Climate Change Alternatives for Central Europe

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Co-authors

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The ReKLiEs-De project

ReKliEs-De
Regionale Klimaprojektionen Ensemble für Deutschland

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 RCMs: CCLM, REMO, WRF
- 2 statistical downscaling 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

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

GCMs / RCMs	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			

Analysis of climate change scenarios

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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

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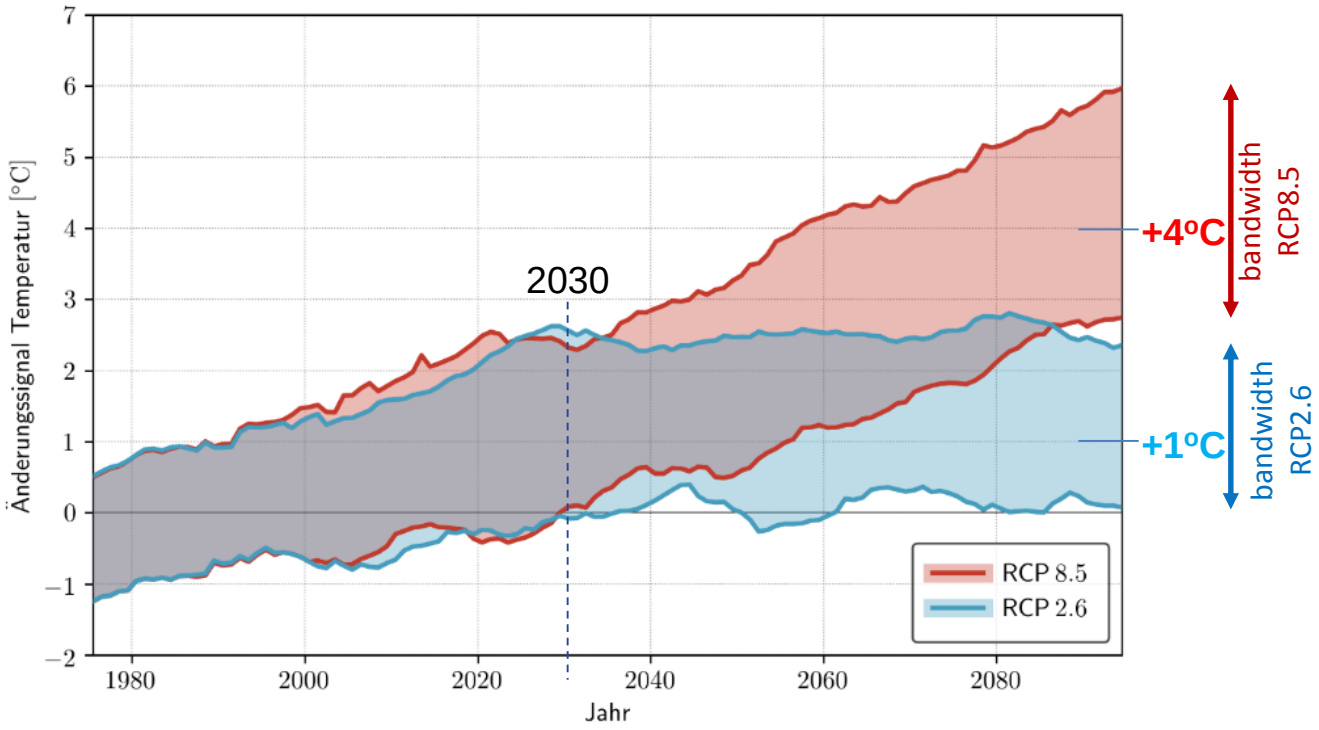
Stronger rise of greenhouse gases = stronger rise of temperature

Change of annual mean temperature (area men ReKliEs-domain) against median of reference period (1971-2000) for all simulations of the
- business as susual (RCP8.5)
- climate protection scenario (RCP2.6)



