Climate Change Projections over Pakistan

Burhan Ahmad (Pakistan Meteorological Department)

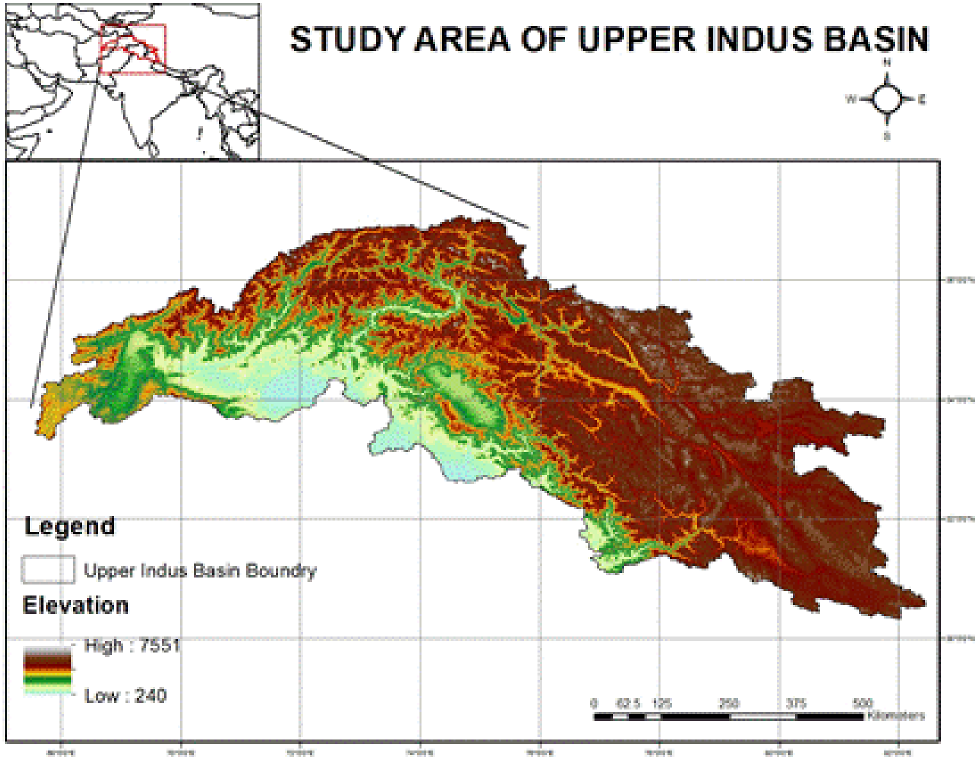
TRAINING ON

Regional climate change projections: Climate change analysis using CORDEX regional climate models over South Asia

12–14 and 19–21 October 2020 | Platform: Microsoft Teams

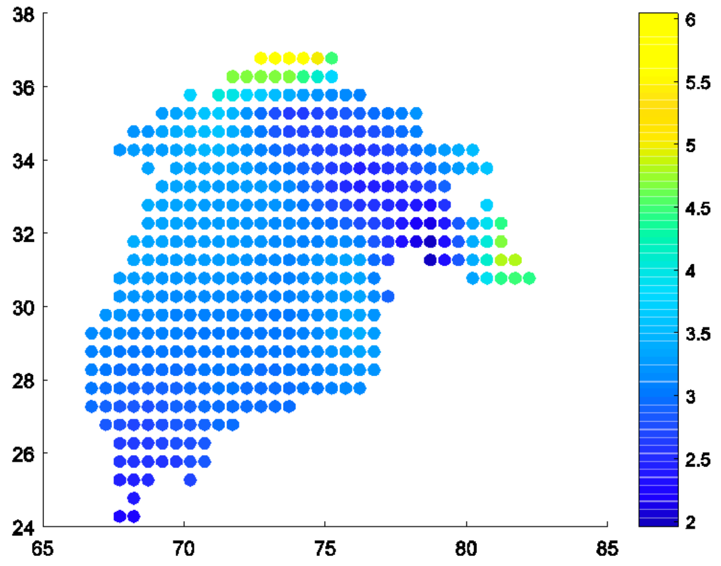
Project of ICIMOD with consultation of Future Water and PMD

- Generation of high resolution gridded datasets for UIB using CMIP5 outputs
- In 2015
- Statistical downscaling with “delta method”
- Mean and variability scenarios
- 0.1 degrees resolution
- RCP4.5 and RCP8.5
- Burhan et al., 2015



