Climate change impacts on river flow in England: a comparison of the UKCP18 and euro-CORDEX regional climate projections

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Background

- UKCP18’s perturbed physics ensemble (PPE) of Regional Climate Model (RCM) variants of the Met Office’s HadGEM-GC3.05 (CMIP6) for RCP8.5

Aim:

Assess how the UKCP18’s PPE-RCMs manifest in streamflow and where they sit compared to euro-CORDEX

Methods

Study Catchments:

1. Western Rother: steep, high natural variability, moderate permeability
2. Idle: lowland, slow-flowing, high permeability

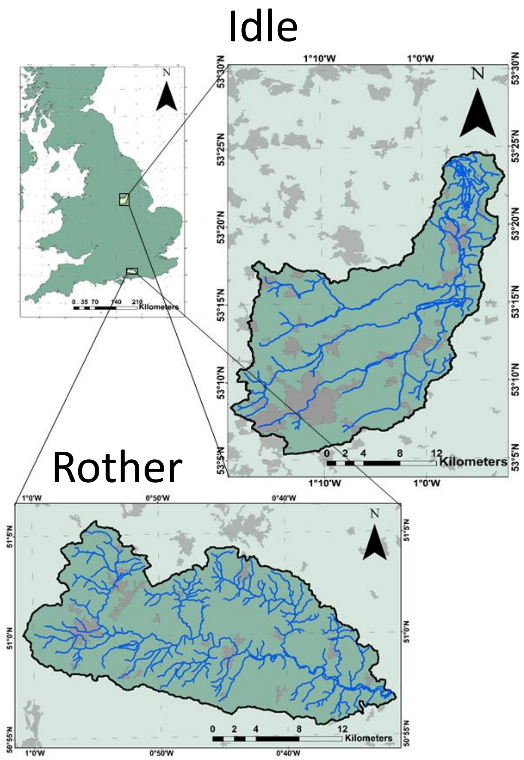

Fig. 1: Location of Study Catchments

Methods

Study Catchments:

1. Western Rother: steep, high natural variability, moderate permeability
2. Idle: lowland, slow-flowing, high permeability

Climate Projections

- 12 PPE-RCMs from UKCP18 for RCP8.5
- 18 RCMs from euro-CORDEX
  six different General Circulation Models (GCMs) across three RCPs
- bias corrected with linear scaling

Hydrological Model: SWAT+

Table 1: Considered Climate Projections

RCP	Driving GCM	RCM
8.5	HadGEM3-GC3.05	12 PPE ensembles , HadREM3-GA7-05
8.5	CNRM-CM5	ALADIN63
8.5	IPSL-CM5A-MR	WRF381P
8.5	NorESM1-M	HIRHAM5
8.5	MPI-ESM-LR	ALADIN63
8.5	IPSL-CM5-MR	REMO2015
8.5	HadGEM2-ES	HadREM3-GA7-05
4.5	CNRM-CM5	RACMO22E
4.5	EC-EARTH	RCA4
4.5	IPSL-CM5A-MR	RCA4
4.5	NorESM1-M	REMO2015
4.5	IPSL-CM5-MR	WRF381P
4.5	HadGEM2-ES	RACMO22E
2.6	CNRM-CM5	RACMO22E
2.6	EC-EARTH	HIRHAM5
2.6	EC-EARTH	RCA4
2.6	MPI-ESM-LR	RCA4
2.6	NorESM1-M	REMO2015
2.6	HadGEM2-ES	HadREM2-GA7-05

Results

- SWAT+ performed good to very good in simulating observed streamflow

Projected Climate Change impacts:

- Distinct differences between catchments and across ensembles
- Strongest hydrological response under UKCP18
- Largest model spread also found under UKCP18
- Annual streamflow increases are driven by high flow increases