Increase of summer temperatures

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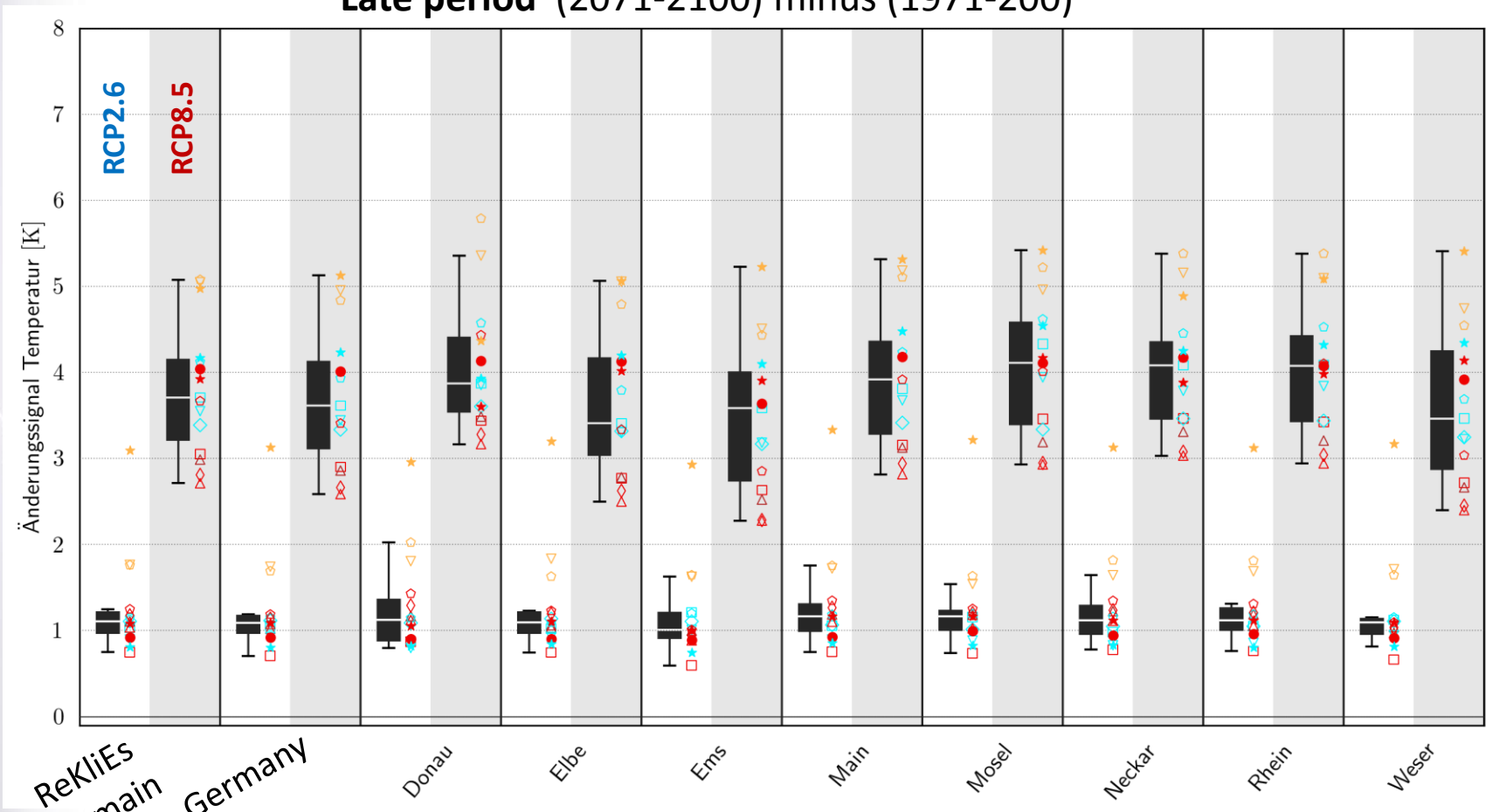
Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



