Table 1. Characteristics of the study sites

	Upper Thames	Glaslyn	Calder	Coquet
Area (km^2)	1616	69	316	346
Maximum elevation (masl[1])	330	1080	556	775
Minimum elevation (masl[1])	52	30	40	71
Mean annual precipitation (mm/year)	762	2957	1251	968
Mean annual temperature (°C)	9.7	8.1	8.4	7.4
Mean annual PET (mm/yr)	522	477	486	473
Mean annual river flow (m^3/s)	15.3	5.8	8.8	6.1
Precipitation 90th percentile (mm/day)	6.7	24.4	10.3	7.7
Precipitation 95th percentile (mm/day)	10.2	34.2	14.8	11.9
[2]Q10 (m^3/s)	34.8	13.5	19.9	12.4
[3]Q95 (m^3/s)	1.90	0.55	1.99	0.84

[1] Meters above the sea level

[2] River flow that is exceeded for 10% of the daily river flow time series

[3] River flow that is exceeded for 95% of the daily river flow time series

Table 2. RCMs used in this study

RCM	Institute	Period	Reference
CCLM-CLMCOM	Brandenburg University of Technology (BTU)	1989-2008	Böhm et al., 2006; Rockel et al., 2008
HIRHAM 5	Danish Meteorological Institute (DMI)	1989-2008	Christensen et al., 1998
RACMO22E	Royal Netherlands Meteorological Institute (KNMI)	1979-2008	Van Meijgaard et al., 2012
RCA4	Swedish Meteorological and Hydrological Institute (SMHI)	1984-2008	Samuelsson et al., 2011
WRF 3.3.1	Institute Pierre Simon Laplace (IPSL) and Institute National de l'Environment Industriel et des Risques (INERIS)	1989-2008	Skamarock et al., 2008

Table 3. Description of the precipitation, temperature and river flow indices used in this study

Index	Description	Performance measure
Precipitation		
95th percentile	A measure of very extreme events: 95th percentile of daily precipitation	Bias (mm/day)
90th percentile	A measure of extreme events: 90th percentile of daily precipitation	Bias (mm/day)
50th percentile	50th percentile of daily precipitation	Bias (mm/day)
25th percentile	25th percentile of daily precipitation	Bias (mm/day)
[a] Wet spell length	Mean wet spell length for a given month of the year	Bias (days)
[a] Dry spell length	Mean dry spell length for a given month of the year	Bias (days)
[a] Annual mean precipitation	Annual accumulated precipitation	Mean percentage error
[a] Monthly mean precipitation	Accumulated precipitation for a given month of the year	Mean percentage error
[b] Relative daily MSE	Mean daily square error, shown as ratio to the largest MSE result (considering both corrected and uncorrected RCMS)	MSE (ratio)
[b] Spearman correlation coefficient	Spearman correlation coefficients between the daily simulated and observed time series	Index
[a] Maximum one day precipitation (RX1day)	Maximum one-day precipitation for a given month of the year	Mean percentage error
[a] Simple Daily Intensity Index (SDII)	Ratio of the annual total precipitation to the number of wet days ($\geq$1 mm) in all years	Index
[a] Number of heavy precipitation days (R10)	Mean number of days with precipitation $\geq$ 10mm within a year	Bias (days)
[a] Number of very heavy precipitation days (R20)	Mean number of days with precipitation $\geq$ 20mm within a year	Bias (days)
[a] Very wet days (R95p)	Mean annual accumulated precipitation from days > 95th percentile in all years	Mean percentage error
Temperature		
[a] Annual mean temperature	Annual mean temperature over the validation period	Mean percentage error
[a] Monthly mean temperature	Monthly mean temperature	Mean percentage error
99th percentile of daily mean temperature	99th percentile of the daily mean temperature	Bias (°C/day)
1st percentile of daily mean temperature	1st percentile of the daily mean temperature	Bias (°C/day)
[b] Pearson correlation coefficient	Pearson correlation coefficient between the daily RCM and observation time series	Index
River Flow		
Q10	A measure of high flows: river flow that is exceeded for 10% of the daily river flow time series	Bias (m^3/s)
Q95	A measure of low flows: river flow that is exceeded for 95% of the daily river flow time series	Bias (m^3/s)
[a] Annual Q10 frequency	Mean number of days for which the observed Q10 is exceeded within a year	Bias (days)
[a] Annual mean river flow	Annual mean daily river flow over the validation period	Mean percentage error
[a] Winter (DJF) mean river flow	Winter mean daily river flow over the validation period	Mean percentage error
[a] Spring (MAM) mean river flow	Spring mean daily river flow over the validation period	Mean percentage error
[a] Summer (JJA) mean river flow	Summer mean daily river flow over the validation period	Mean percentage error
[a] Autumn (SON) mean river flow	Autumn mean daily river flow over the validation period	Mean percentage error
[b] Monthly NSE	Monthly Nash Sutcliffe Efficiency index	Index
[b] Relative daily MSE	Mean daily square error, shown as ratio to the largest MSE result (considering both corrected and uncorrected RCMS)	MSE (ratio)
[b] Spearman correlation coefficient	Spearman correlation coefficient between the daily simulated and observed time series	Index

[a] Estimated using the long term mean (one value over the entire series)

[b] Estimated considering the time series values (one value per time step)

Table 4. Indices from the calibration and validation of the hydrological models

				Q10 bias		Q95 bias	
Catchment	Step	Period	Daily NSE	(m^3/s)	(%)	(m^3/s)	(%)
Upper Thames	Calibration	1986-2010	0.70	-2.1	-6	-0.45	-25
	Validation	1961-1985	0.57	1.5	5	-0.90	-44
Glaslyn	Calibration	1991-2010	0.78	1.0	8	-0.07	-11
	Validation	1971-1990	0.78	0.7	5	-0.03	-6
Calder	Calibration	1994-2010	0.62	1.5	8	-0.31	-16
	Validation	1976-1993	0.60	1.3	7	-0.24	-12
Coquet	Calibration	1992-2010	0.63	1.3	11	-0.24	-27
	Validation	1973-1991	0.52	-0.6	-5	-0.25	-31

Table 5. RCM rank for the temperature indices for each catchment: 1 = best, 10 = worst. The asterisks (*) indicate the resolution with the best simulation skill of each RCM in each catchment