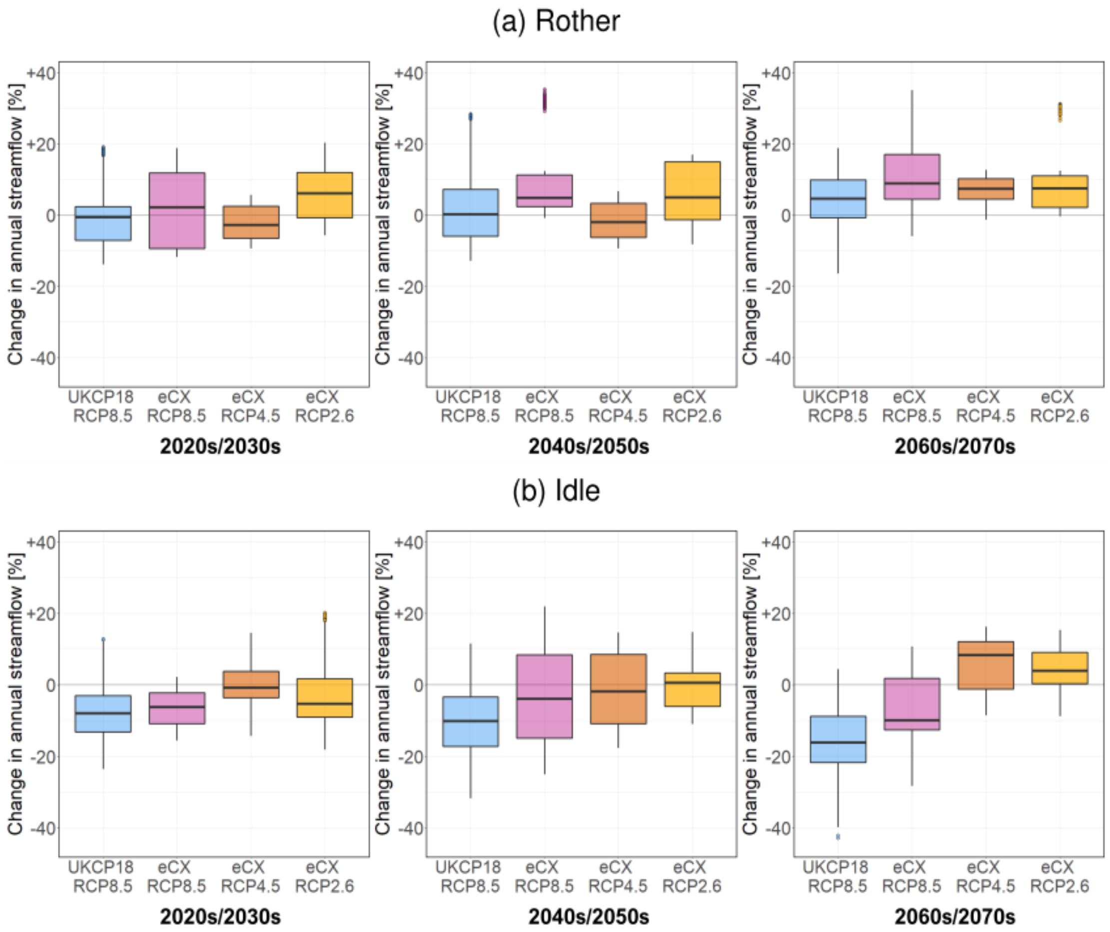

Fig.1: Change in mean annual streamflow, reference period: 2001-2017, [%]

Results

- SWAT+ performed good to very good in simulating observed streamflow

Projected Climate Change impacts:

- Distinct differences between catchments and across ensembles
- Strongest hydrological response under UKCP18
- Largest model spread also found under UKCP18
- Annual streamflow increases are driven by high flow increases
- euro-CORDEX for the same emissions pathway agree on direction of change w/ smaller magnitudes of change
- Low and medium emissions euro-CORDEX outline some wetter futures