8 German river catchments

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

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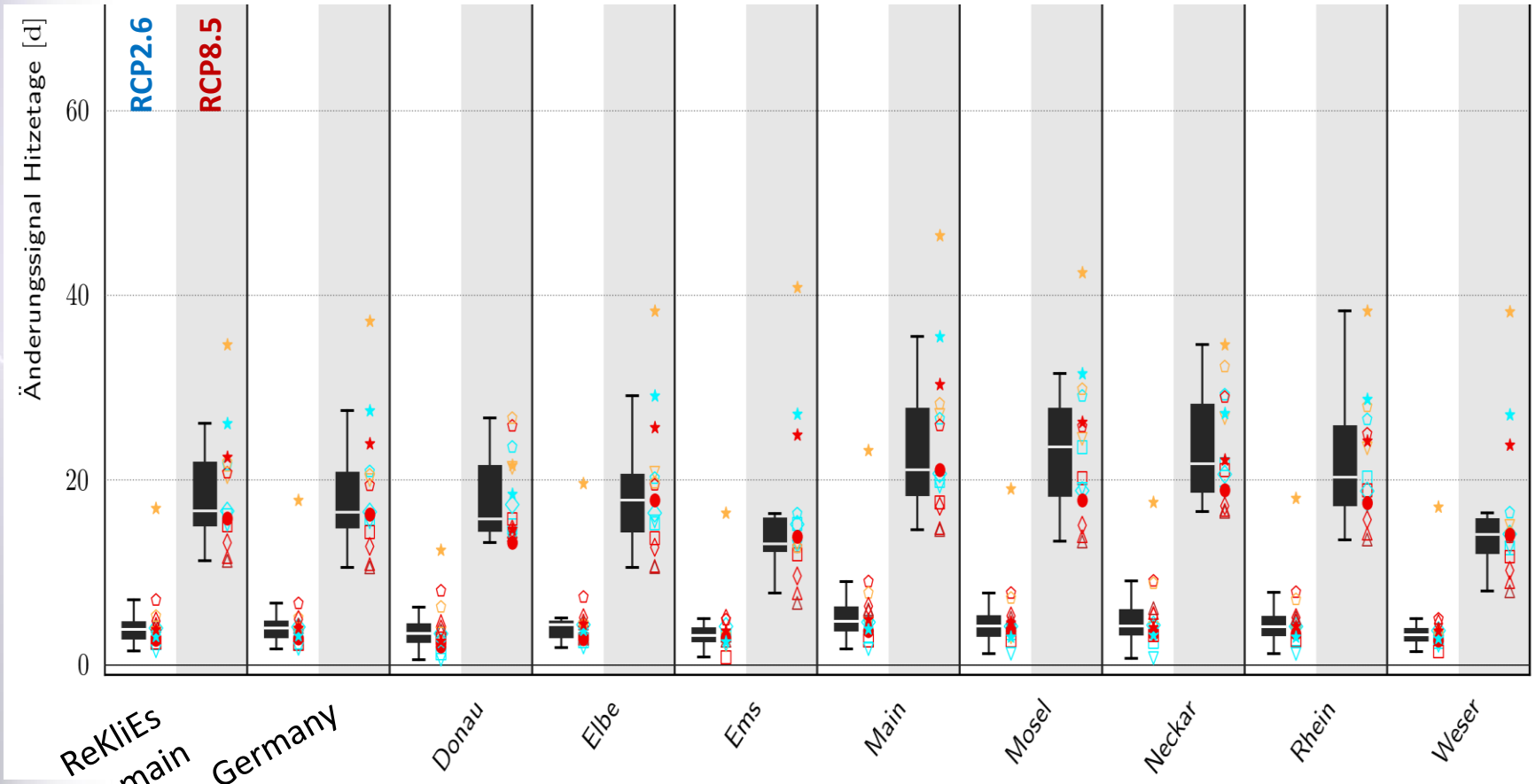

8 German river catchments

Decrease of frost days (T_{min} < 0 °C)

