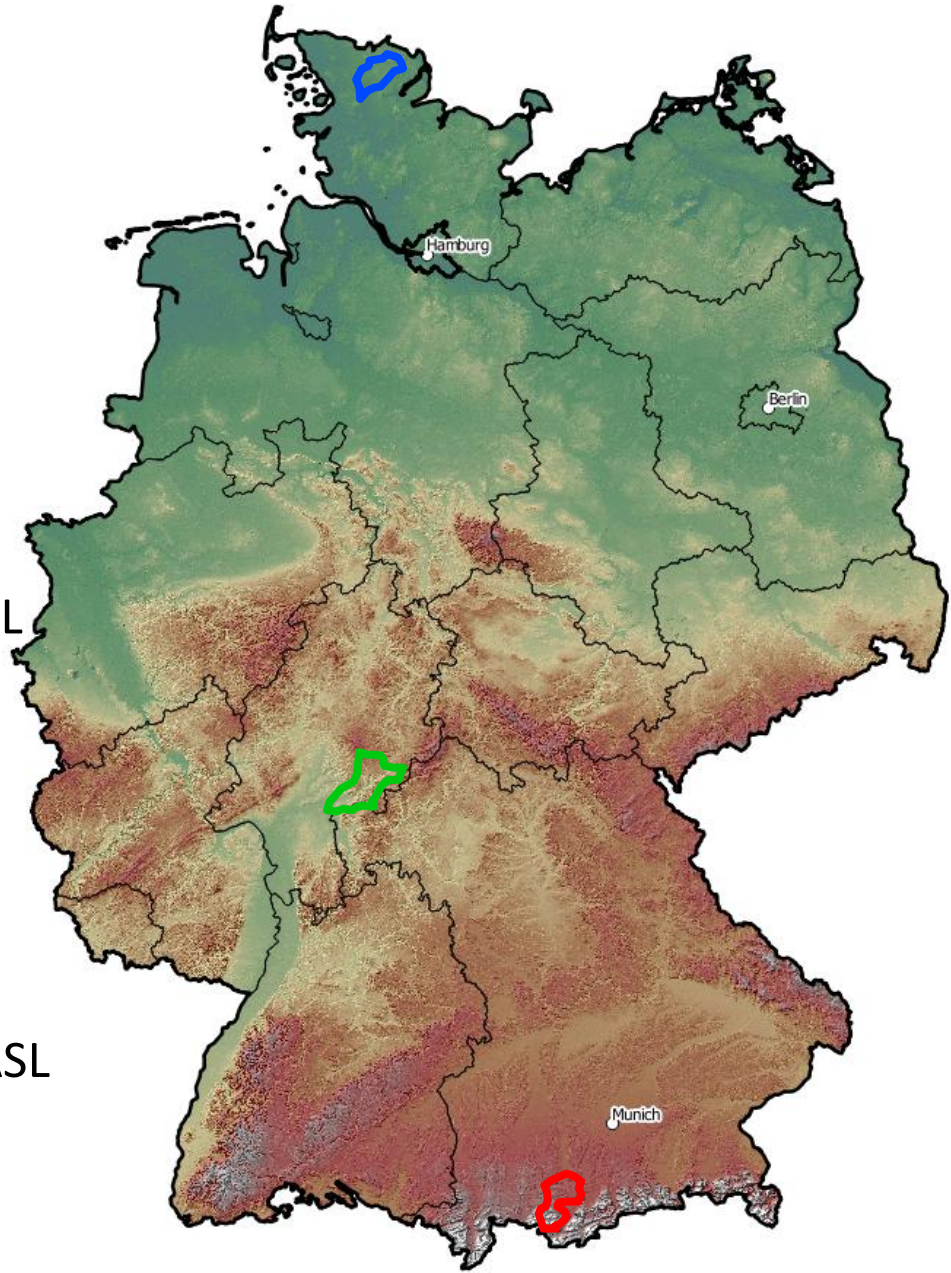
11 $Ls^{-1}km^{-2}$

Ammer

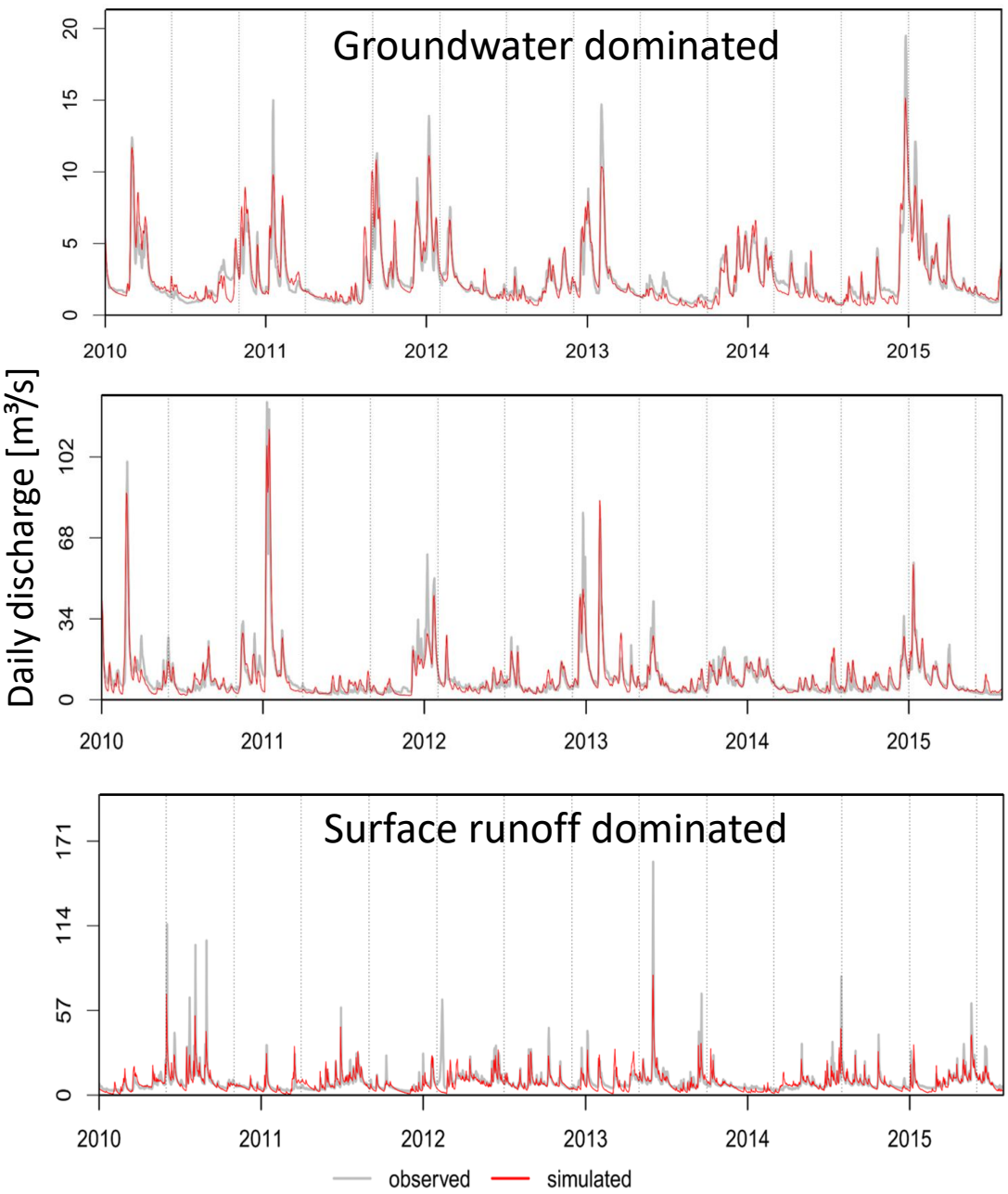
602km²

551-2157mASL

25 $Ls^{-1}km^{-2}$



Hydrological models SWAT (calibration shown)



	Cal 2010-2015	Val 1997-2009
KGE	0.94	0.91
NSE	0.88	0.84

	Cal 2010-2015	Val 1997-2009
KGE	0.93	0.87
NSE	0.87	0.81

	Cal 2010-2015	Val 1997-2009
KGE	0.61	0.74
NSE	0.48	0.59

Methodology

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CORDEX historical climate

Bias corrections

Fitted hydrological model

Simulated flow

CORDEX flow

Uncertainty assessment

CORDEX Climate change data in Europe

- Daily data on 11km grid
  Lowland = 5 cells
  Central = 8 cells
  Alpine = 4 cells

