

Climate Change Alternatives for Central Europe

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Regional Climate Projections Ensemble for Germany

- a joint research project funded by German Ministry of Education and Research

Major objective

- provide **robust climate change information** on high spatial resolution for **Germany** and adjacent **large river catchments draining into Germany** (the **ReKLiEs-domain**)

Extended the Euro-CORDEX ensemble by 27 simulations with

- 3 dynamical downscaling (DDS) RCMs: CCLM, REMO, WRF
- 2 statistical downscaling (ESD) RCMs: WETTREG, STARS

For two scenarios RCP8.5 and RCP2.6

Resulting in a total ensemble of

- **52 regional climate simulations** (incl. the existing Euro-CORDEX simulations)
- with global forcings from 7 different GCMs
- downscaled by 6 different dynamical and 2 statistical RCMs
- analyzed on the full **ReKLiEs-domain** and 9 subdomains (incl. 8 river catchments)

The simulation ensemble

- **37** simulations of the **business as usual** scenario (RCP8.5)
- **15** simulations of the **climate protection** scenario (RCP2.6)

RCMs \ GCMs	MPI-ESM-LR r1, r2	CNRM-CM5	HadGEM2-ES	EC-EARTH r1, r3, r12	MIROC5	CanESM2	IPSL-CM5A-MR
CCLM	X X	X	X	X X	X	X	
REMO	X X XX	X	X	X	X	X	
WRF	X X		X	X			X
WETTREG	X X	X	X	X	X	X	
STARS 3	X X	X	X X	X X	X	X	
RCA4	X X	X	X X	X X			X
RACMO			X X	X X			
HIRHAM5				X X			

Climate change indices (CCI)

- **24 climate change indices** have been calculated for each simulation
- characterizing climatological means and extremes
- mainly for temperature and precipitation
- on monthly, seasonal and annual time scales

Climate change detection

- calculation of 30-year means for CCIs
- for 3 periods **1971-2000, 2021-2050, 2071-2100**
- climate change signal = difference between future and past period

Focus of this talk: Comparison of the two alternative emissions scenarios

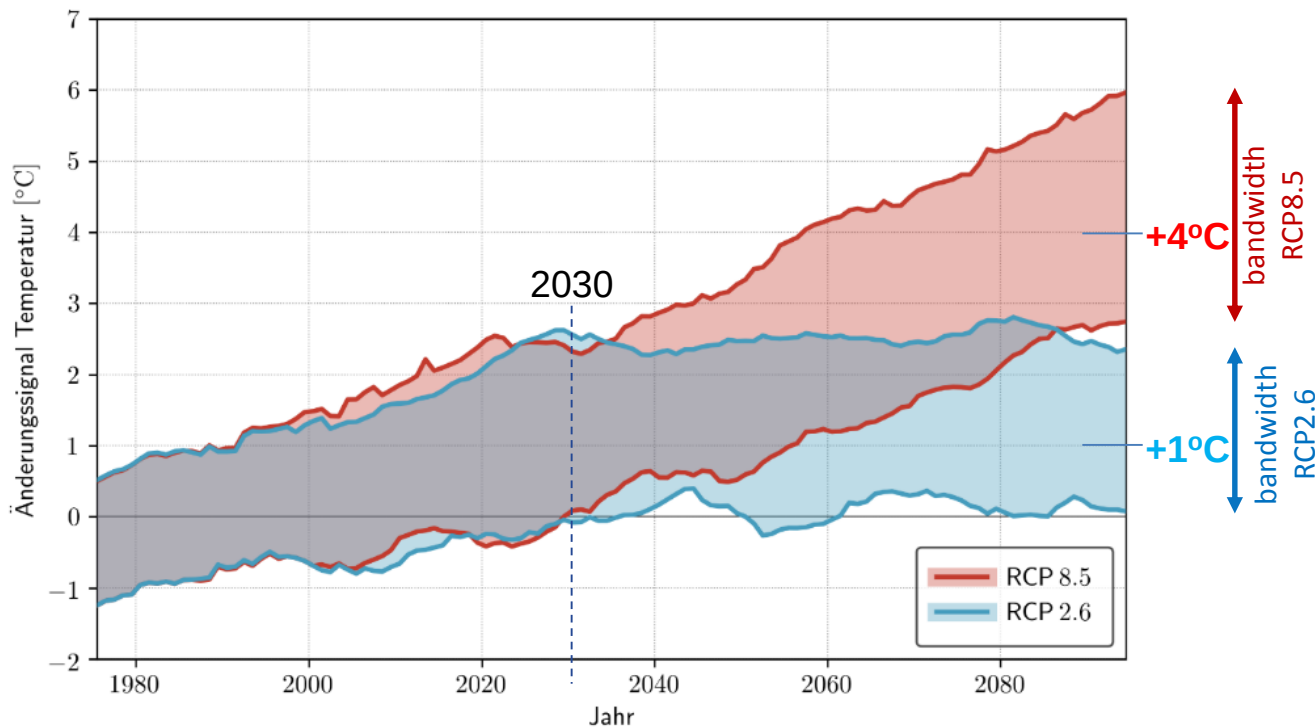
- climate change signals for RCP2.6 and RCP8.5
- using only those **15 GCM-RCM (X)** combinations which have been used to simulate both scenarios