		99th percentile	1st percentile	Annual mean Temp.	Monthly mean Temp.	Correlation	Average score	Ranking	
Upper Thames	0.11°CCLM	10	7	2	9	1	5.8	6	*
	0.11°HIRHAM	3	9	3	5	6	5.2	5	
	0.11°RACMO	2	8	9	7	4	6.0	7	
	0.11°RCA	7	5	10	10	5	7.4	10	
	0.11°WRF	4	1	5	4	8	4.4	2	*
	0.44°CCLM	9	10	1	8	2	6.0	7	
	0.44°HIRHAM	1	6	4	3	9	4.6	3	*
	0.44°RACMO	5	4	7	2	3	4.2	1	*
	0.44°RCA	8	2	6	1	7	4.8	4	*
	0.44°WRF	6	3	8	6	10	6.6	9	
Glaslyn	0.11°CCLM	9	2	4	3	1	3.8	3	*
	0.11°HIRHAM	7	6	2	4	7	5.2	5	*
	0.11°RACMO	3	7	1	1	4	3.2	1	*
	0.11°RCA	2	4	3	2	6	3.4	2	*
	0.11°WRF	4	8	5	6	10	6.6	7	*
	0.44°CCLM	10	1	6	5	2	4.8	4	
	0.44°HIRHAM	8	3	8	7	9	7.0	8	
	0.44°RACMO	5	5	7	8	3	5.6	6	
	0.44°RCA	6	9	9	9	5	7.6	9	
	0.44°WRF	1	10	10	10	8	7.8	10	
Calder	0.11°CCLM	9	7	8	8	1	6.6	7	
	0.11°HIRHAM	5	9	7	7	5	6.6	7	
	0.11°RACMO	8	10	10	10	4	8.4	9	
	0.11°RCA	10	8	9	9	6	8.4	9	
	0.11°WRF	7	3	1	4	8	4.6	4	*
	0.44°CCLM	6	6	6	5	2	5	5	*
	0.44°HIRHAM	4	2	2	1	9	3.6	2	*
	0.44°RACMO	2	4	5	2	3	3.2	1	*
	0.44°RCA	3	1	4	3	7	3.6	2	*
	0.44°WRF	1	5	3	6	10	5	5	
Coquet	0.11°CCLM	9	2	2	3	2	3.6	3	*
	0.11°HIRHAM	1	3	3	2	5	2.8	1	*
	0.11°RACMO	3	7	9	7	4	6.0	5	*
	0.11°RCA	7	6	8	4	6	6.2	6	*
	0.11°WRF	5	1	1	1	8	3.2	2	*
	0.44°CCLM	4	4	7	5	1	4.2	4	
	0.44°HIRHAM	10	8	5	6	9	7.6	9	
	0.44°RACMO	6	9	6	9	3	6.6	8	
	0.44°RCA	2	5	10	8	7	6.4	7	
	0.44°WRF	8	10	4	10	10	8.4	10	

Table 6. RCM rank for the precipitation indices for each catchment: 1 = best, 10 = worst. The asterisks (*) indicate the resolution with the best simulation skill of each RCM in each catchment

		Pr 95th	Pr 90th	Pr 50th	Pr 25th	Annual Mean	Monthly MSE	Dry Spell Length	Wet Spell Length	Monthly Mean	Correlation	SDII	R10	R20	R95p	RX1day	Average score	Ranking	
Upper Thames	0.11°CCLM	8	5	1	2	5	2	1	4	5	1	6	8	4	8	2	4.1	1	*
	0.11°HIRHAM	7	4	4	3	3	5	6	6	1	3	5	7	6	3	7	4.7	4	
	0.11°RACMO	3	2	9	8	7	3	4	5	4	10	9	3	5	5	9	5.7	8	
	0.11°RCA	10	10	10	10	10	10	10	10	10	6	2	10	10	10	8	9.1	10	
	0.11°WRF	1	1	6	7	6	8	7	3	8	5	7	1	3	1	3	4.5	2	*
	0.44°CCLM	9	9	2	1	8	4	3	8	7	2	4	9	8	9	1	5.6	7	
	0.44°HIRHAM	5	6	3	5	2	7	5	9	3	7	3	4	1	4	5	4.6	3	*
	0.44°RACMO	4	3	5	6	4	1	2	2	2	9	8	5	7	6	6	4.7	4	*
	0.44°RCA	2	8	8	4	9	9	9	1	9	4	1	2	1	2	4	4.9	6	*
	0.44°WRF	6	7	7	9	1	6	8	7	6	8	10	6	9	7	10	7.1	9	
Glaslyn	0.11°CCLM	5	5	8	2	5	5	6	5	5	1	5	5	5	5	5	4.8	5	*
	0.11°HIRHAM	1	1	6	5	1	3	5	3	2	3	1	3	1	1	1	2.5	1	*
	0.11°RACMO	3	3	3	9	3	1	3	8	3	2	3	2	3	2	4	3.5	3	*
	0.11°RCA	2	2	2	10	2	2	8	6	1	6	2	1	2	3	2	3.4	2	*
	0.11°WRF	4	4	1	6	4	4	4	4	4	7	4	4	4	4	3	4.1	4	*
	0.44°CCLM	10	9	10	3	9	9	9	9	9	5	9	9	9	8	7	8.3	9	
	0.44°HIRHAM	9	10	9	1	10	10	10	10	10	9	7	10	10	9	9	8.9	10	
	0.44°RACMO	7	7	4	7	7	7	2	1	7	4	10	7	7	7	8	6.1	7	
	0.44°RCA	8	8	7	4	8	8	7	7	8	8	8	8	8	10	10	7.8	8	
	0.44°WRF	6	6	5	8	6	6	1	2	6	10	6	6	6	6	6	5.7	6	
Calder	0.11°CCLM	1	2	2	1	1	1	2	3	1	1	1	2	2	2	9	2.1	1	*
	0.11°HIRHAM	10	10	8	5	9	9	7	8	9	5	7	9	10	10	10	8.4	9	
	0.11°RACMO	2	1	9	9	3	5	5	9	4	4	4	1	1	1	3	4.1	2	*
	0.11°RCA	9	9	10	10	10	10	10	10	10	6	3	10	9	9	1	8.4	9	
	0.11°WRF	3	3	6	4	6	8	6	5	7	8	2	4	3	3	8	5.1	5	*
	0.44°CCLM	6	7	4	2	8	3	4	4	8	2	5	7	4	6	2	4.8	3	
	0.44°HIRHAM	4	4	1	3	7	4	9	6	6	7	6	3	5	4	5	4.9	4	*
	0.44°RACMO	8	8	7	7	5	2	3	1	3	3	10	8	8	8	6	5.8	7	
	0.44°RCA	7	6	3	6	4	7	8	2	5	9	8	6	7	7	7	6.1	8	*
	0.44°WRF	5	5	5	8	2	6	1	7	2	10	9	5	6	5	4	5.3	6	
Coquet	0.11°CCLM	4	5	1	1	2	1	1	3	1	1	3	4	2	1	2	2.1	1	*
	0.11°HIRHAM	6	9	9	7	9	9	9	7	9	5	1	7	5	6	4	6.8	8	
	0.11°RACMO	5	3	6	8	1	3	7	5	2	4	9	5	4	5	5	4.8	4	*
	0.11°RCA	10	10	10	10	10	10	10	10	10	9	7	10	9	10	1	9.1	10	
	0.11°WRF	2	1	5	3	3	6	5	6	3	7	5	2	1	2	3	3.6	2	*
	0.44°CCLM	7	6	4	2	8	4	3	8	7	2	3	6	7	7	6	5.3	6	
	0.44°HIRHAM	3	2	8	9	4	5	8	2	4	8	1	1	3	4	8	4.7	3	*
	0.44°RACMO	8	7	3	4	6	2	2	4	6	3	9	8	10	9	10	6.1	7	
	0.44°RCA	1	4	7	5	5	8	6	1	5	6	7	3	6	3	7	4.9	5	*
	0.44°WRF	9	8	2	6	7	7	4	9	8	10	5	9	8	8	9	7.3	9	

Table 7. RCM rank for the river flow indices for each catchment: 1 = best, 10 = worst. The asterisks (*) indicate the resolution with the best simulation skill of each RCM in each catchment