- Precipitation
  Min-, max temperature

- Bias correction: 1995-2005
  Validation (hindcasted): **2005-2014**
  Projection: 2045-2054; 2085-2094

- RCP 4.5, 8.5

- 16 combinations of GCM + RCM

www.cordex.org

Jacob et al. (2014, Reg. Env. Change)

Bias corrections

Precipitation	Temperature	Combination	Description
Linear scaling (LS)	Linear scaling (LS)	pLS+tLS	Adjust monthly mean
Distribution mapping (DM)	Distribution mapping (DM)	pDM+tDM	Adjust monthly mean, monthly frequency distribution
Local intensity scaling (LIS)	Linear scaling (LS)	pLIS+tLS	Adjust monthly mean, wet-day frequency, precipitation intensity
Power trans-formation (PT)	Variance scaling (VS)	pPT+tVS	Adjust monthly mean and variance
No correction (NO)	No correction (NO)	pNO+tNO	Raw CORDEX data

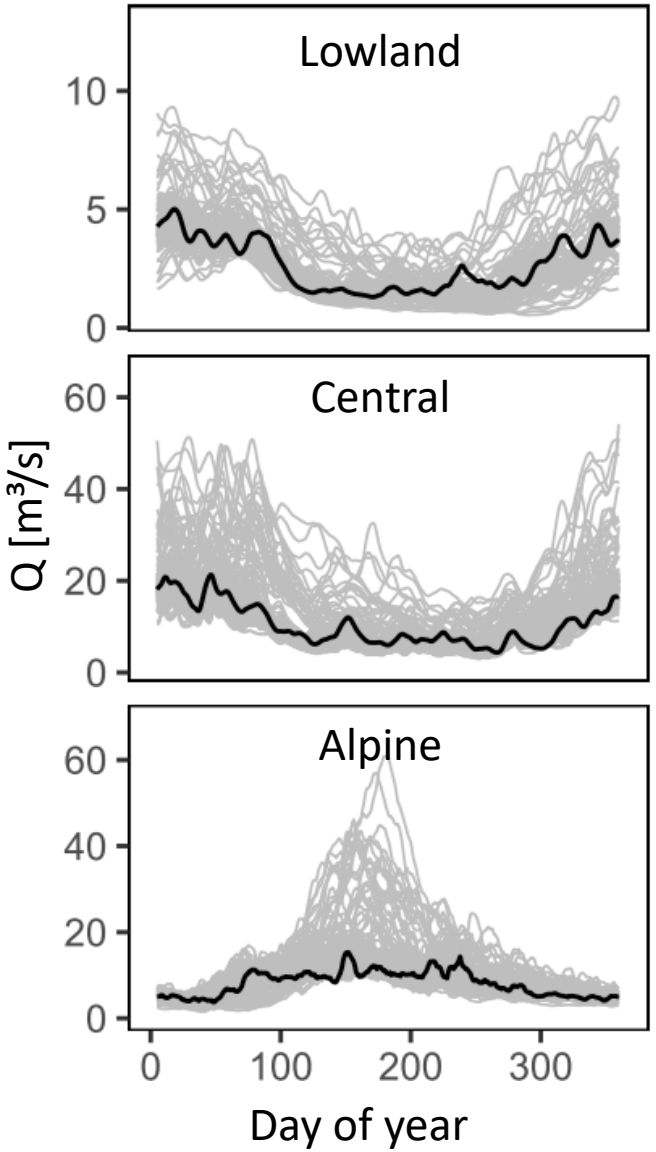
Teutschbein & Seibert (2012) JOH

„Climate Model data for Hydrologic Modelling“ (CMhyd)

http://swat.tamu.edu/software/cmhyd

Uncertainties in methods and models

10-day sliding mean discharge (2005-2014)



CORDEX models
GCM+RCM+
Bias Correction+
RCP
(=160 combinations)