Annual mean temperature rise

Stronger rise of greenhouse gases = stronger rise of temperature

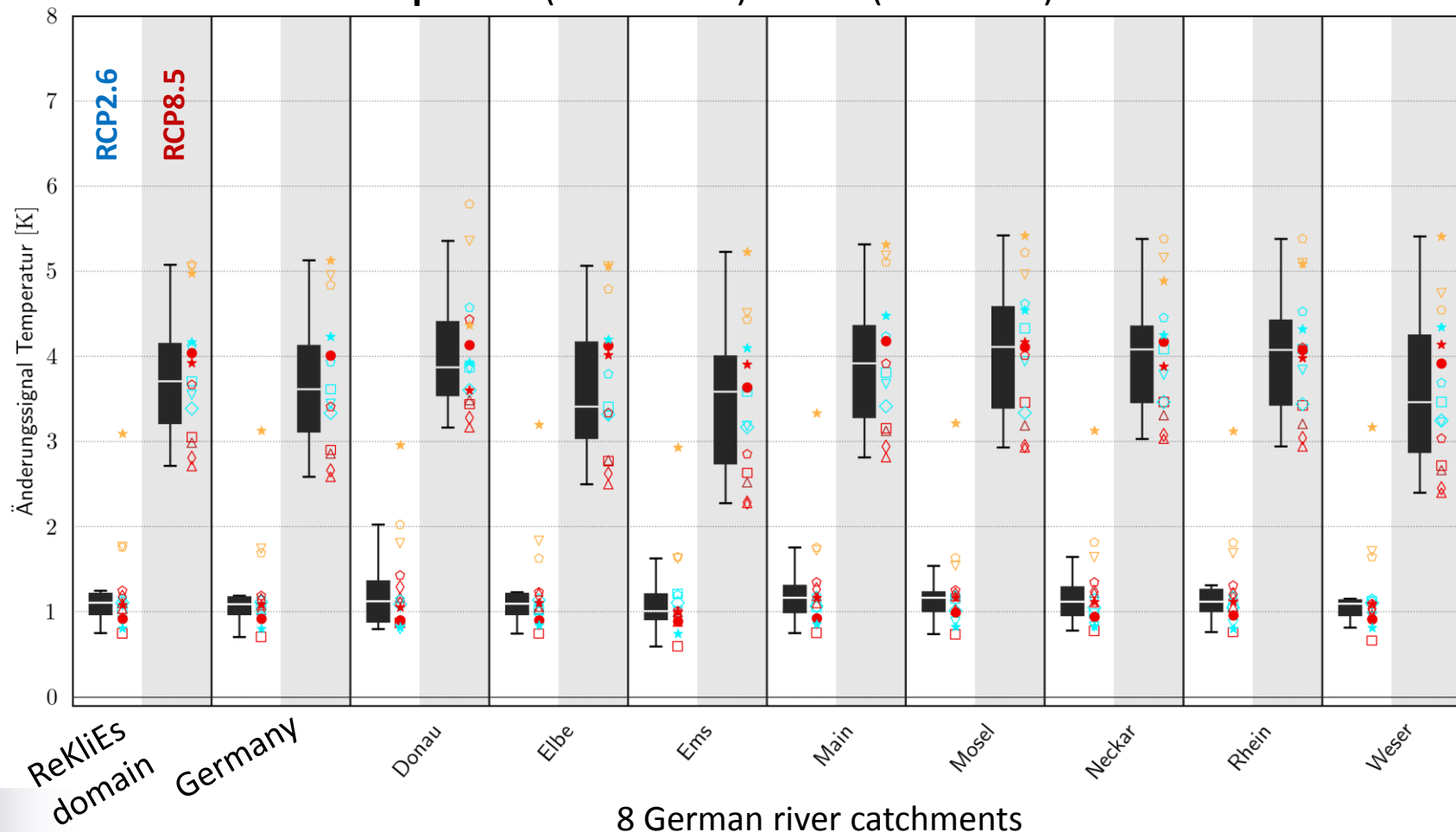
Change of annual mean temperature (area men ReKliEs-domain) against median of reference period (1971-2000) for all simulations of the