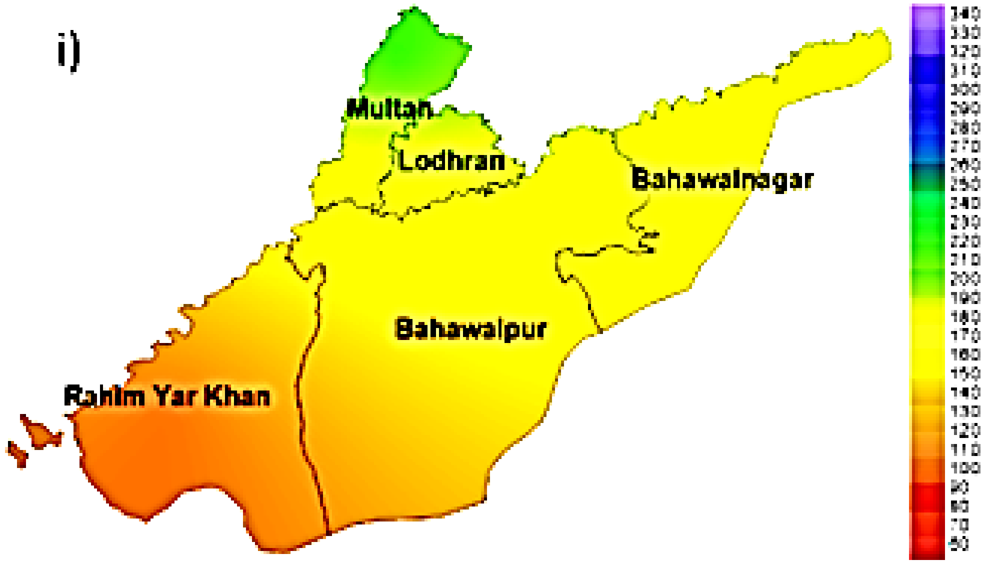
Strategic Basin Assessment (CSIRO)

- In 2015
- Delta with mean and variability scenarios
- CCSM4 model downscaled at 0.22 and 0.44 degrees resolution
- Coverage of whole Indus Basin
- Data available for impact studies at PMD website
- RCPs 4.5 and 8.5
- Farah et al., 2016



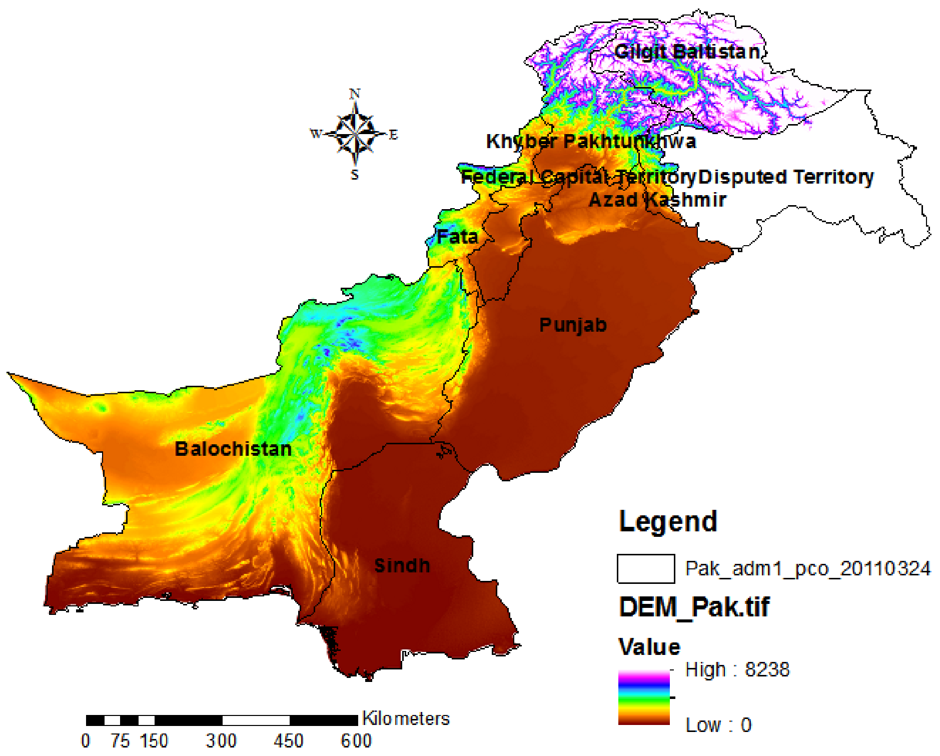
Agriculture Models Inter-comparison and Improvement Project UAF-PMD

- 2013-2017
- Downscaling with “mean and variability scenarios”
- Downscaling at farm level
- Using stretched distribution (mean and variability scenarios)
- AR5 RCPs 4.5, 8.5
- Ahsan et al., 2017



Projections and Attributions of Streamflow Composition in River Basins of China and Pakistan