Observed Climate

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Uncertainty Assessment

Difference of baseline and hindcasted streamflow indicators

- Monthly averages [m³/s]
- Magnitude of 25%- and 75%-flows [m³/s]
- Timing of extremes [d]
- Frequency of 25%- and 75%-flows [-]
- Duration of 25%- und 75%-flows [d]

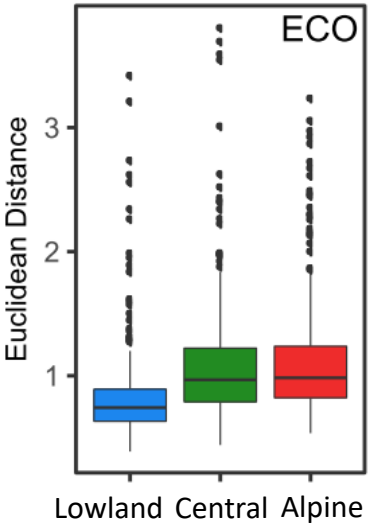
Indicators of Hydrologic Alteration (IHA), Richter et al. (1996) Cons.Biol.

Euclidean Distance to combine indicators

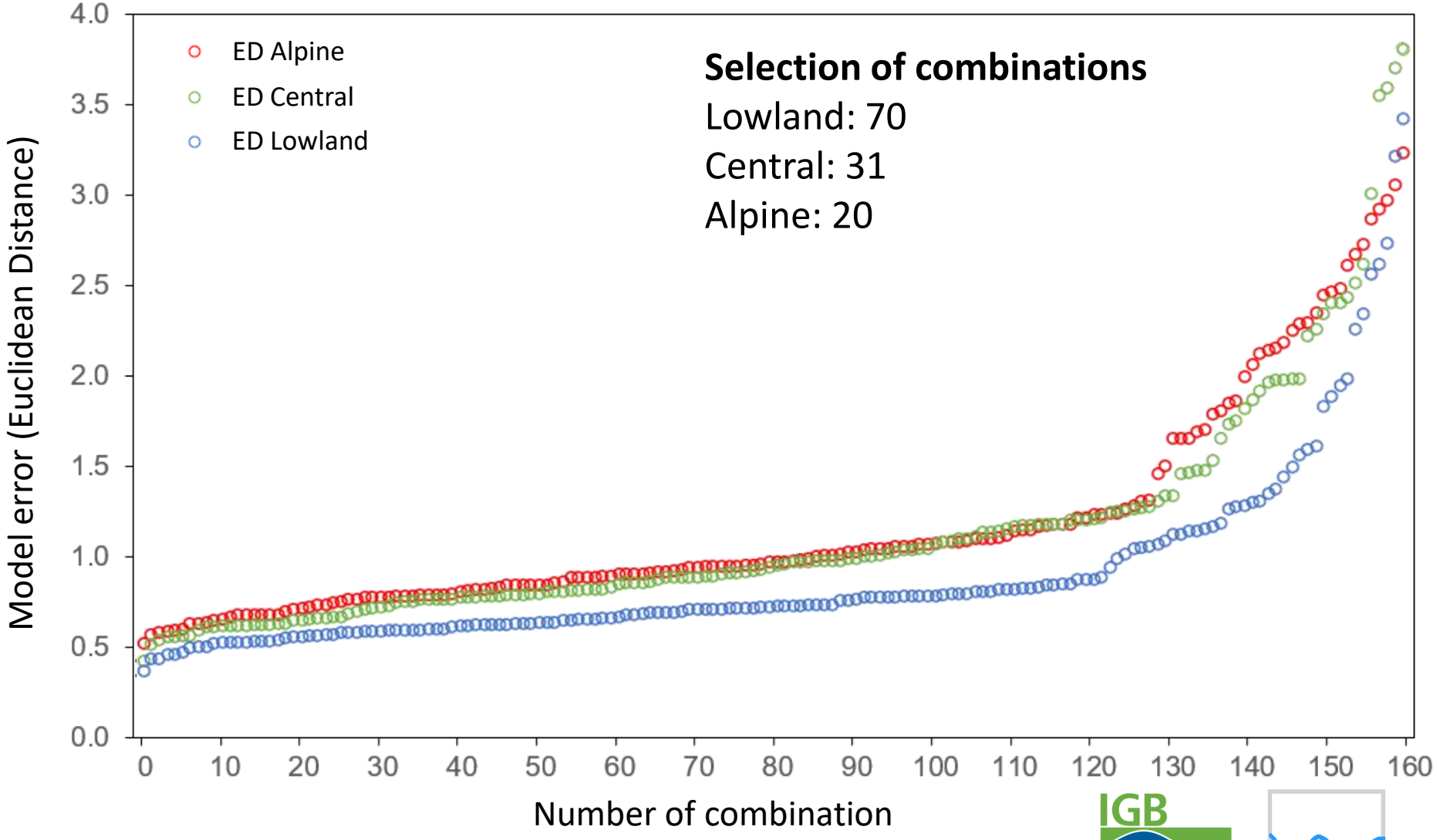
$$ED = \sqrt{\sum \left(\text{Standardized } \textbf{baseline} \text{ indicator} - \text{Standardized } \textbf{hindcasted} \text{ indicator} \right)^2}$$