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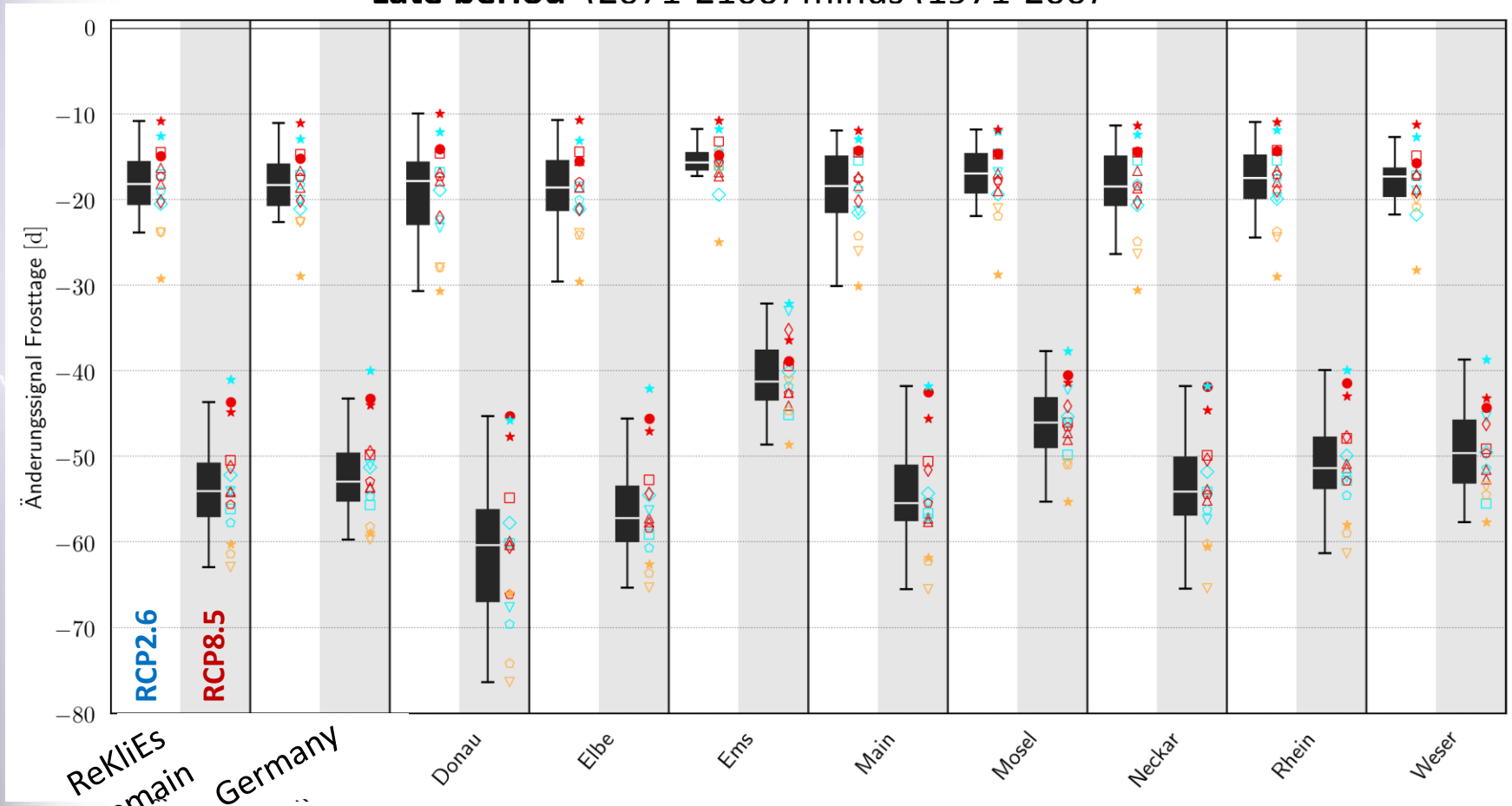

8 German river catchments

Summary of temperature effects

centennial climate change

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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

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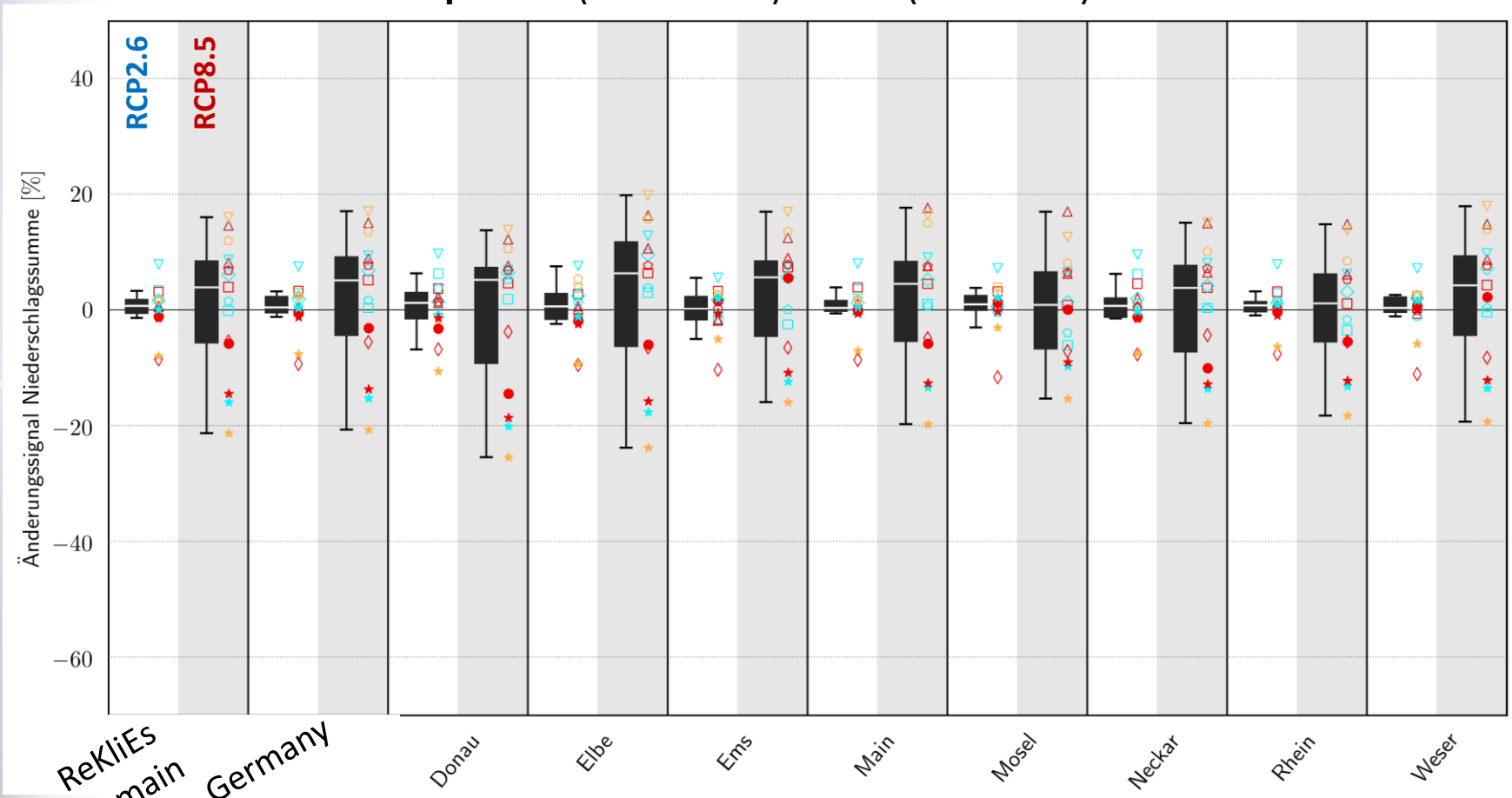
Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios
Late period (2071-2100) minus (1971-200)