- **business as usual (RCP8.5)**
- **climate protection scenario (RCP2.6)**



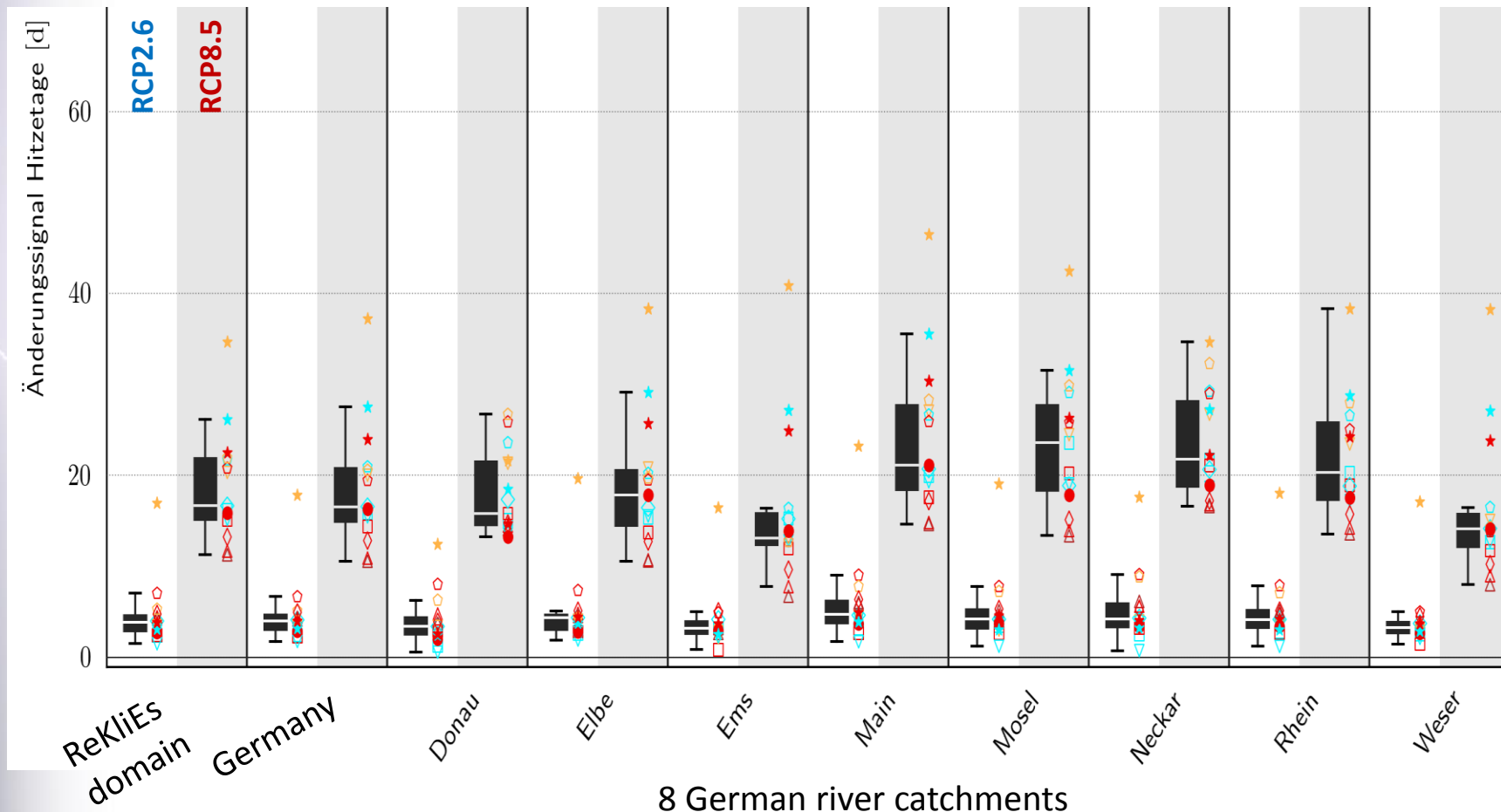
Increase of summer temperatures

Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