		Annual mean RF	Winter mean RF	Spring mean RF	Summer mean RF	Autumn mean RF	Monthly NSE	Daily MSE	Spearman correlation	Q10	Annual Q10 frequency	Q95	Average	Rank	
Upper Thames	0.11° CCLM	1	2	2	3	3	1	1	4	1	1	1	1.8	1	*
	0.11° HIRHAM	3	4	4	2	1	3	3	1	3	3	4	2.8	2	*
	0.11° RACMO	8	9	8	6	9	9	8	7	8	8	9	8.1	9	
	0.11° RCA	10	10	10	10	10	10	10	10	10	10	10	10.0	10	
	0.11° WRF	7	1	6	9	5	6	6	8	5	6	8	6.1	6	*
	0.44° CCLM	4	7	1	4	7	2	2	3	6	4	3	3.9	4	
	0.44° HIRHAM	2	5	3	1	2	4	5	5	2	2	2	3.0	3	
	0.44° RACMO	5	6	5	5	6	5	4	2	4	5	7	4.9	5	*
	0.44° RCA	9	8	9	7	8	8	9	6	9	9	6	8.0	8	*
	0.44° WRF	6	3	7	8	4	7	7	9	7	7	5	6.4	7	
Glaslyn	0.11° CCLM	5	5	5	6	6	5	5	4	5	5	8	5.36	5	*
	0.11° HIRHAM	1	1	1	4	1	1	3	2	1	1	4	1.82	1	*
	0.11° RACMO	2	2	2	3	3	2	1	1	2	2	2	2	2	*
	0.11° RCA	3	3	3	1	2	3	2	6	3	3	1	2.73	3	*
	0.11° WRF	4	4	4	2	4	4	4	5	4	4	3	3.82	4	*
	0.44° CCLM	9	9	10	10	10	9	9	8	10	8	9	9.18	9	
	0.44° HIRHAM	10	10	9	9	9	10	10	9	9	8	10	9.36	10	
	0.44° RACMO	7	6	7	8	7	7	7	3	7	7	6	6.55	7	
	0.44° RCA	8	8	8	7	8	8	8	10	8	10	7	8.18	8	
	0.44° WRF	6	7	6	5	5	6	6	7	6	6	5	5.91	6	
Calder	0.11° CCLM	2	2	6	4	5	2	1	2	1	1	1	2.45	2	*
	0.11° HIRHAM	9	10	9	8	9	9	9	4	9	9	9	8.55	9	
	0.11° RACMO	6	6	7	6	6	5	6	3	6	8	8	6.09	6	
	0.11° RCA	10	9	10	10	10	10	10	9	10	10	10	9.82	10	
	0.11° WRF	7	8	8	9	2	8	8	6	7	7	7	7	8	
	0.44° CCLM	8	5	5	7	8	6	3	5	8	6	6	6.09	6	
	0.44° HIRHAM	5	4	3	5	7	4	5	10	5	5	4	5.18	5	*
	0.44° RACMO	3	3	2	1	1	1	2	1	3	2	2	1.91	1	*
	0.44° RCA	4	7	4	3	3	7	7	8	4	4	5	5.09	4	*
	0.44° WRF	1	1	1	2	4	3	4	7	2	3	3	2.82	3	*
Coquet	0.11° CCLM	1	5	1	1	6	4	5	1	4	1	1	2.73	1	*
	0.11° HIRHAM	9	6	9	9	8	9	9	5	8	9	9	8.18	9	
	0.11° RACMO	7	1	7	7	5	6	3	6	2	2	8	4.91	5	
	0.11° RCA	10	10	10	10	10	10	10	10	10	10	10	10	10	
	0.11° WRF	2	2	2	5	2	2	6	4	1	3	5	3.09	2	*
	0.44° CCLM	8	9	8	4	9	7	2	2	9	8	2	6.18	7	
	0.44° HIRHAM	6	3	4	8	7	8	8	9	5	7	7	6.55	8	*
	0.44° RACMO	3	7	3	2	3	1	1	3	6	6	4	3.55	3	*
	0.44° RCA	5	4	6	6	4	5	7	7	3	4	6	5.18	6	*
	0.44° WRF	4	8	5	3	1	3	4	8	7	5	3	4.64	4	

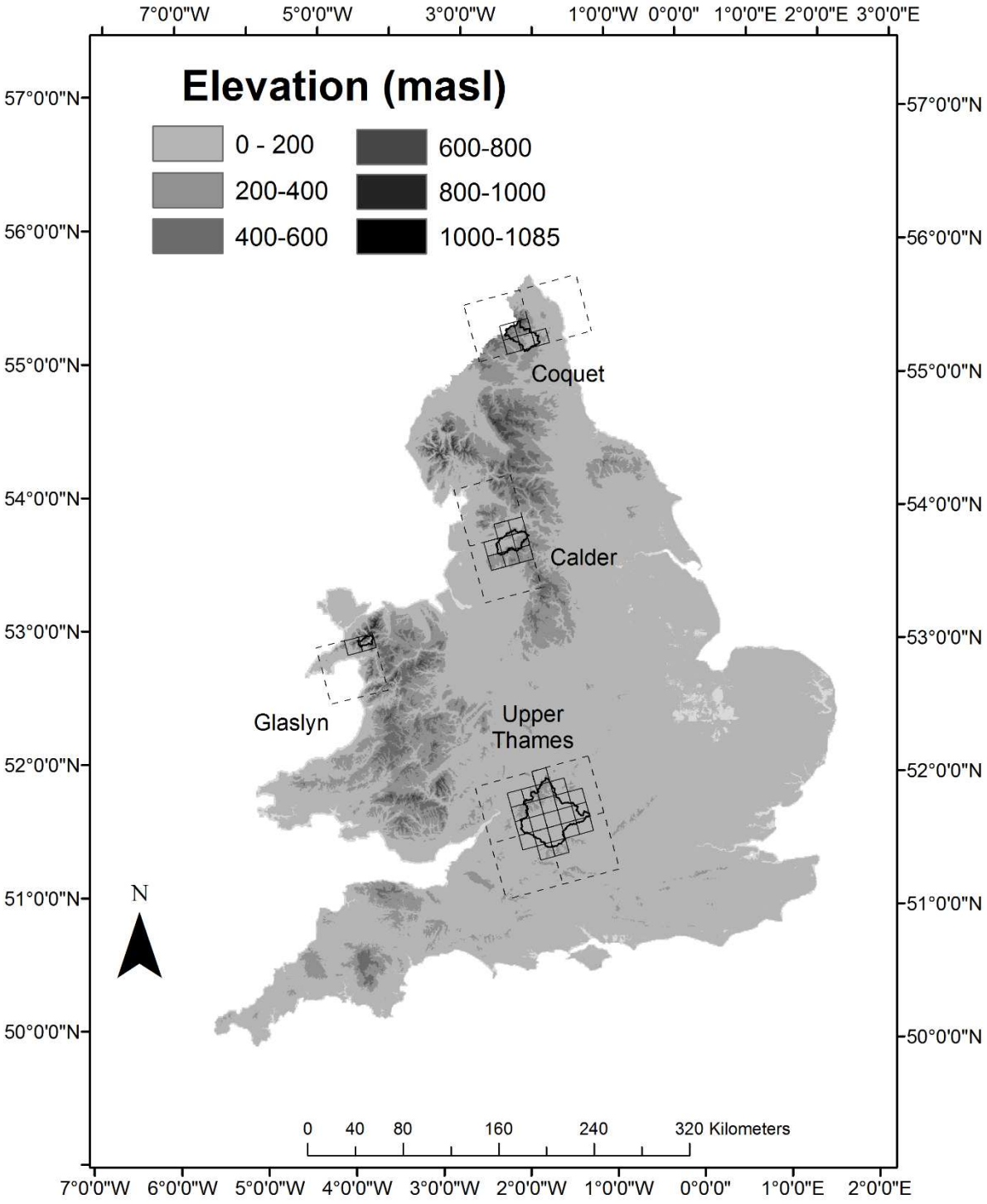

Figure 1. Location of the study catchments and the RCM grid boxes used for their simulation. The 0.11° and 0.44° grid boxes are shown with solid and dashed lines, respectively