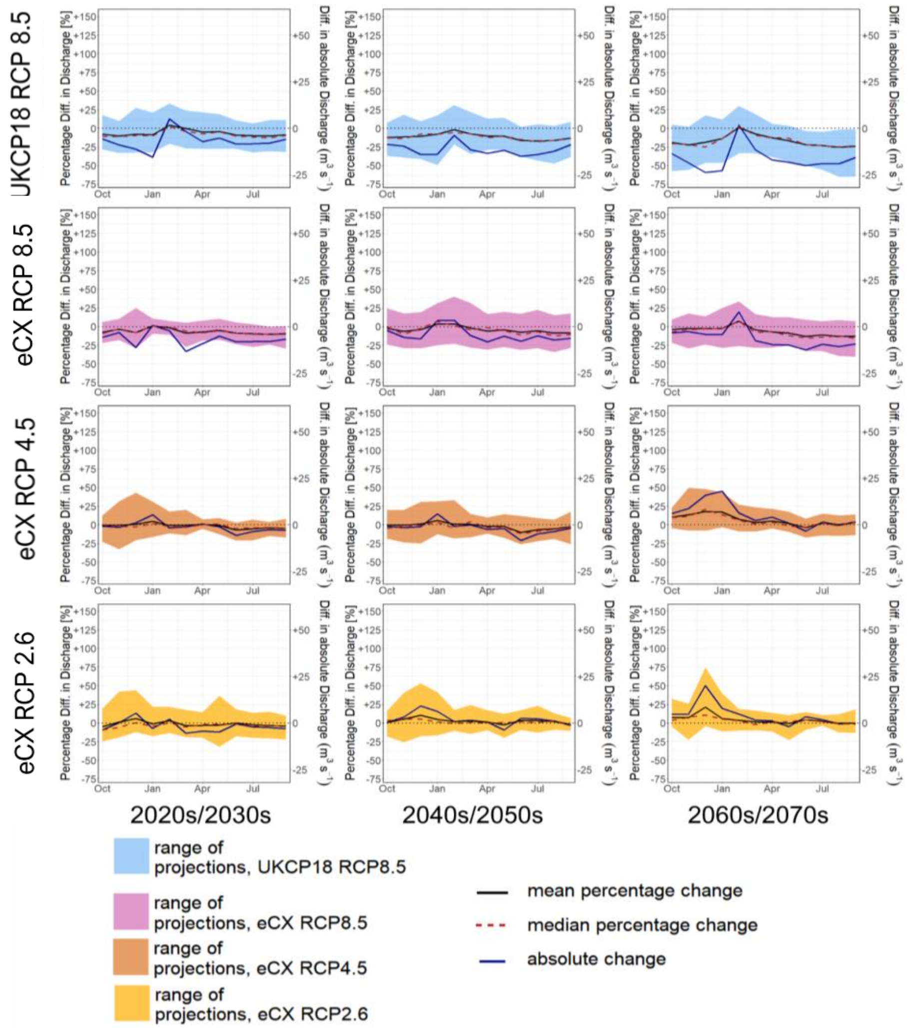

Fig. 2: Change in mean annual dynamics, reference period: 2001-2017, Idle [%]

Discussion

- PPE = high-end warming scenario useful for risk-averse decision making (Yamazaki et al., 2021)
- Parametric uncertainty within HadGEM-GC3.05 translates into higher range of streamflow projections than GCM-RCM uncertainty represented in euro-CORDEX
- UKCP18’s PPE - limited meaning as standalone projections, also considering recent findings on biases and high climatic sensitivity (Yamazaki et al., 2021; Rostron et al., 2020)

Management implications:

- Large envelope of uncertainty hinders scenario-led climate adaptation (Wilby & Dessai, 2010)
- smaller balanced subset, weighting according to performance, or storyline-approach (Shepherd et al., 2018) potentially better suited to address water management challenges

Thank you for the attention

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APPENDIX

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SWAT+ performance during the observations period

Table A1: SWAT+ performance during calibration and validation

	Calibration 2001 - 2008	**Validation** 2009 - 2017
Rother		
pbias (%)	5.1 - 14.9	-4.4 - 5.9
VE (%)	0.8 - 0.85	0.75 - 0.8
bR^2	0.77 - 0.83	0.78 - 0.83
KGE	0.65 - 0.8	0.54 - 0.75
NSE/NSE_inv	0.7 - 0.81 | 0.81 - 0.95	0.6 - 0.74 | 0.61 - 0.87
Idle		
pbias (%)	-2.8 - 9.3	-8.9 - 1.9
VE (%)	0.86 - 0.91	0.83 - 0.88
bR^2	0.79 - 0.87	0.71 - 0.81
KGE	0.71 - 0.93	0.73 - 0.88
NSE/NSE_inv	0.71 - 0.88 | 0.69 - 0.77	0.66 - 0.79 | 0.66 - 0.8