8 German river catchments

Intensive precipitation

accumulated precipitation of intensive rain days (**r95ptot**)

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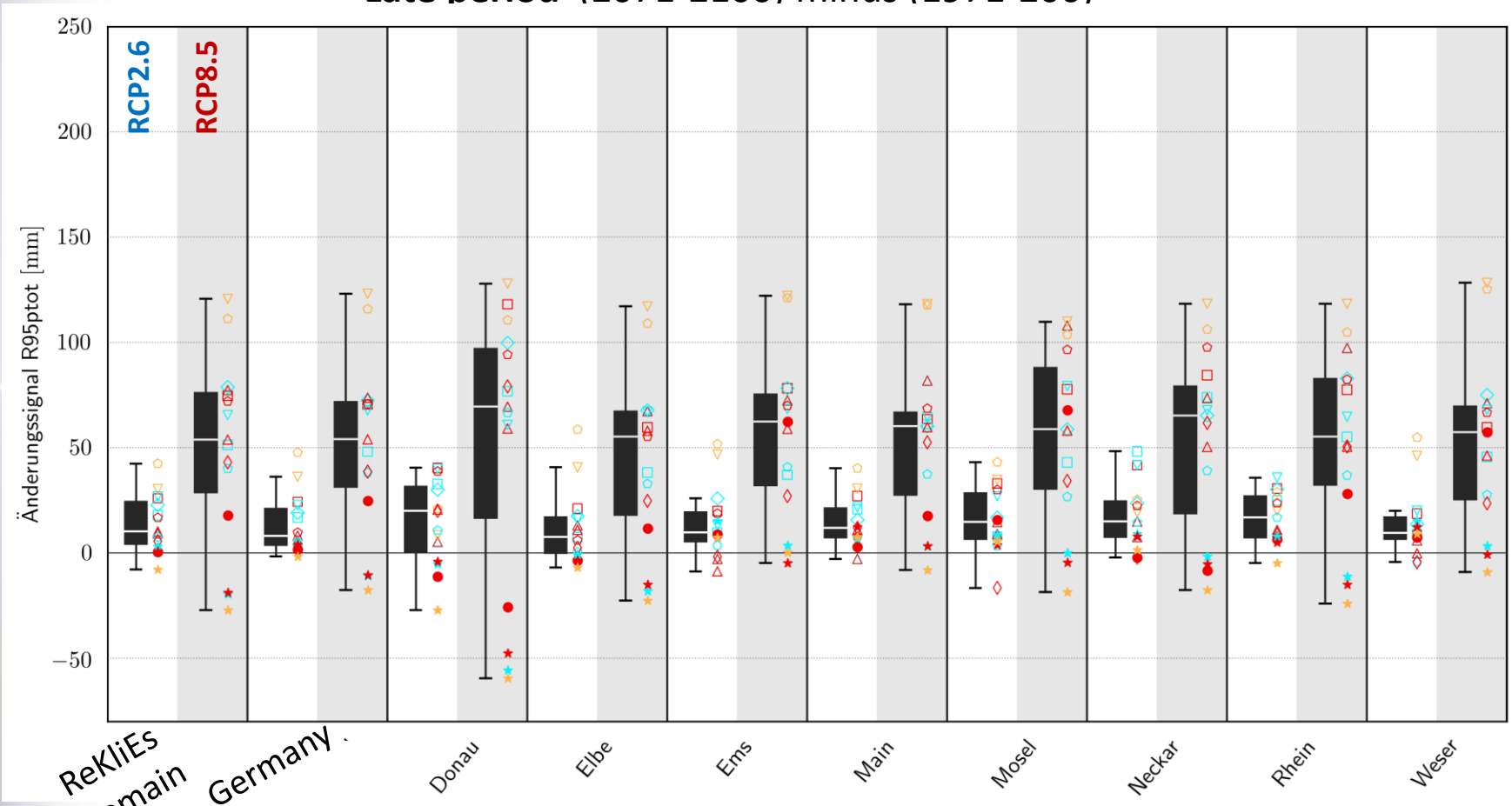
Differences of climatol. area means for 10 ReKliEs-subdomains and two scenarios