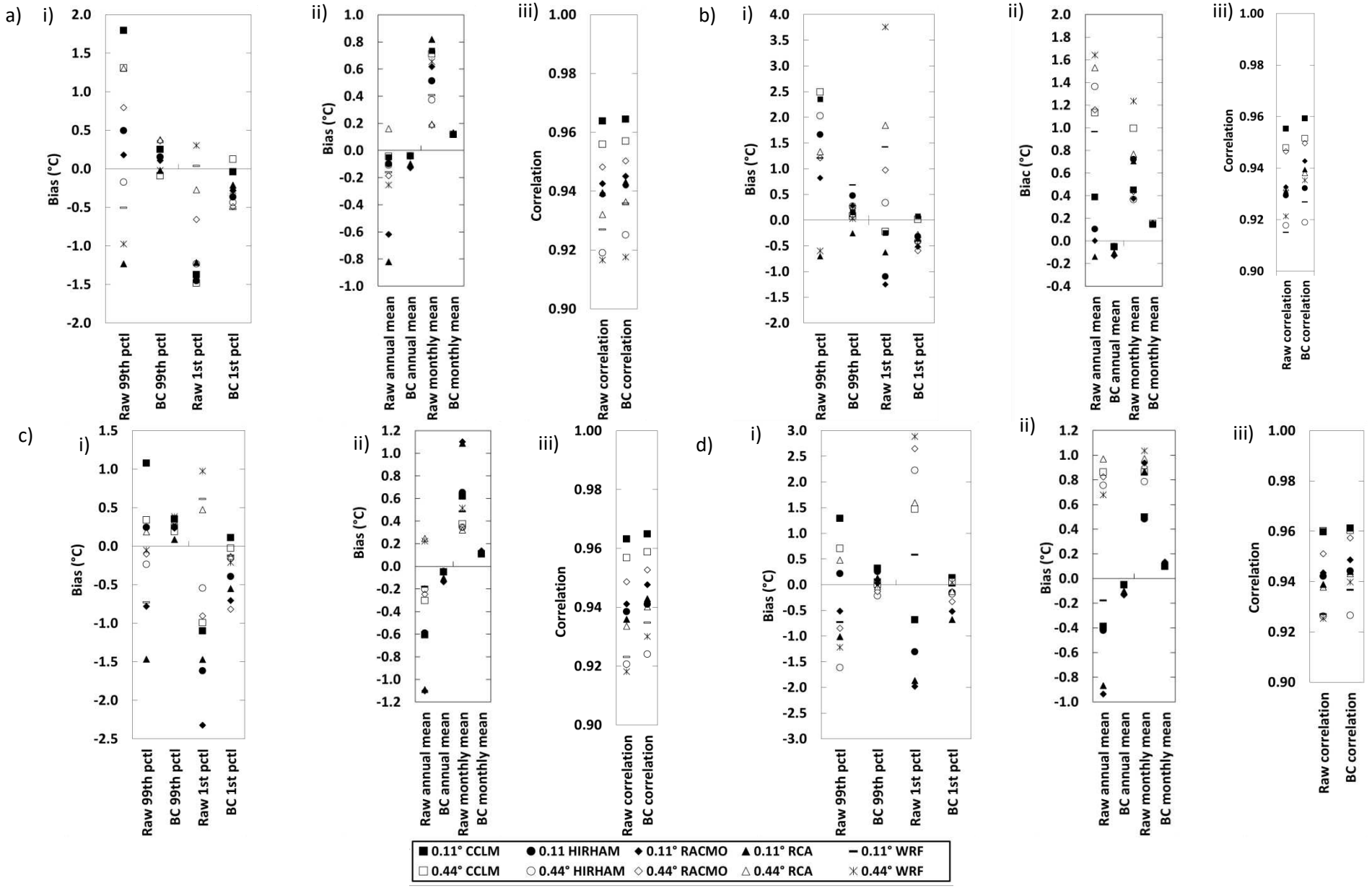

Figure 2. Results of the temperature performance measures, described on Table 3, for the a) upper Thames, b) Glaslyn, c) Calder and d) Coquet catchments. Please note the differences in the y-axis (BC = Bias corrected)

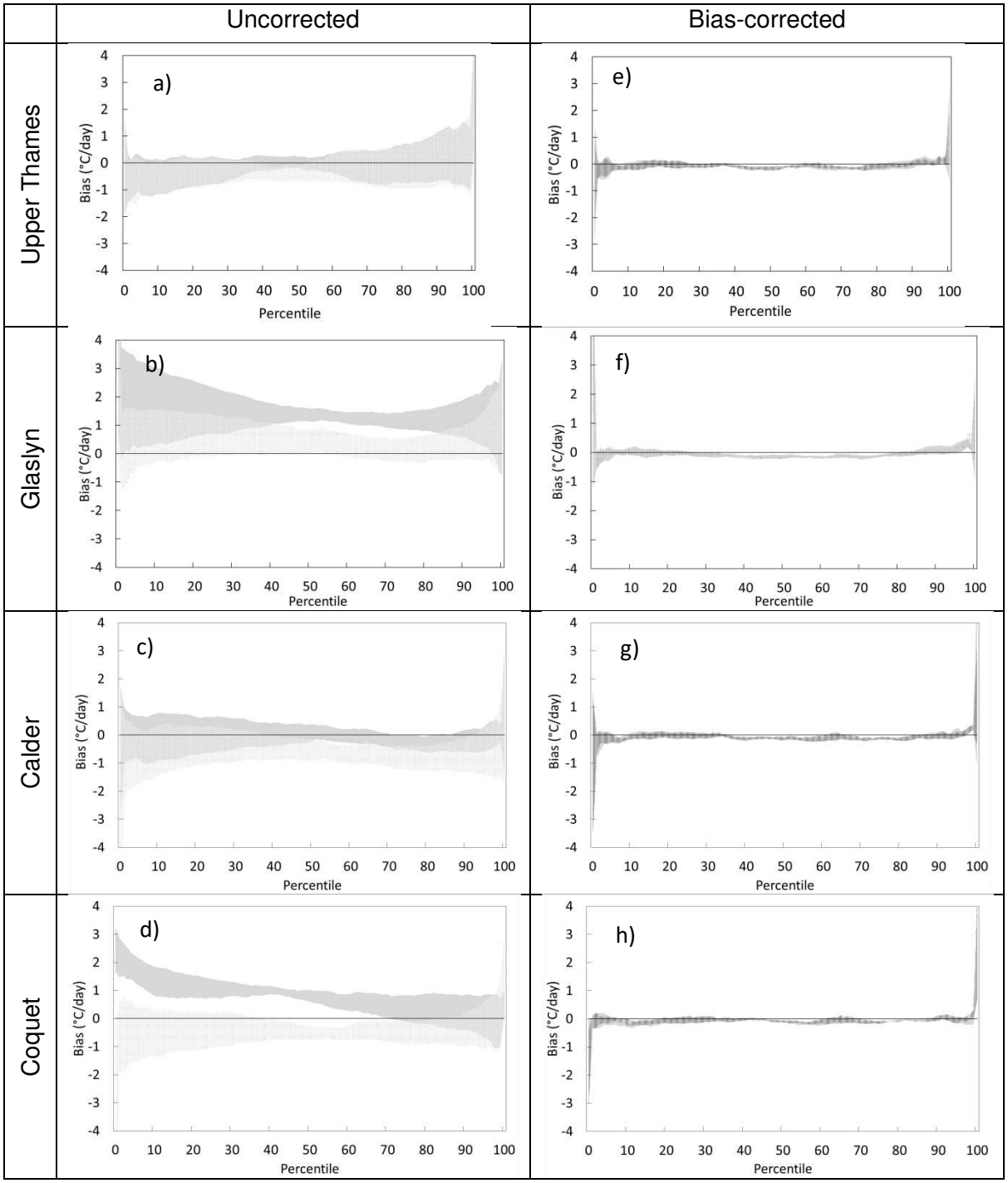

Figure 3. Temperature percentile biases for the uncorrected and bias-corrected RCMs. The solid fill represents the spread form the 0.44° RCMs and the dotted fill is the spread from the 0.11° RCMs