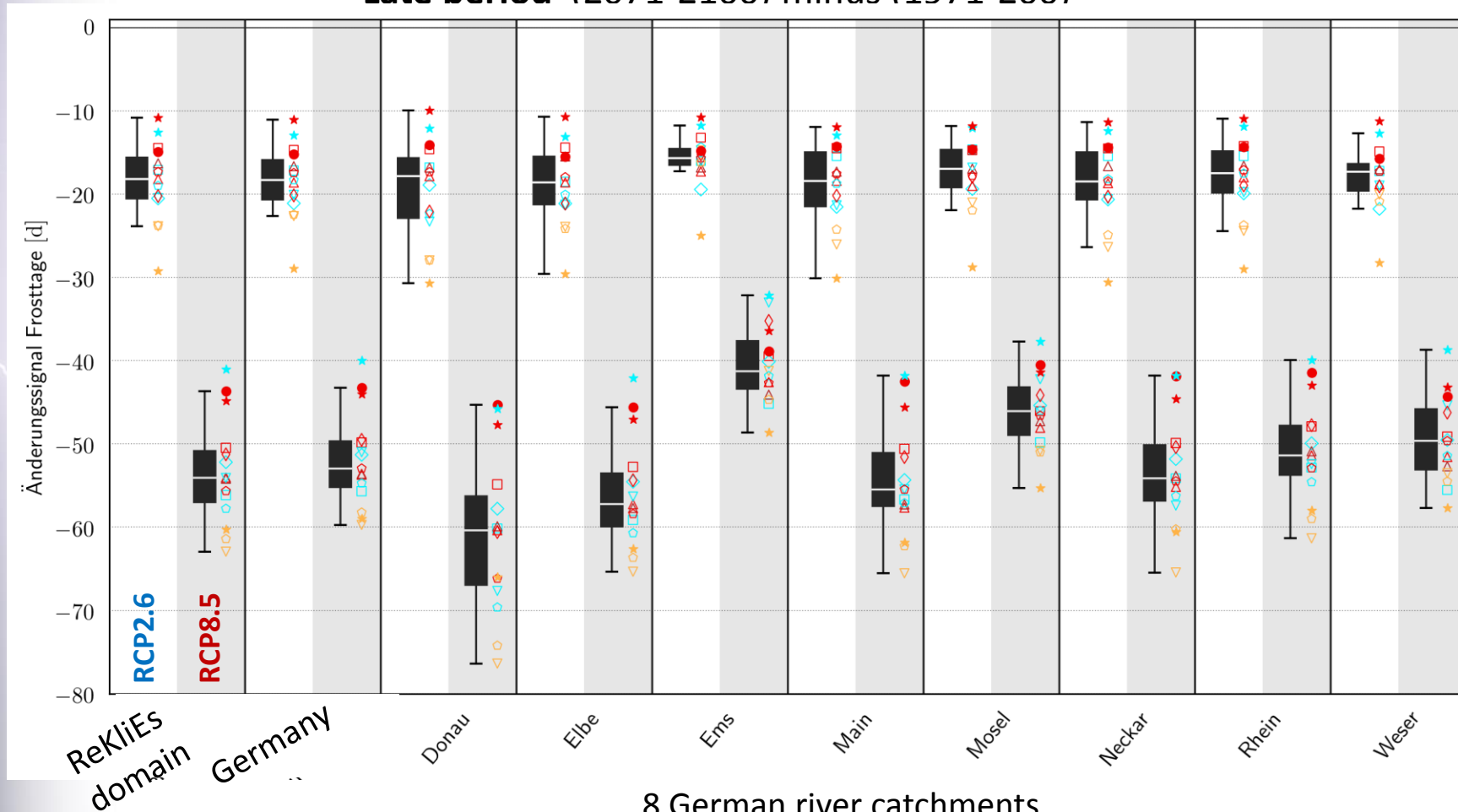
Increase of hot days ($T_{\max} \geq 30\text{ °C}$)

Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-2000)



Decrease of frost days ($T_{\min} < 0\text{ }^{\circ}\text{C}$)

Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



Summary of temperature effects

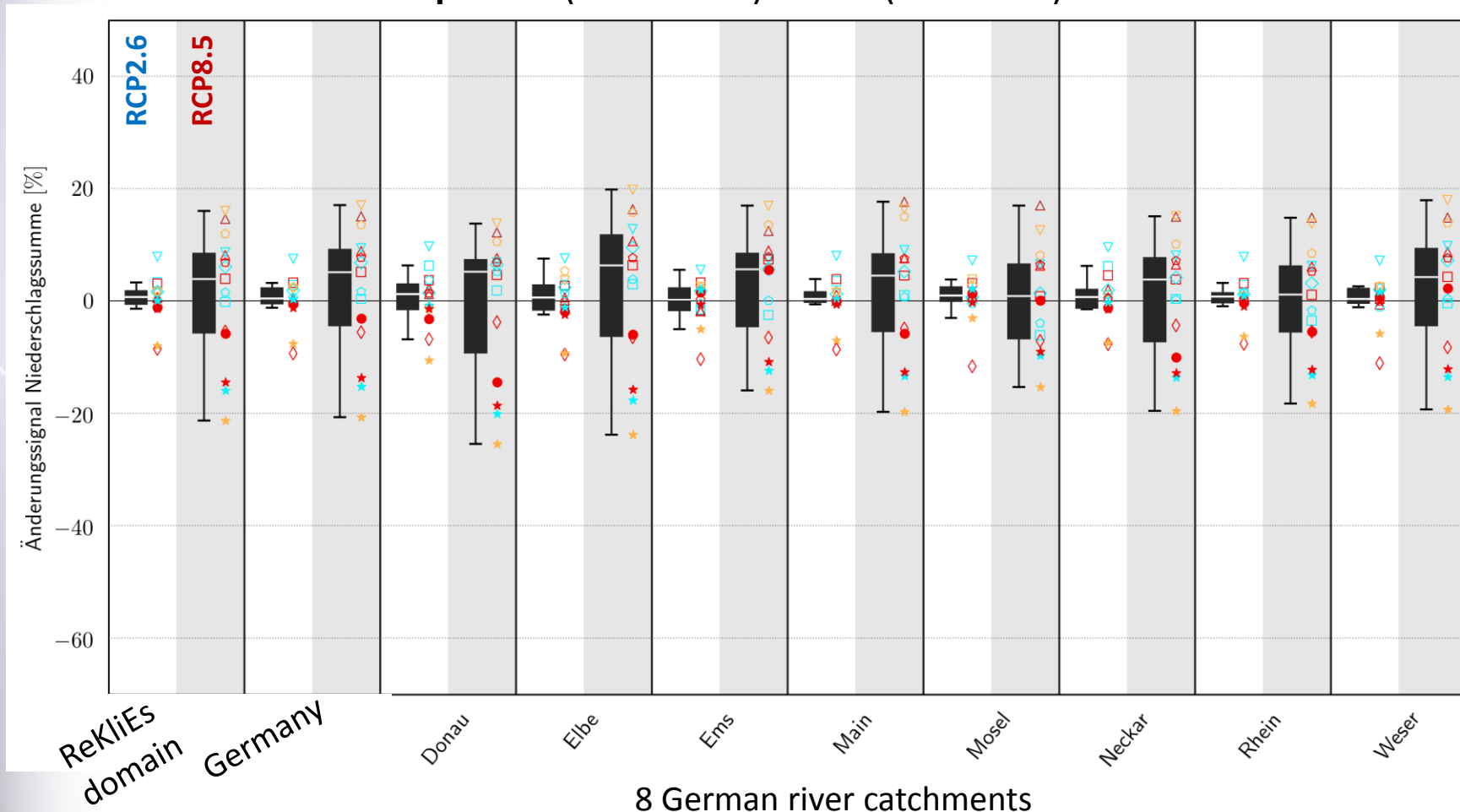
centennial climate change

Difference of ensemble median, annual values, area mean over Germany

Climate Change Index	RCP 2.6	RCP 8.5	Ratio of changes
Mean temperature	+1 °C	+3,5 °C	3 ½ x lesser
Ice days (Tmax < 0°C)	-7.3 d	-16 d	> 2 x lesser
Frost days (Tmin < 0°C)	-18 d	-53 d	3 x lesser
Summer days (Tmax > 25°C)	11 d	+42 d	~ 4 x lesser
Hot days (Tmax > 30°C)	+4 d	+16 d	4 x lesser
Tropical nights (Tmin > 20°C)	0.5 d	+4.8 d	neglectable
Diurnal temperature range	+0.05 °C	-0.05 °C	no difference
Ratio of cold days per year (tx10p)	-5.1 %-points	-9.3 %-points	~ 2 x lesser
Ratio of warm days per year (tx90p)	+5 %-points	+23 %-points	4 ½ x lesser
Cold spell duration index (csdi)	-3 d	-6 d	2 x lesser
Warm spell duration index (wsdi)	+10.5 d	+53.5 d	5 x lesser