- Calculated from all hindcasted and baseline indicators
- One Euclidean Distance value for each of the 160 combinations
- E=0 for perfect simulation

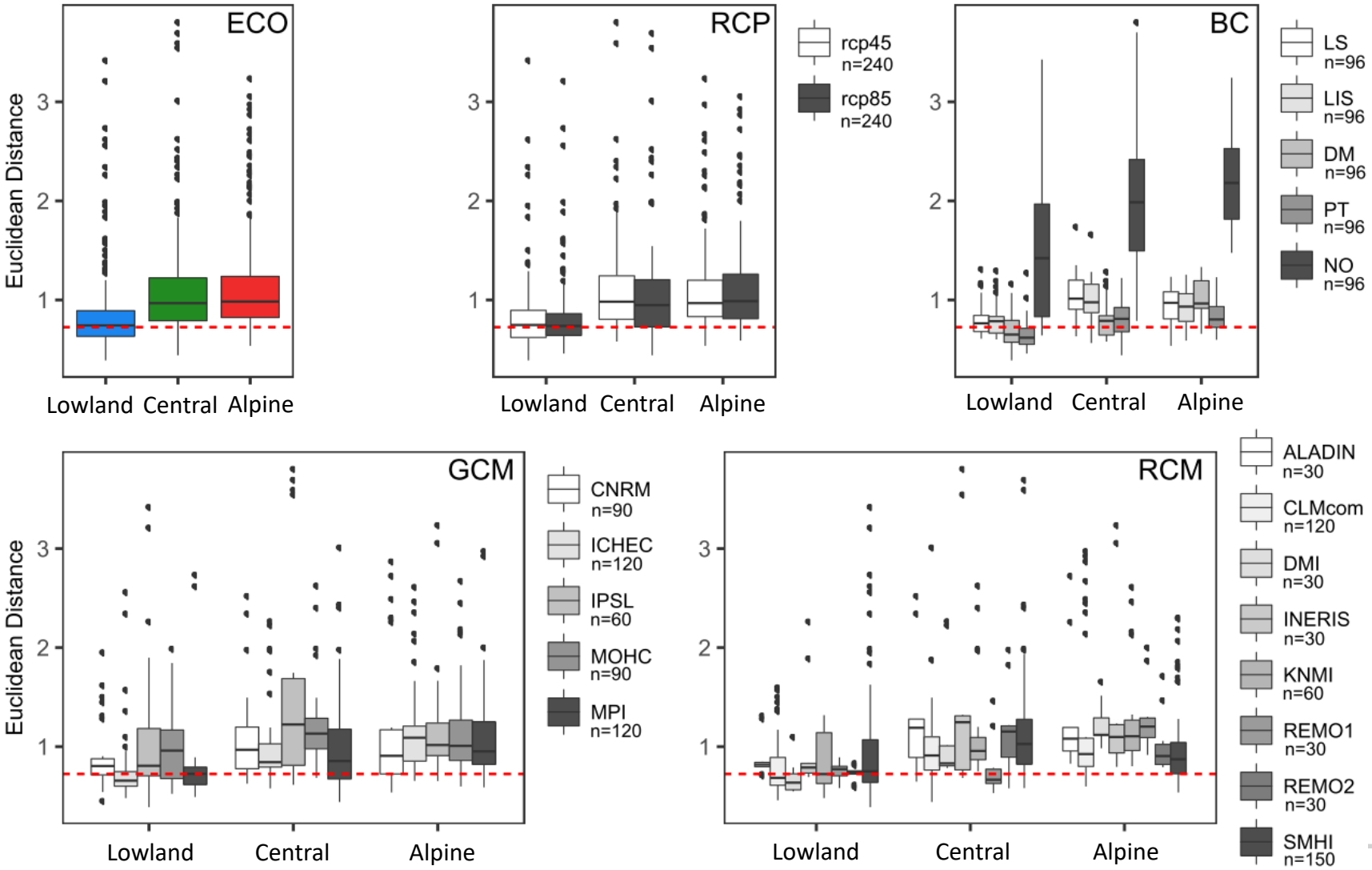
ED of all methods and models



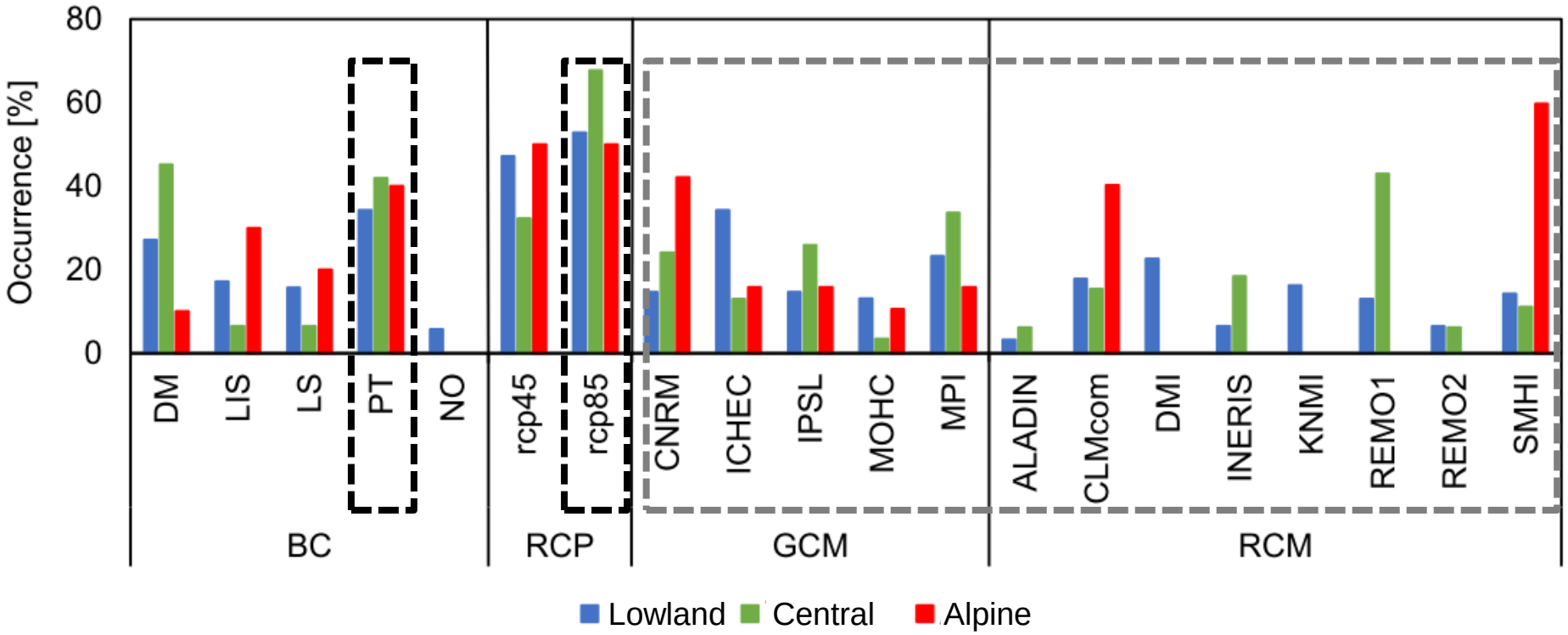
Reduction of uncertainty through selection