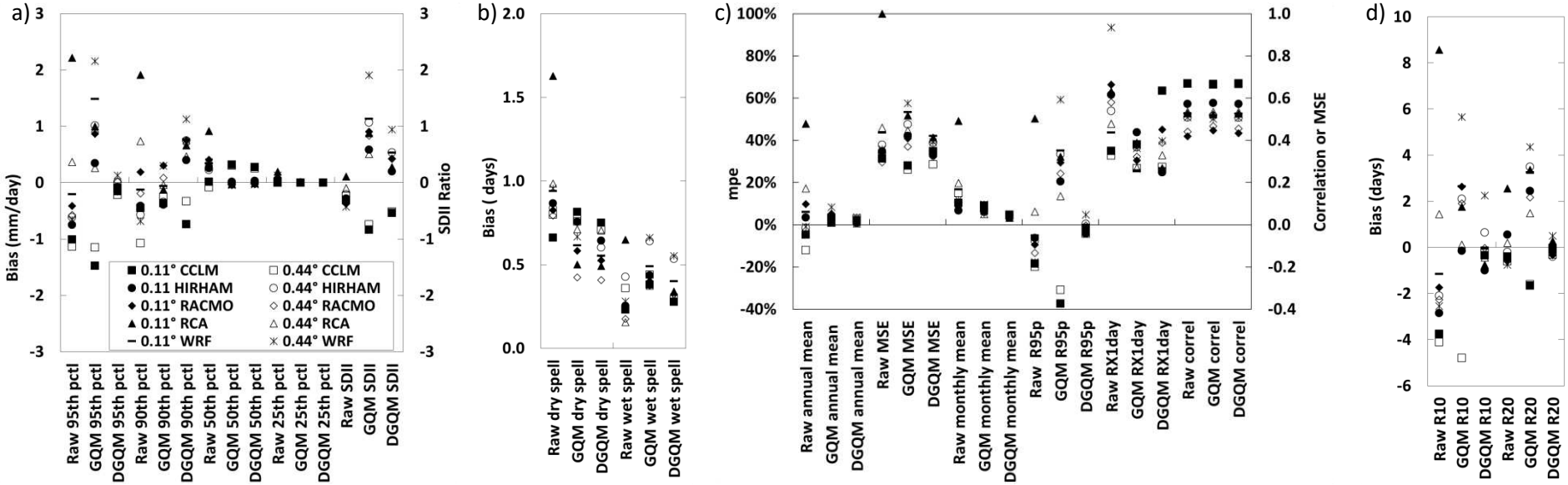

Figure 4. Results of the precipitation performance measures for the upper Thames catchment. Please note the differences in the y-axis. For definitions of the performance measures refer to Table 3 (BC-1G = Bias corrected using the Gamma distribution QM approach, BC-2G = Bias corrected using the Double Gamma distribution approach)

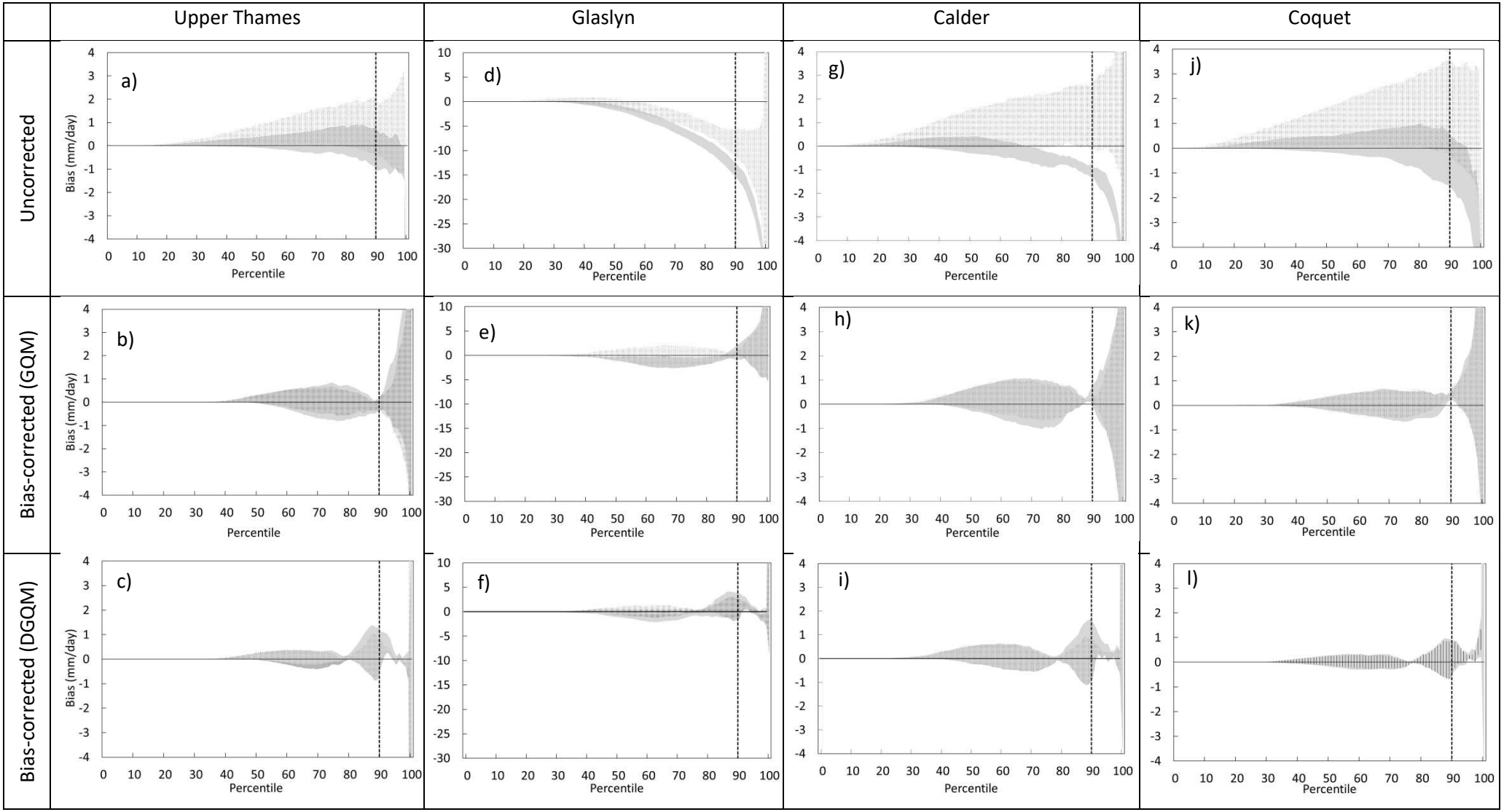

Figure 5. Precipitation percentile biases for the uncorrected and bias-corrected RCMs using the Gamma distribution (GQM) and Double Gamma distribution (DGQM) QM. The solid fill represents the spread of the 0.44° RCMs and the dotted fill the spread of the 0.11° RCMs. The 90th precipitation percentile is represented by a vertical dotted line