Annual precipitation

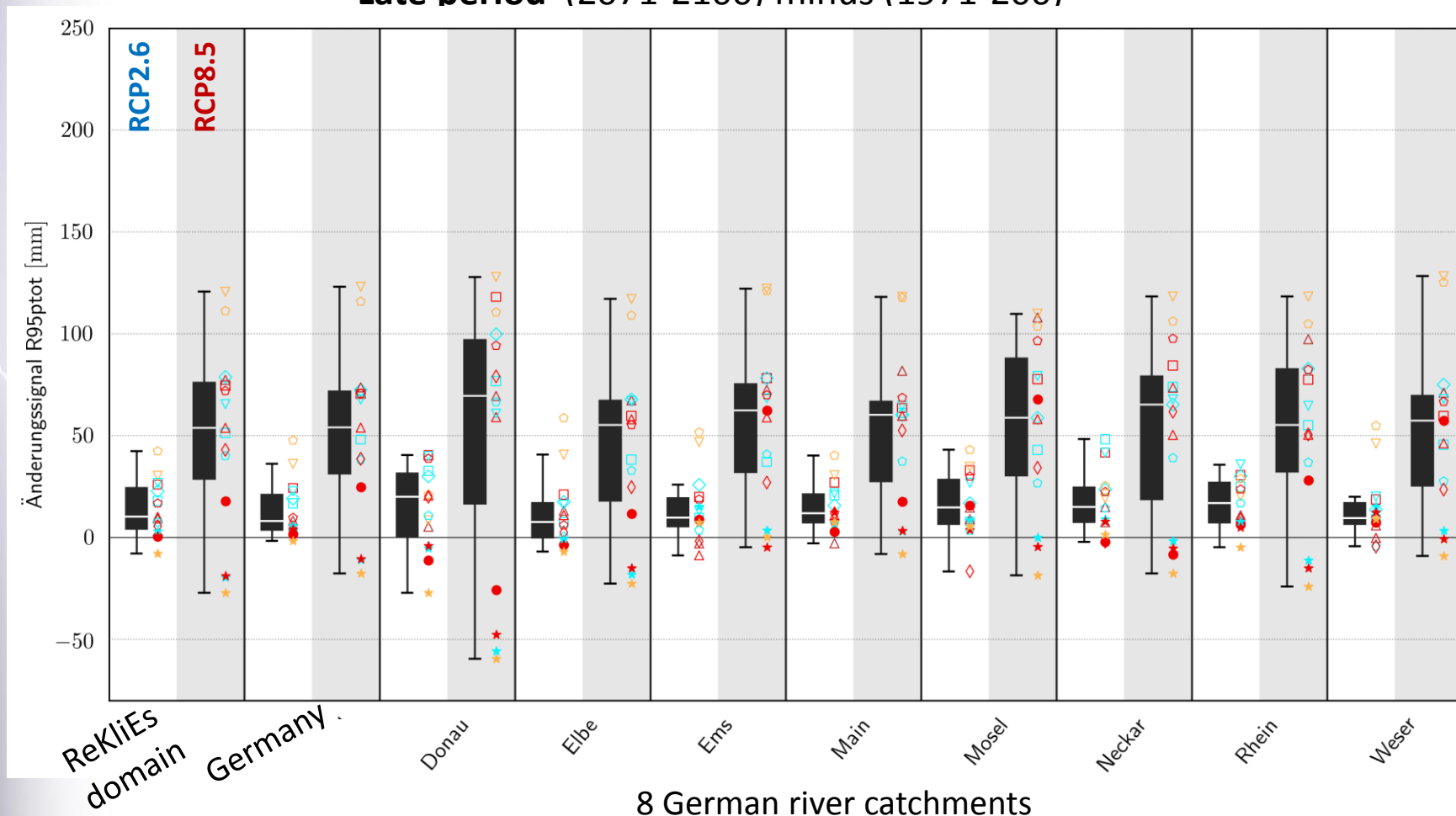
Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



Intensive precipitation

accumulated precipitation of intensive rain days (r95ptot)

Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



Summary of precipitation effects

centennial climate change

Difference of ensemble median, annual/seasonal values, area mean over Germany

Climate Change Index	RCP 2.6	RCP 8.5	Ratio of changes
Annual precipitation	+0 %	+5 %	-5 %-points
Winter precipitation	+3.5 %	+15 %	4 x lesser
Summer precipitation	-4.5 %	-15 %	3 x lesser
Number of dry days (pr < 1mm)	+1.3 d	+2.4 d	2 x lesser
Number of rain days (pr ≥ 1 mm)	-1.3 d	-2.4 d	2 x lesser
Number of intensive rain days (pr ≥ 10 mm)	+0.4 d	+2.8 d	7 x lesser
Number of heavy rain days (pr ≥ 20 mm)	+0.2 d	+1.1 d	5 ½ x lesser
Strong precipitation amount (r95ptot)	+8.3 mm	+ 53 mm	6 ½ x lesser
Extreme precipitation amount (r99ptot)	+5.4 mm	+29.3 mm	5 ½ x lesser

All temperature and precipitation changes evolve **substantially weaker** with a more **moderate** CO₂-increase!

Further climate change is unavoidable!

But it still can be limited to an acceptable level!

However, the climate protection scenario (RCP2.6) requires an **extensive reduction** of CO₂ emissions

- consequently from all sectors
- globally
- Immediately

beginning with year 2020

No time left to opt for the right emission path!