ED of all methods and models



Selected methods and models



- Bias correction Power Transformation performs best in the three catchments
- RCP85 slightly better results than RCP45
- Global and regional climate models perform differently in different catchments

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CORDEX historical climate

Bias corrections

Fitted hydrological model

Simulated flow

CORDEX flow

Uncertainty assessment

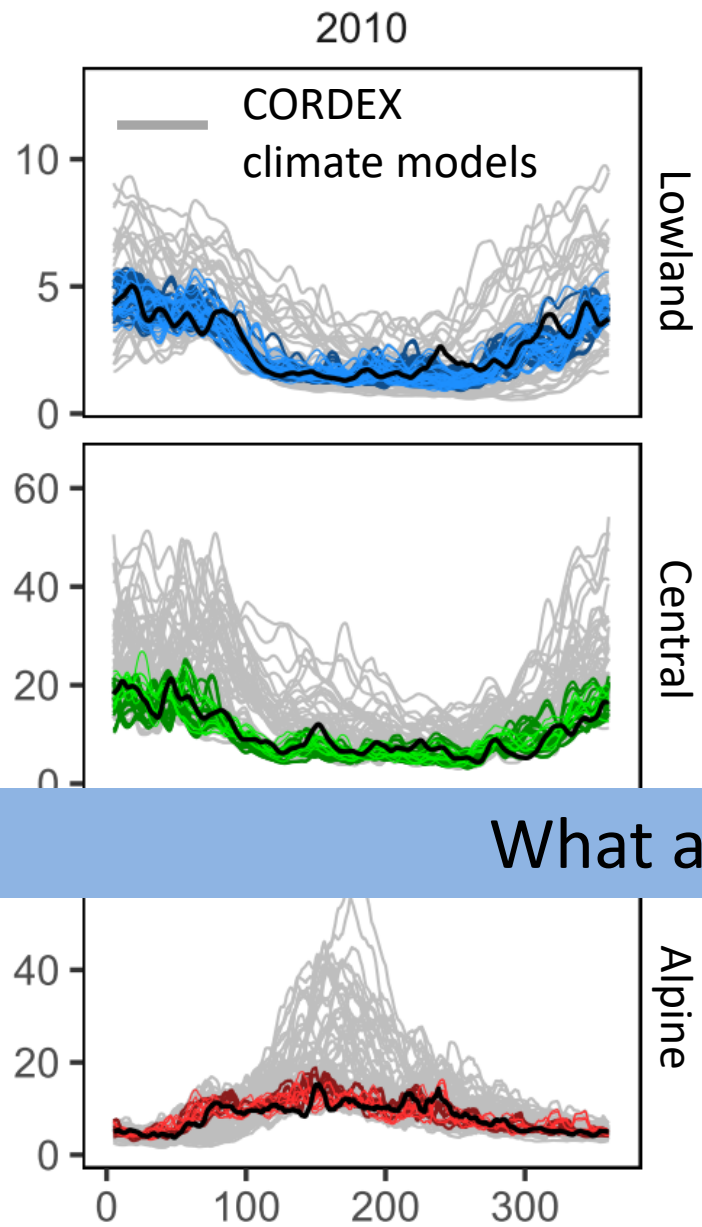
Best combinations future climate

Fitted hydrological model

CORDEX flow

Significant changes

Projected changes in discharge



What are significant changes?