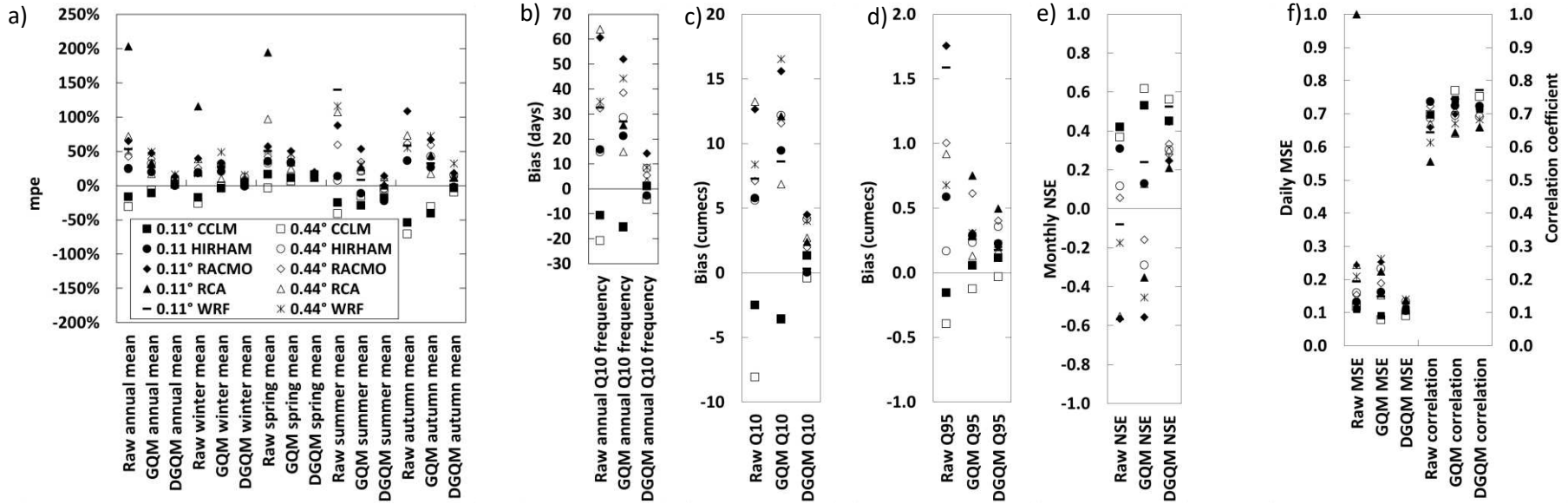

Figure 6. Results of the river flow performance measures for the upper Thames catchment. Please note the differences in the y-axis. For definitions of the performance measures refer to Table 3 (GQM = Gamma distribution Quantile Mapping and DGQM = double Gamma distribution Quantile Mapping)

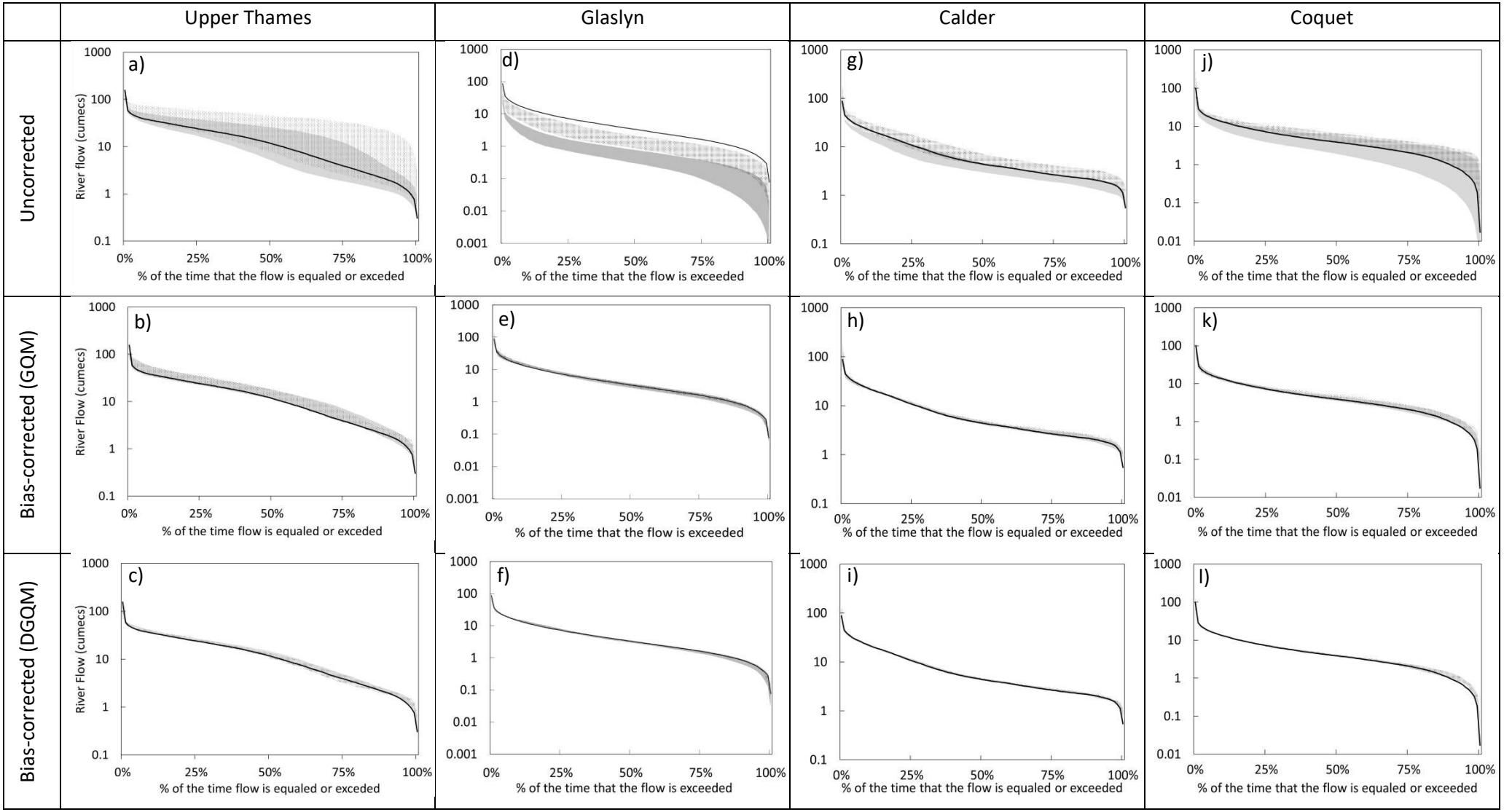

Figure 7. Flow duration curve biases from using the uncorrected and bias-corrected temperature and precipitation simulations. The 0.44° RCMs spread is shown with a solid fill, the 0.11° RCMs spread with a dotted fill and the reference FDC with a solid line. (GQM = Gamma distribution Quantile Mapping and DGQM = double Gamma distribution Quantile Mapping)