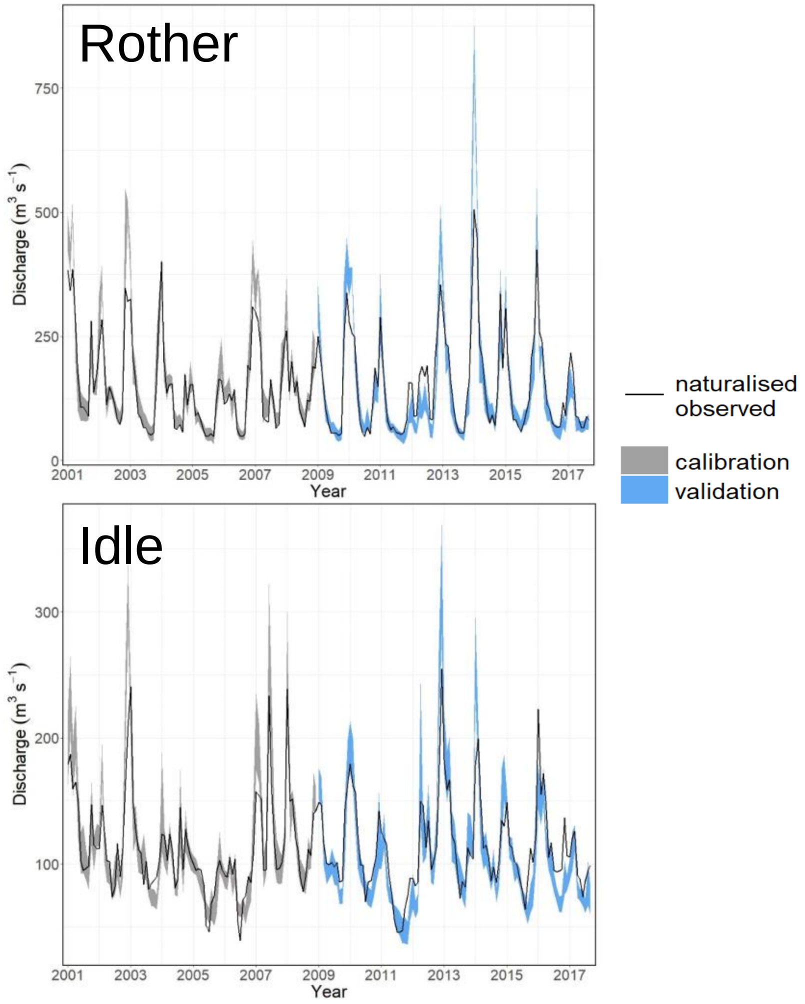

Fig. A1: SWAT+ -simulated streamflow during calibration and validation

Comparison of three bias correction methods (1/2)

Comparison of the ISIMIP method (Hempel et al., 2013), gamma-Pareto quantile mapping (GPQM) (Gutjahr and Heinemann, 2013) and linear scaling (LS) (Lenderink et al., 2007)

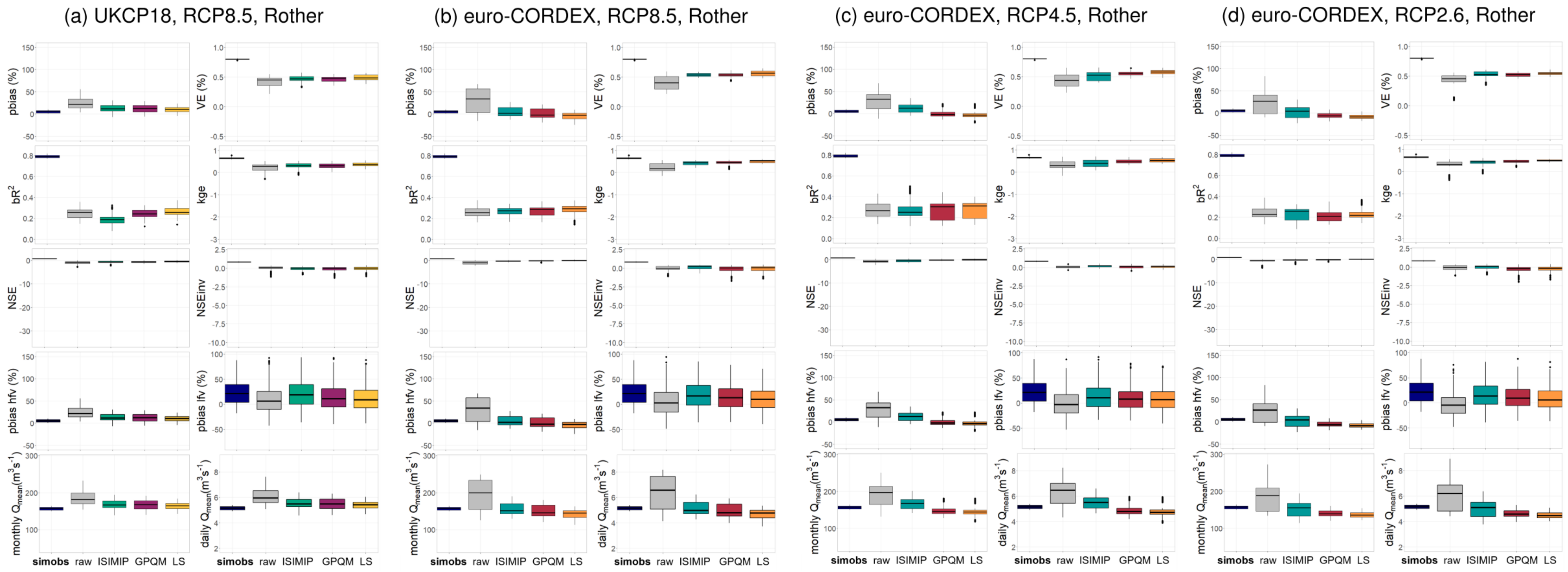

Fig. A2: Model Performance during observations period, models run with observed climate (simobs), uncorrected “raw” simulated climate and with climate simulations bias corrected with ISIMIP, GPQM and LS monthly performance according to pbias, VE, bR2, kge, NSE, NSE inv and in mean monthly flows, daily performance according to pbias, VE, bR 2, kge, NSE, NSEinv and in mean monthly flows, daily performance according to pbias in high flow volume (hfv,Q30 to Q5) and low flow volume (lfv, Q70 to Q95) and in mean daily flows, for the Rother (a-d) and Idle (e-h)