Late period (2071-2100) minus (1971-200)



8 German river catchments

Summary of precipitation effects

centennial climate change

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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

Summary and conclusions

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All temperature and precipitation changes evolve substantially weaker with a more moderate CO_2-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 CO_2 emissions

- consequently from all sectors
- globally
- Immediately

beginning with year 2020

No time left to opt for the right emission path!

Acknowledgements

Contributing project partners of ReKliEs-De

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- Peter Hoffmann, Christoph Menz, Arne Spekat (PIK)
- Hans Ramthun, Frank Toussaint (DKRZ)
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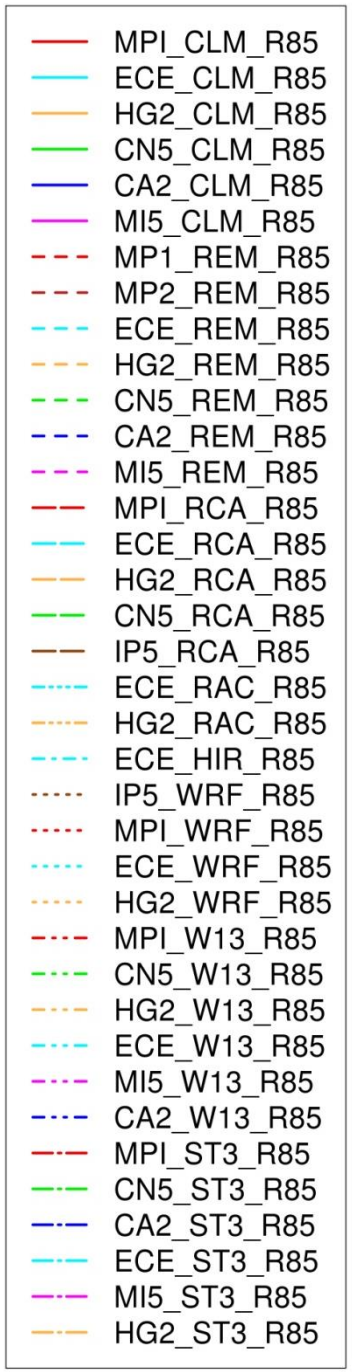
- Kai Radtke, Michael Woldt, Klaus Keuler (BTU)

- **Thank you for your attention**


⊙ CA2
⊙ CN5
⊙ ECE
□ CLM
◇ HIR
▽ RAC
⬠ RCA
★ ST3
⊙ HG2
▽ RAC
⬠ RCA
★ ST3
⊙ IP5
⊙ MI5
⊙ MPI
□ CLM
⬠ RCA
△ REM
★ ST3
● W13
◊ WRF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MP2_REM_R85
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CN5_REM_R85
CA2_REM_R85
MI5_REM_R85
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IP5_RCA_R85
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ECE_HIR_R85
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CN5_ST3_R85
CA2_ST3_R85
ECE_ST3_R85
MI5_ST3_R85
HG2_ST3_R85