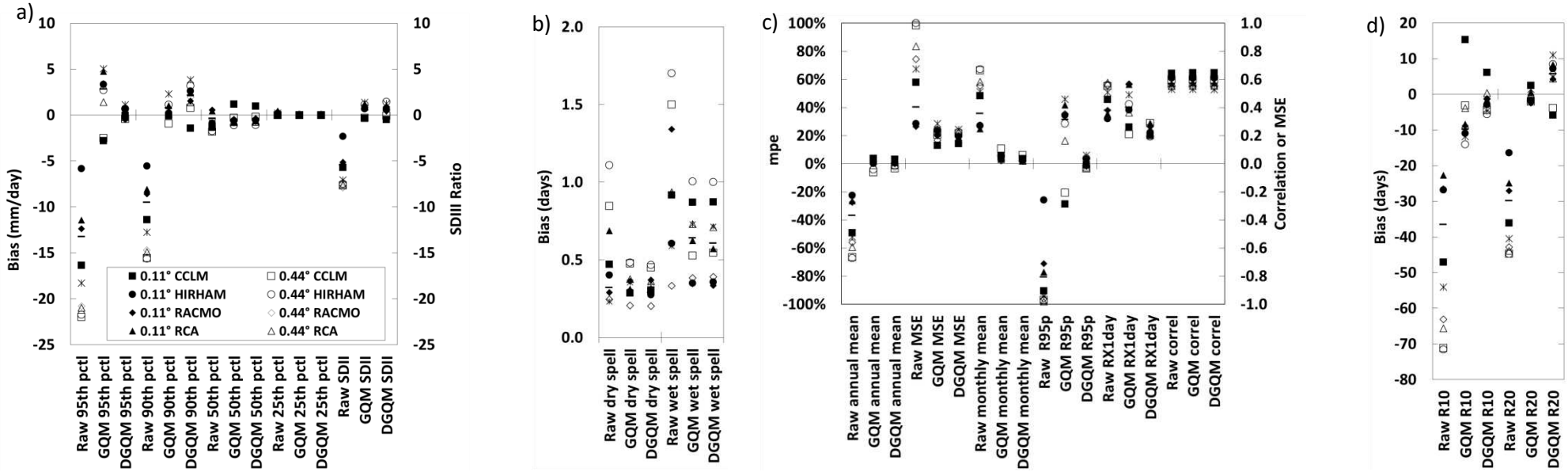

Figure S1. Similar to Figure 5 but for the Glaslyn catchment

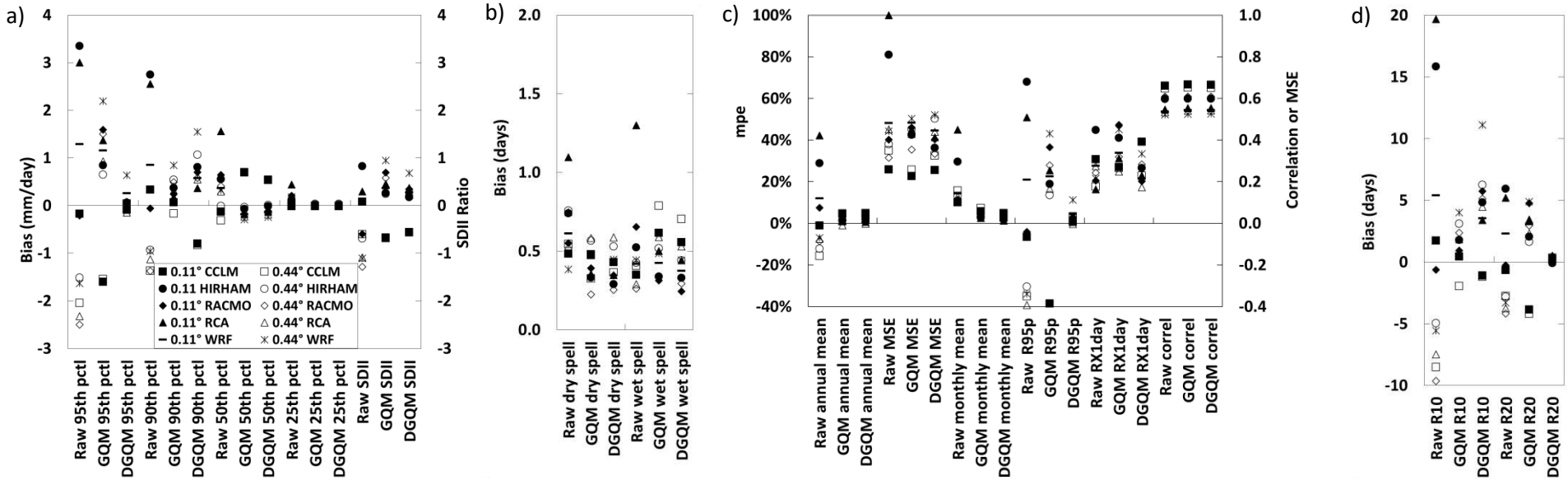

Figure S2. Similar to Figure 5 but for the Calder catchment

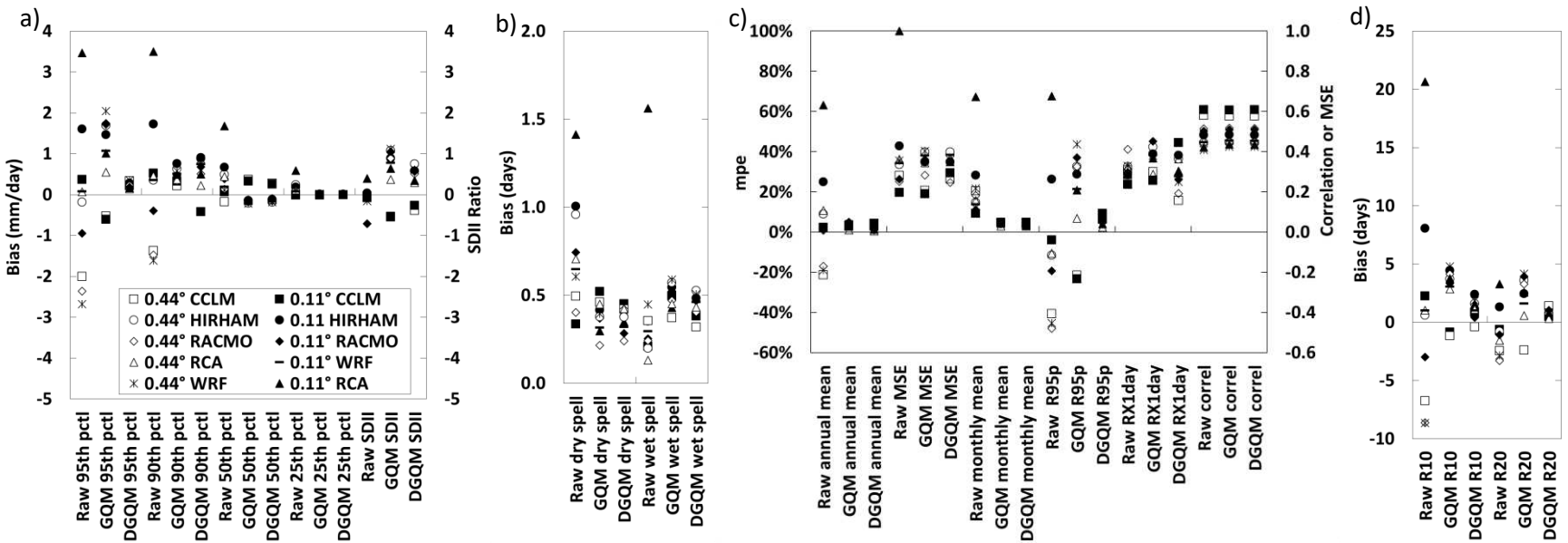

Figure S3. Similar to Figure 5 but for the Coquet catchment