Comparison of three bias correction methods (2/2)

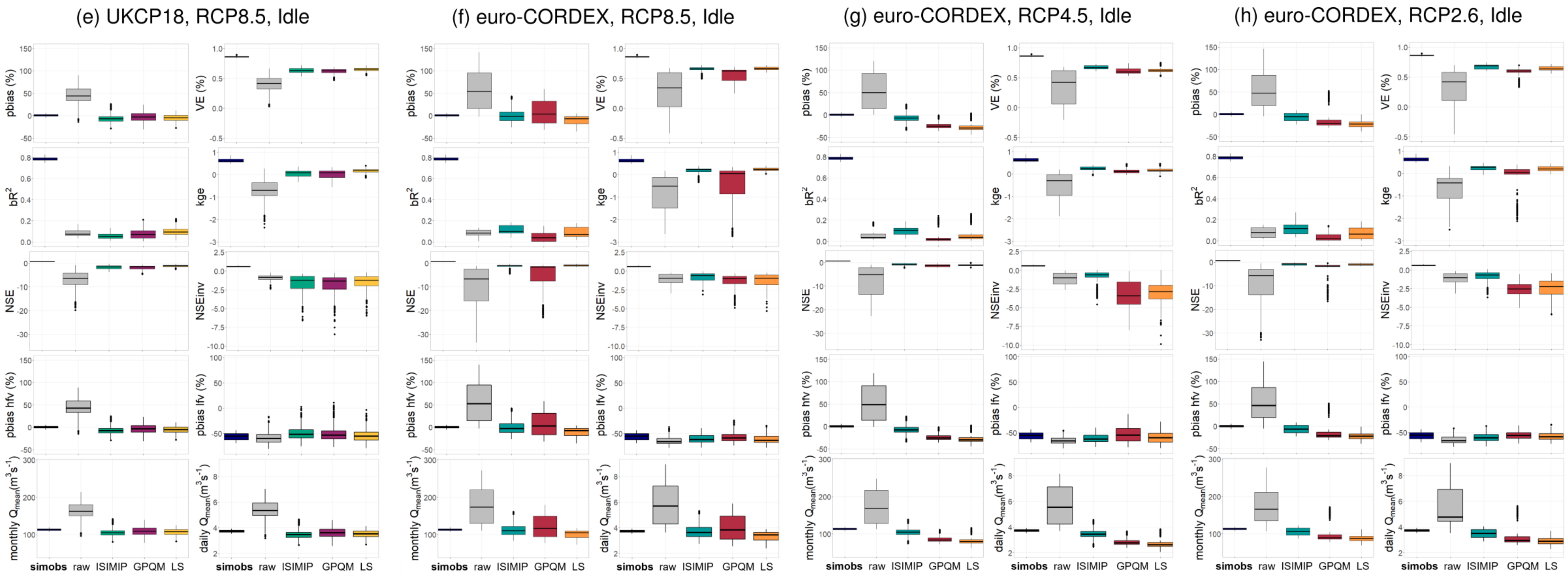

Fig. A2, continued

Additional Results, Rother

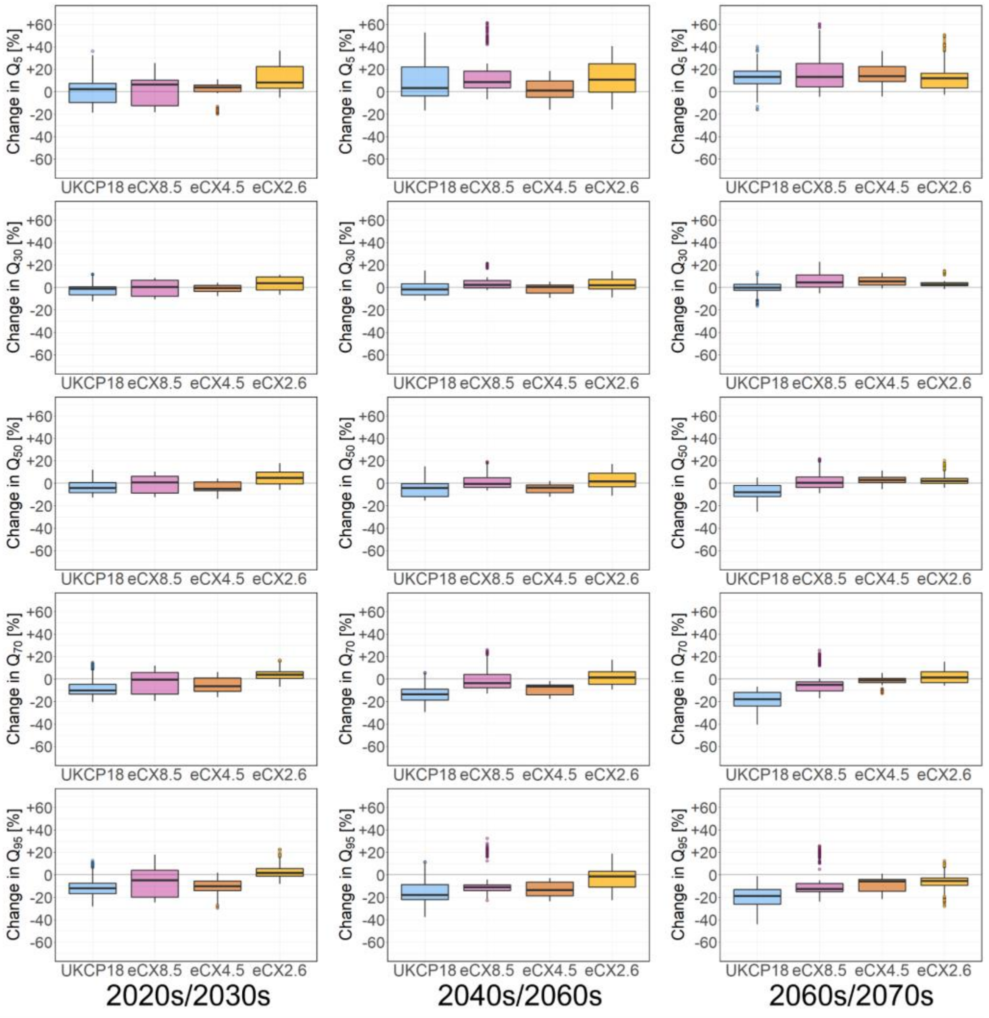

Fig. A3: Change in flow duration curve statistics, Rother [%]