ReKliEs-De data bas and domains

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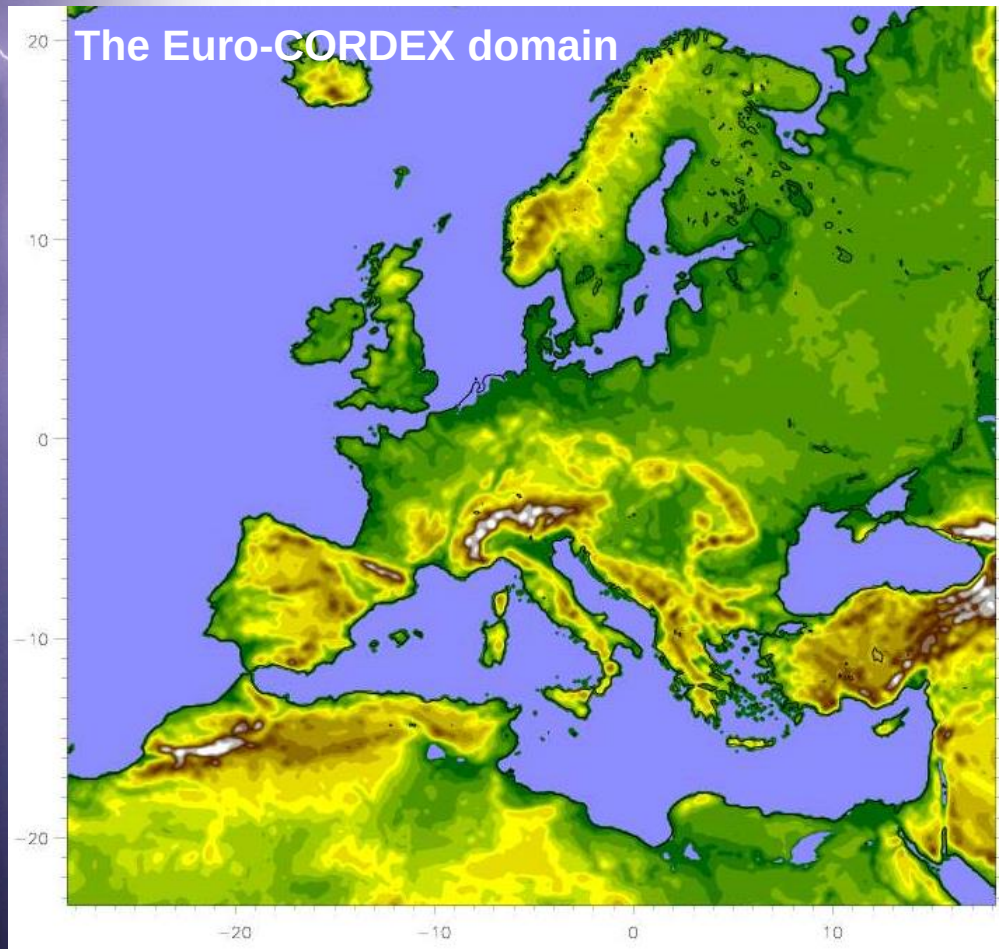
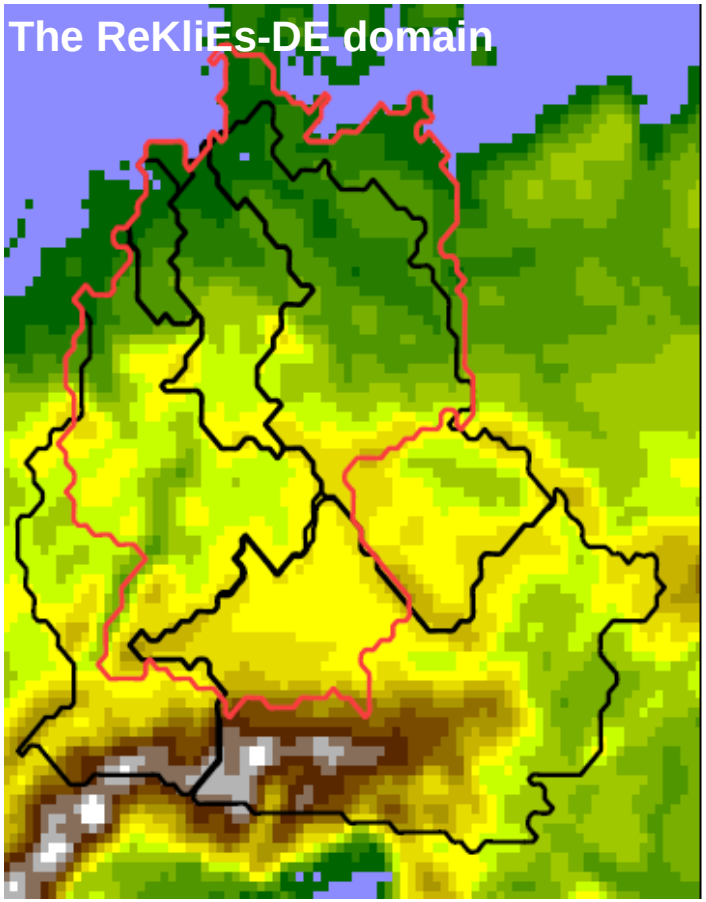
A combination of 25 Euro-CORDEX and 27 ReKliEs-DE simulations