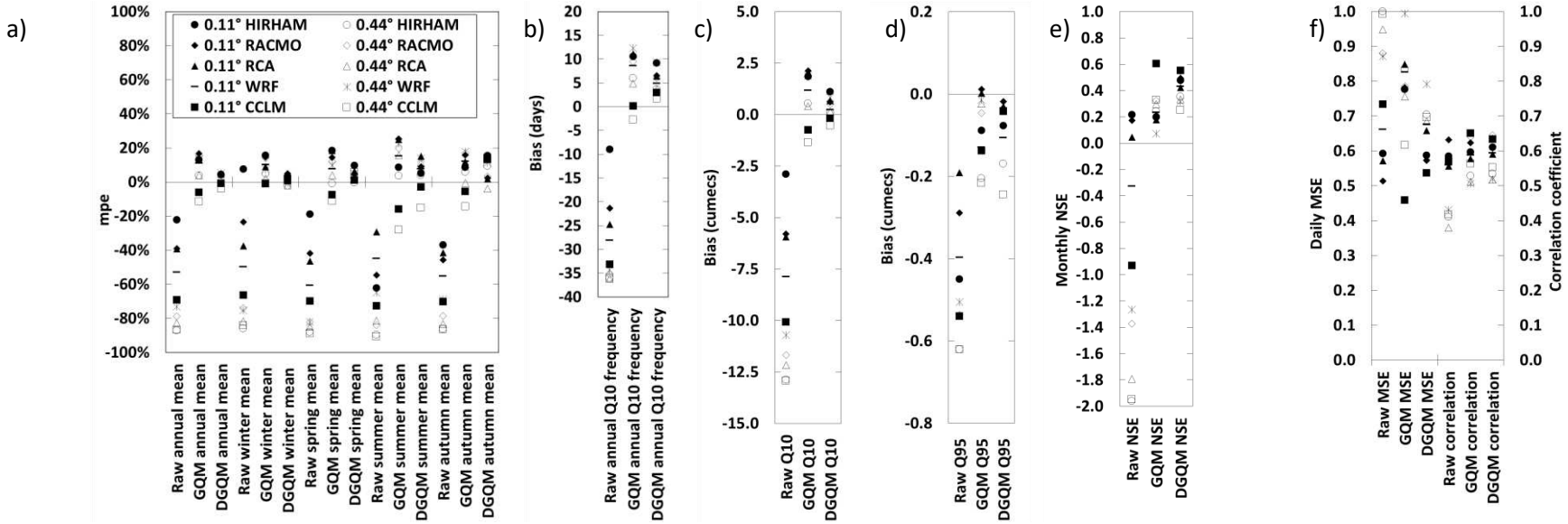

Figure S4. Similar to Figure 7 but for the Glaslyn catchment

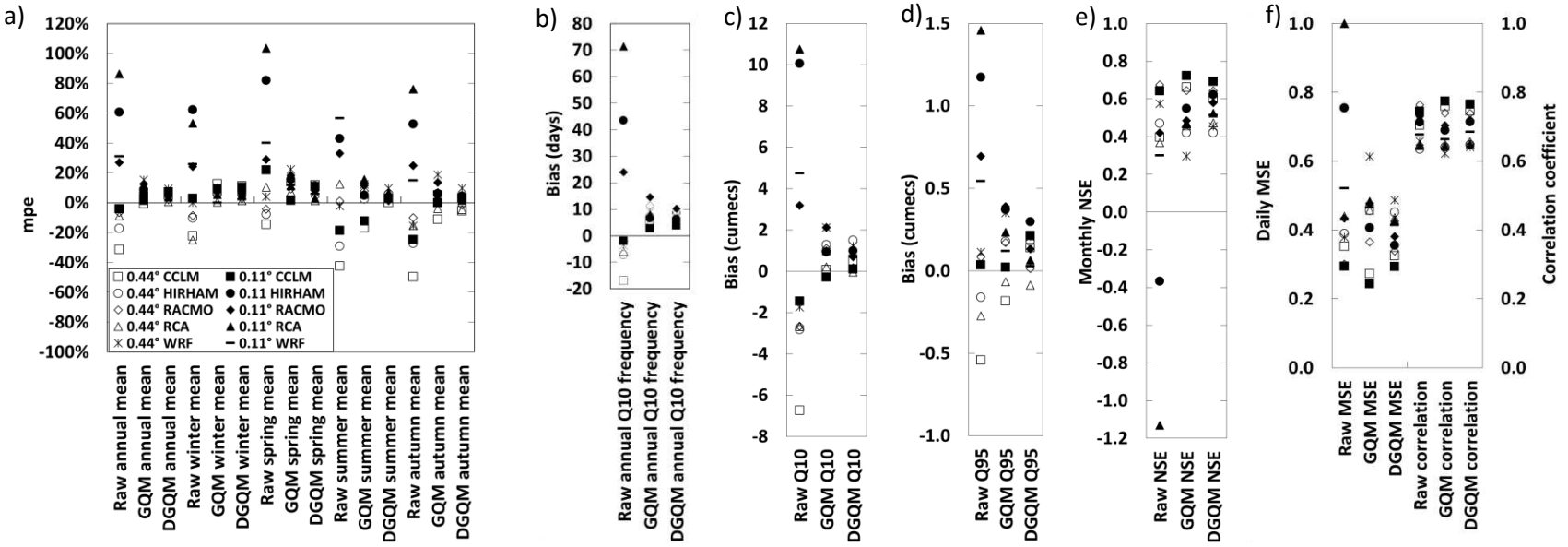

Figure S5. Similar to Figure 7 but for the Calder catchment

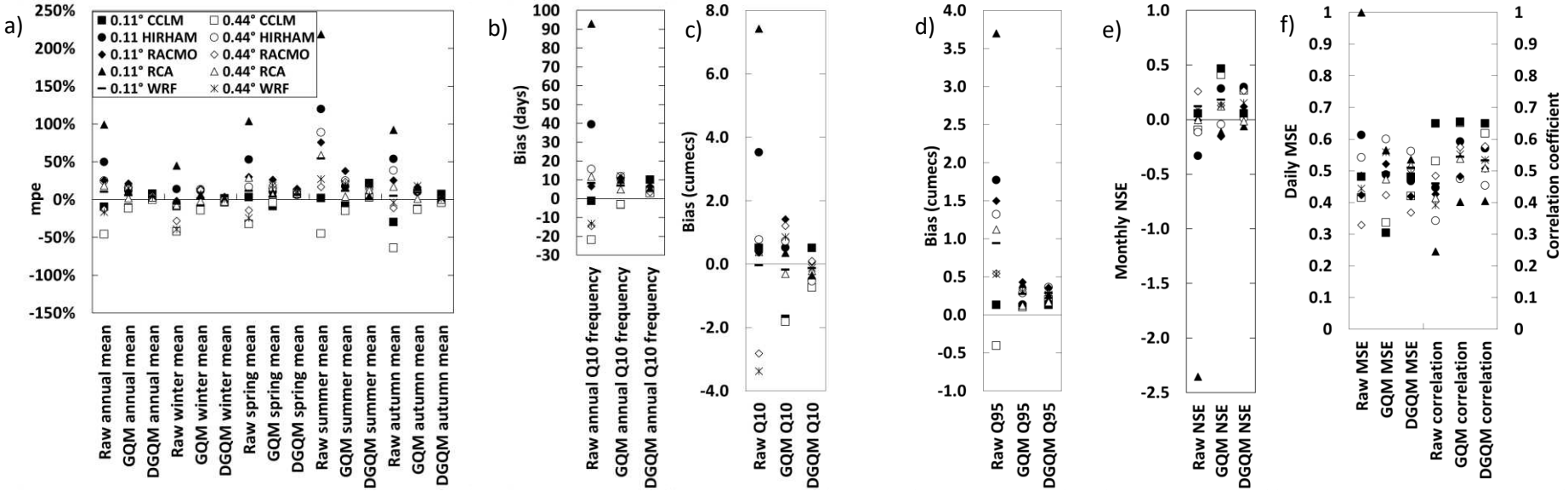

Figure S6. Similar to Figure 7 but for the Coquet catchment