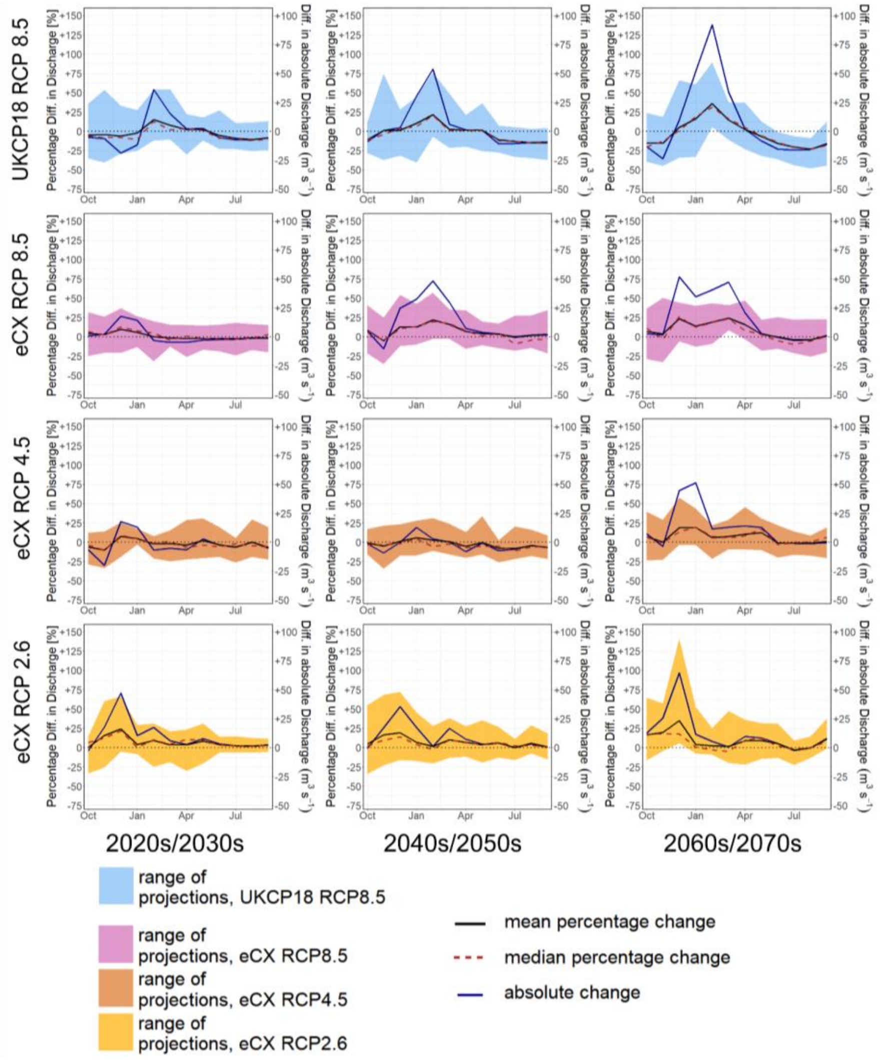

Fig. A4: Change in mean annual dynamics, Rother [%]

Additional Results, Idle & Percentage Changes

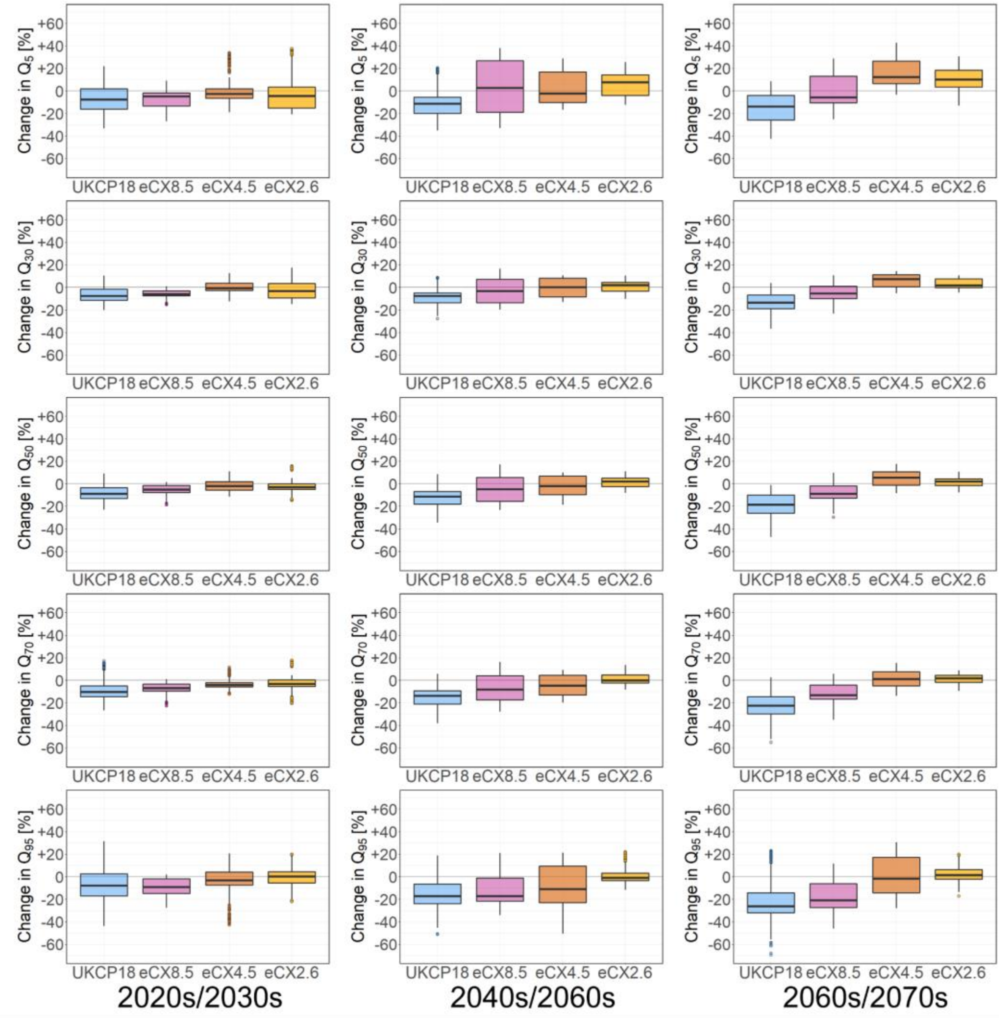

Fig. A5: Change in flow duration curve statistics, Idle [%]