Contributing project partners of ReKliEs-De

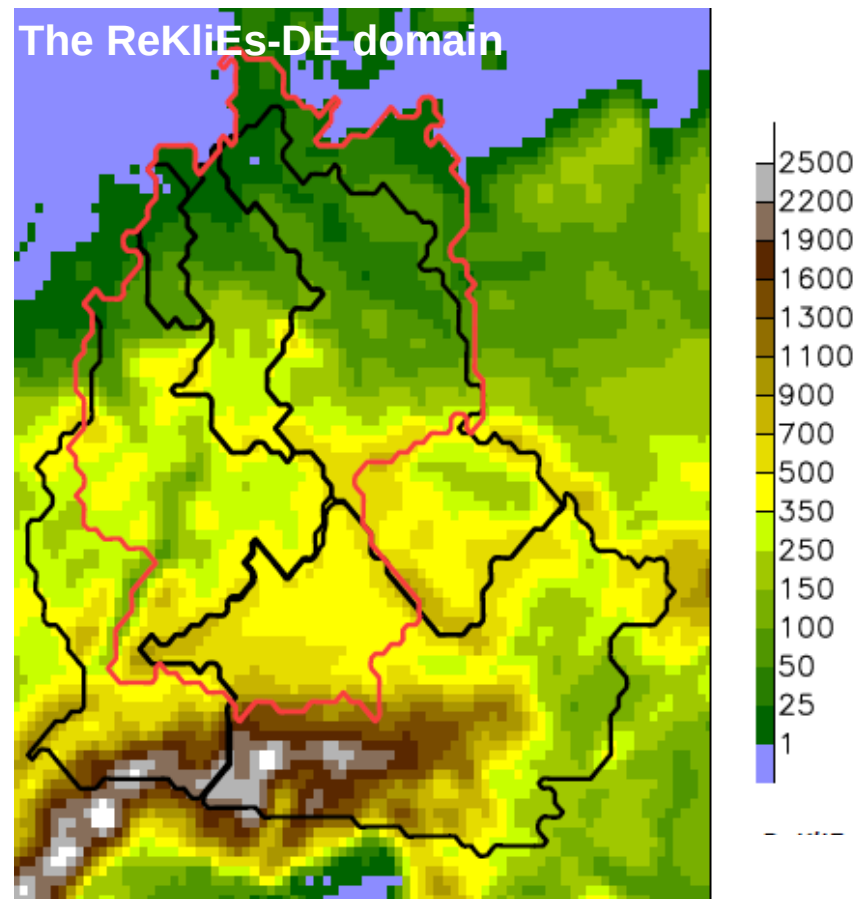
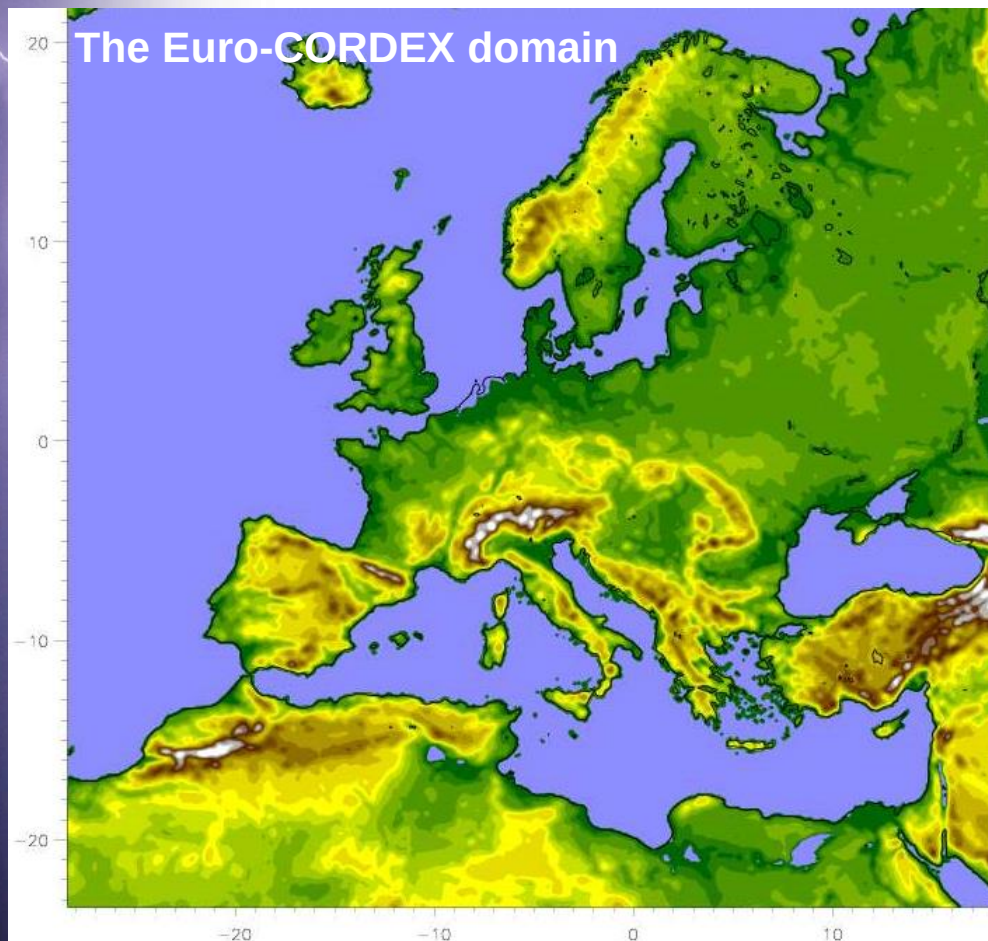
- Heike Hübener, Cornelia Fooker (HLNUG) → **Poster X5.470**
- Katharina Bülow (GERICS)
- Barbara Früh, Christian Steger, Simona Höpp (DWD)
- Peter Hoffmann, Christoph Menz, Arne Spekat (PIK)
- Hans Ramthun, Frank Toussaint (DKRZ)
- Kirsten Warrach-Sagi, Victoria Mohr (UHOH) → **Poster X5.497**
- Kai Radtke, Michael Woldt, Klaus Keuler (BTU)