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





Greenhouse gas scenarios

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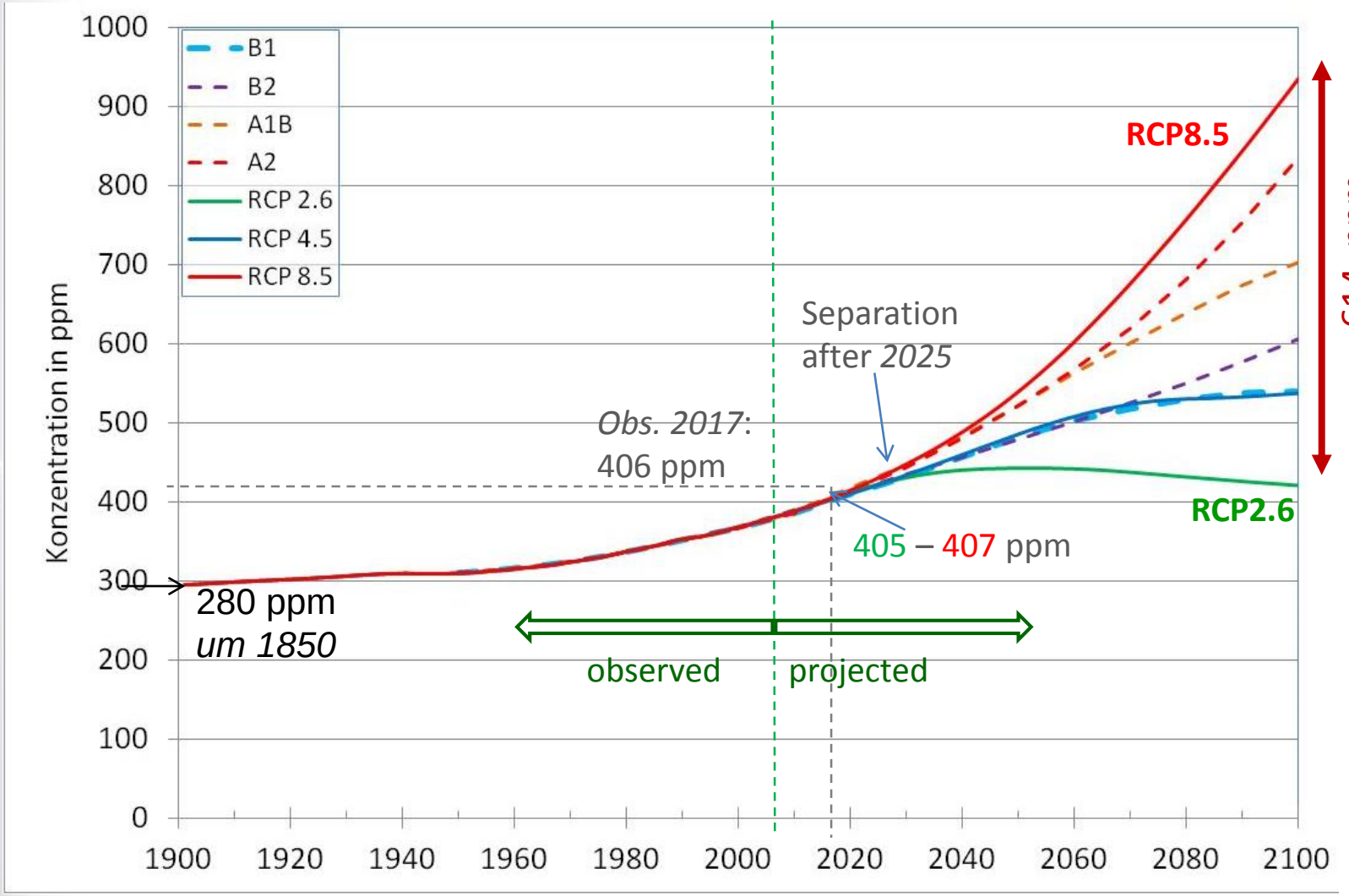
Development of CO_2 concentration from 1900 to 2100



Emission scenarios

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Development of CO_2 emissions from 1900 to 2100