Rother	**flow (m^3/s)**	**UKCP18 RCP 8.5 (%)**			**eCX RCP 8.5 (%)**			**eCX RCP 4.5 (%)**			**eCX RCP 2.6 (%)**		
period	2001 2017	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s 2050s	2060s 2070s
Jan	284.8	-2.3	10.1	16.1	5.4	12.4	13.5	4.7	5.7	19.0	3.9	6.8	4.0
Feb	220.6	15.2	21.4	36.0	-0.0	21.6	18.7	-2.4	2.7	5.8	9.2	1.6	2.1
Mar	188.6	7.6	2.7	14.7	-1.9	15.8	24.0	-1.7	0.6	7.4	3.5	9.9	1.7
Apr	135.2	2.1	1.4	2.0	-2.5	6.8	15.6	-4.1	-5.4	10.3	3.5	6.9	8.7
May	115.3	2.1	1.4	-6.7	-2.0	4.1	3.3	2.1	-0.8	12.2	8.5	3.6	9.2
Jun	83.9	-5.4	-11.2	-15.9	-2.4	3.1	-0.5	-3.6	-8.1	-0.9	4.1	5.8	5.1
Jul	81.3	-9.3	-13.3	-20.5	-2.6	-0.2	-4.0	-6.2	-8.2	-1.4	2.1	-0.1	-3.4
Aug	73.0	-10.7	-14.6	-23.4	-1.9	2.1	-4.0	-0.2	-4.8	-1.7	1.8	5.4	-0.4
Sep	68.8	-8.6	-15.1	-17.3	-1.4	3.0	1.7	-6.8	-6.6	0.9	3.5	0.6	12.1
Oct	123.8	-5.0	-10.7	-15.6	4.5	8.2	6.7	-6.4	-1.1	7.0	0.3	4.5	16.6
Nov	190.7	-4.2	1.0	-15.4	2.9	-5.2	3.5	-10.5	-5.0	0.1	15.6	16.5	19.8
Dec	228.5	-6.2	1.5	5.1	9.6	12.7	23.0	7.3	0.9	18.5	23.9	19.4	35.0
annual	149.1	-0.3	1.9	4.4	1.7	9.4	11.7	0.1	-0.9	8.9	7.7	7.8	9.5

Idle	**flow (m^3/s)**	**UKCP18 RCP 8.5 (%)**			**eCX RCP 8.5 (%)**			**eCX RCP 4.5 (%)**			**eCX RCP 2.6 (%)**		
period	2001 2017	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s 2050s	2060s 2070s	2020s 2030s	2040s/ 2050s	2060s 2070s
Jan	154.2	-8.7	-7.9	-13.9	0.5	3.3	-2.5	4.4	5.7	17.0	-1.4	4.7	6.1
Feb	138.3	4.2	-2.0	1.1	-1.7	3.6	7.3	-1.2	0.7	7.2	3.2	1.7	3.7
Mar	130.6	-0.2	-7.5	-7.5	-9.0	-2.1	-4.5	-0.7	0.4	3.0	-3.5	2.7	1.6
Apr	114.5	-4.9	-10.3	-12.9	-7.5	-5.9	-7.3	0.6	-2.2	5.0	-3.5	1.0	1.0
May	106.3	-4.3	-10.6	-16.6	-5.1	-4.5	-9.1	-1.1	-2.3	1.7	-3.1	-2.7	-1.0
Jun	94.9	-9.0	-16.4	-22.0	-9.1	-7.9	-13.2	-7.0	-10.1	-4.0	-0.2	3.6	4.4
Jul	85.7	-10.1	-17.0	-23.2	-9.9	-5.8	-11.3	-5.3	-6.7	2.3	-2.6	3.1	2.3
Aug	90.9	-10.4	-16.4	-25.5	-10.5	-8.9	-13.1	-4.4	-5.4	-0.0	-3.3	2.0	-0.7
Sep	87.7	-8.8	-13.3	-23.9	-9.7	-8.7	-13.0	-4.9	-2.7	3.1	-4.7	-1.9	0.1
Oct	102.6	-7.7	-12.2	-19.2	-7.9	-2.4	-4.3	-1.0	-0.8	10.0	-4.8	0.9	7.1
Nov	117.6	-10.3	-11.4	-22.3	-3.6	-6.4	-2.4	-0.7	-0.8	13.5	1.1	5.2	7.0
Dec	131.4	-8.0	-10.8	-18.9	-8.0	-4.3	-2.8	0.7	1.0	17.8	6.0	10.3	21.1
annual	112.8	-6.7	-11.5	-16.1	-7.4	-3.9	-6.2	-2.2	-3.1	6.2	-1.8	2.1	4.3

Table A2: Observed monthly flow in the reference period (2001-2017) and projected mean monthly percentage change in natural streamflow

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