• **Thank you for your attention**

ReKliEs-De data base and domains

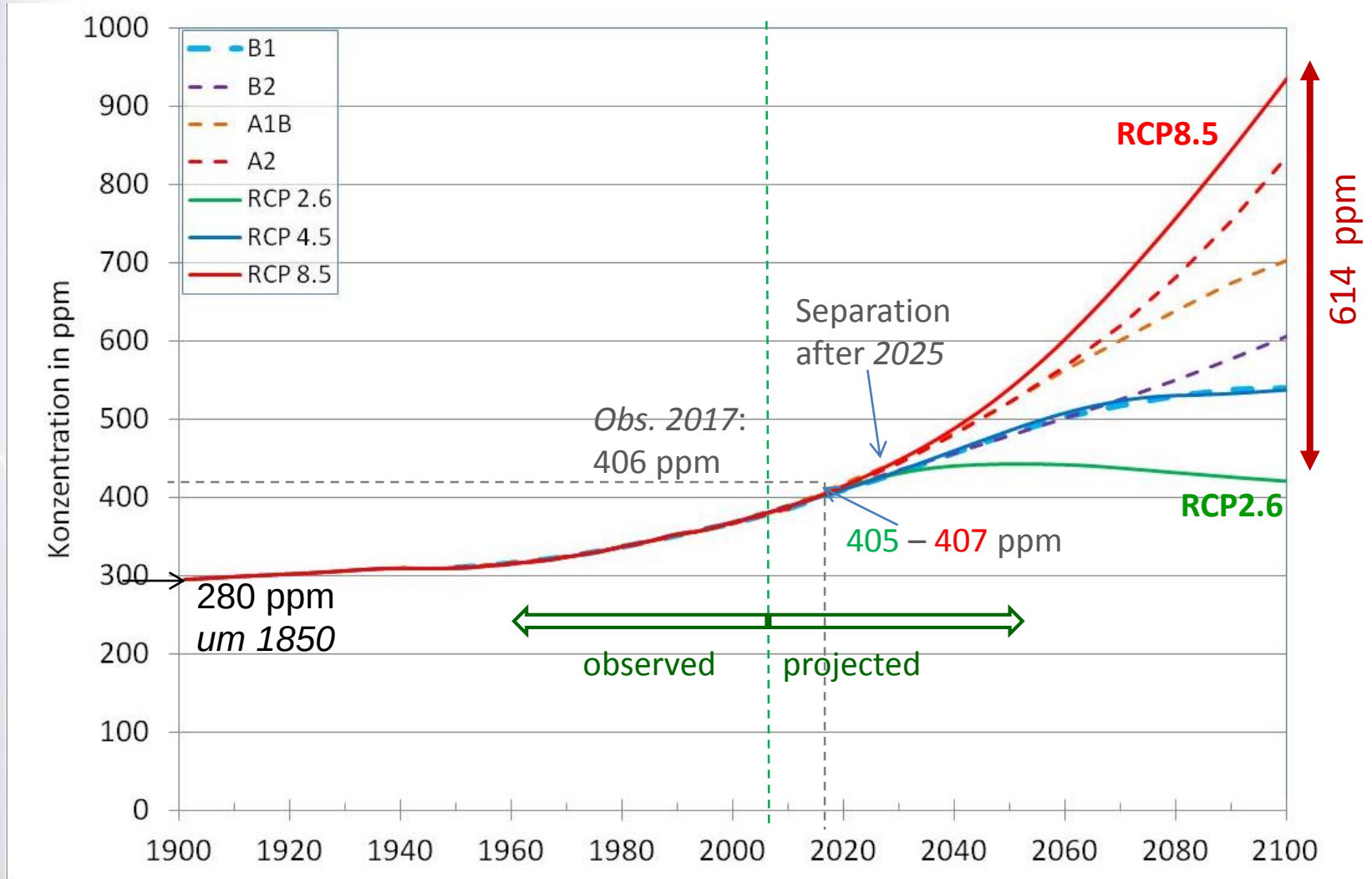
A combination of 25 Euro-CORDEX and 27 ReKliEs-DE simulations

- DDS-RCMs on full Euro-CORDEX domain
- ESD-RCMs on ReKliEs-De domain only



Greenhouse gas scenarios

Development of CO₂ concentration from 1900 to 2100



Emission scenarios

Development of CO₂ emissions from 1900 to 2100

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