	Indicator	Unit	Lowland					Central					Alpine				
			2010	2050		2090		2010	2050		2090		2010	2050		2090	
			Baseline	rcp 45	rcp 85	rcp 45	rcp 85	Baseline	rcp 45	rcp 85	rcp 45	rcp 85	Baseline	rcp 45	rcp 85	rcp 45	rcp 85
Monthly Mean	Q av Jan	[m³/s]	4.4	-	+	+	0.6	18.4	-3.3	4.1	-	+	4.8	+	1.3	+	+
	Q av Feb		3.8	0.7	0.7	0.4	0.9	17.2	-	+	+	4.3	4.6	1.1	1.1	+	1.8
	Q av Mar		3.7	-	-	-	+	14.6	+	-	+	-1.9	9.1	-	+	-	-1.7
	Q av Apr		2.4	-0.2	+	-0.4	+	9.1	-2.2	+	-	+	9.6	+	-0.7	-1.8	-3.4
	Q av May		1.6	-	0.3	-	0.4	7.8	-	1.4	-	+	10.1	+	-	-1.4	-4.0
	Q av Jun		1.4	-	+	-	0.5	8.0	-	+	-	+	11.9	+	-	+	-
	Q av Jul		1.6	-	+	-	0.3	7.2	+	+	+	-	10.0	+	-	-	-3.1
	Q av Aug		1.9	+	+	+	-	7.5	-	+	+	-	12.2	-	+	-	-
	Q av Sep		1.9	+	+	+	+	5.0	+	+	-	+	8.2	-	+	-	-
	Q av Oct		2.3	-0.4	-	-0.4	-0.3	6.8	-	+	-	-	6.3	-	+	-	-
	Q av Nov		3.4	-0.5	-	-	-0.4	9.7	+	-	-	-	5.2	-	+	-	-
	Q av Dec		3.8	-	-0.5	-	+	14.0	+	-	-	-	4.7	+	0.9	-	+
Magnitude	Q min 1d	[m³/s]	0.8	-	-	-	-	2.0	-	-	-	-	2.0	-	+	-	-0.7
	Q min 3d		0.8	-	-	-	-	2.1	-	-	-	-	2.1	-	+	-	-0.7
	Q min 7d		0.8	-	-	-	+	2.2	-	-	-	-	2.2	-	+	-	-0.7
	Q min 30d		1.0	-	+	-	-	3.3	-	+	-	-	3.1	-	+	-	-0.6
	Q min 90d		1.4	-	+	-	-	5.8	-	+	-	-	4.9	-	+	-	-0.8
	Q max 1d		10.7	+	+	+	2.1	64.5	-	-	-	-	78.8	12.1	+	+	+
	Q max 3d		10.4	+	+	+	2.0	61.5	-	-	-	-	52.3	+	+	+	+
	Q max 7d		9.2	+	+	+	1.7	51.6	-	-	-	+	33.2	+	+	+	+
	Q max 30d		6.2	+	0.5	+	1.1	28.0	-	+	-	+	17.0	+	+	-	-
	Q max 90d		4.3	+	+	+	0.5	17.0	-	+	+	+	12.2	+	+	-	-
	Days high Q	[day]	14.1	2.6	+	2.7	2.1	9.3	-	+	2.2	1.7	3.0	0.7	-	+	+
	Days low Q		12.6	+	+	+	-	8.6	-	-1.0	+	+	6.3	3.7	-1.4	+	+
Tim	Day Q min	[day]	261	+	+	-	15	279	-15	-	-	-	50	-60	-67	-105	-136
	Day Q max		16	-	-	-	+	19	-	-	-	-	176	+	+	-	-
Fre	Nr high Q	[-]	6.2	-0.5	-	-1.1	-0.8	9.1	-	-0.7	-	-0.8	30.2	-	+	-	-
	Nr low Q		7.2	-	-	-0.8	-	9.5	+	+	+	-0.6	13.2	-	2.9	-	-

- **Lowland and Alpine**: Increase of winter average flow
- **Alpine 2090**: Reduction of spring / summer average flow
- **Lowland**: Reduction of autumn / winter average flow
- **Alpine 2090**: Reduction of low flows
- **Lowland 2090**: Increase in high flows
- **Alpine**: Earlier annual minimum
- **Lowland**: Less high & low flow events

- / + Non-significant in-/decrease

4.3 / -1.9 Significant in/decrease

Summary

- Climate models and bias correction methods have different performances in different ecoregions
- Power Transformation and rcp85 show best depiction of recent conditions
- GCM and RCM need to be evaluated in each ecoregion
- We have shown a methodology to select combinations with low uncertainty for the predictions
- Streamflow predictions should go hand in hand with an analysis of statistical significance of the changes

Bundesministerium
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IGB
Leibniz-Institute of
Freshwater Ecology
and Inland Fisheries

Glance projects
global change effects on river ecosystems

AUG 2014 – APR 2019

Global Change Effects on River Ecosystems (GLANCE)

Auswirkungen des globalen Wandels auf Fließgewässerökosysteme

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Department of Ecosystem Research

Thank you for your attention