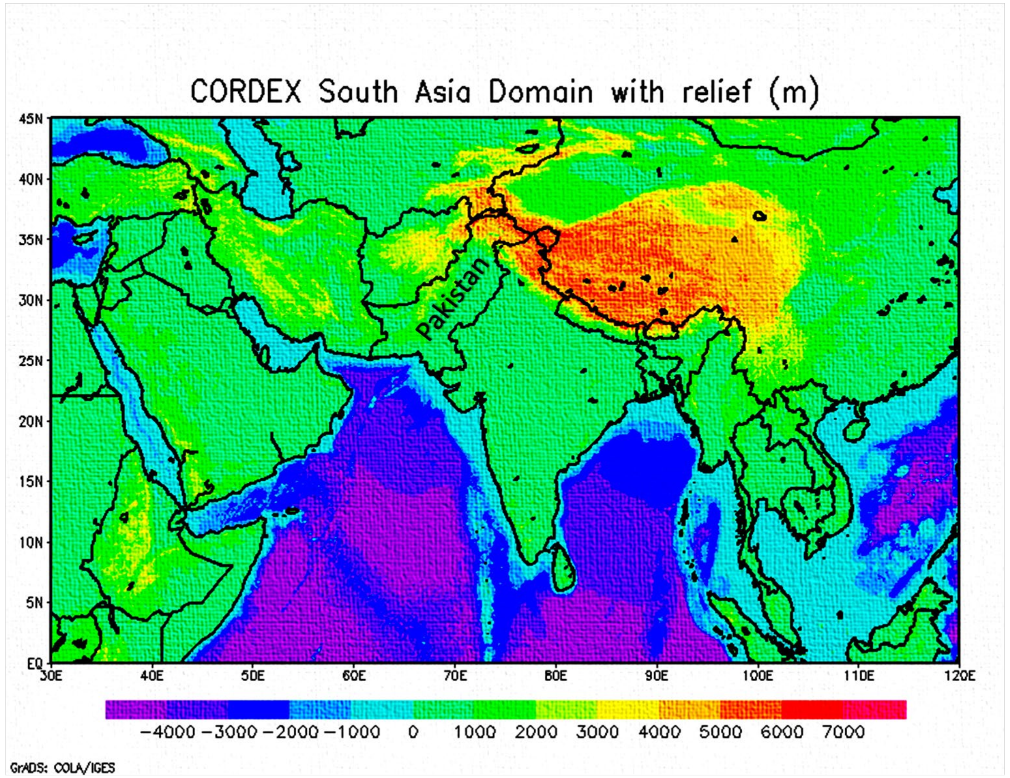
- In 2018
- Statistical downscaling using quantile mapping
- 0.11 degrees resolution
- Burhan and Rasul (2018)
- CORDEX South Asia
- Whole Pakistan
- RCPs 4.5 and 8.5



Statistical Bias Correction of Projections derived from CORDEX South Asia using Quantile Mapping, and climate extremes over Pakistan Region

DOMAIN SETTINGS

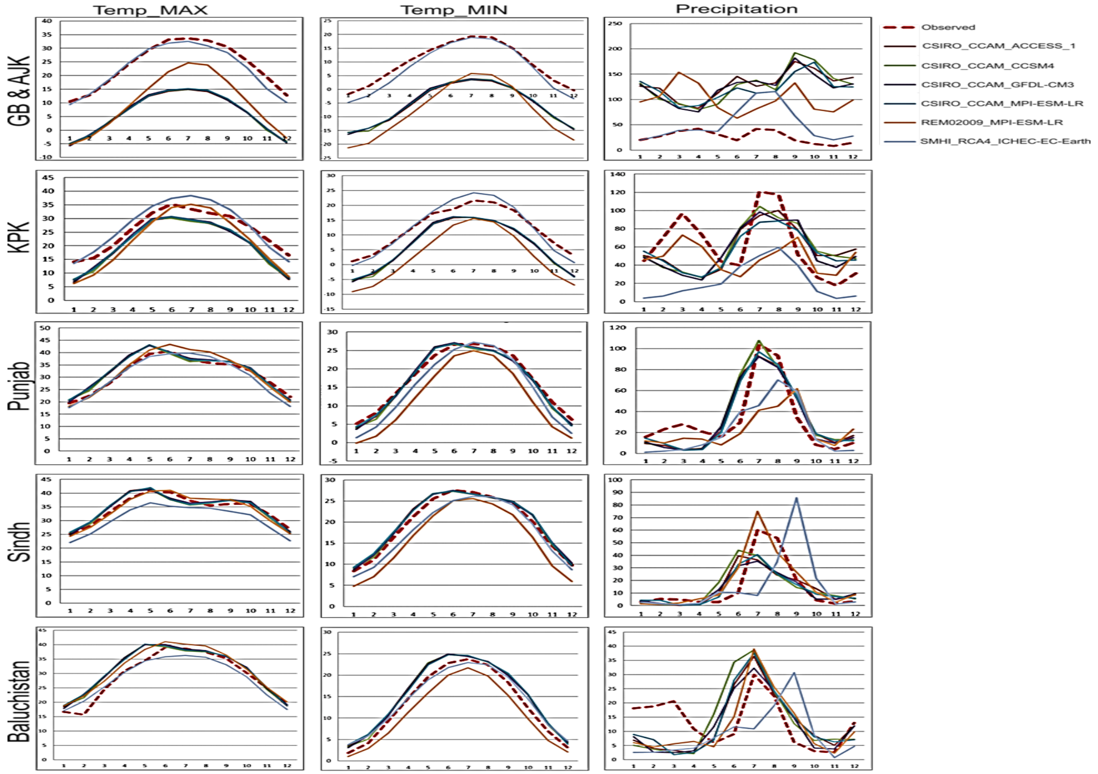
CORDEX SOUTH ASIA DOMAIN



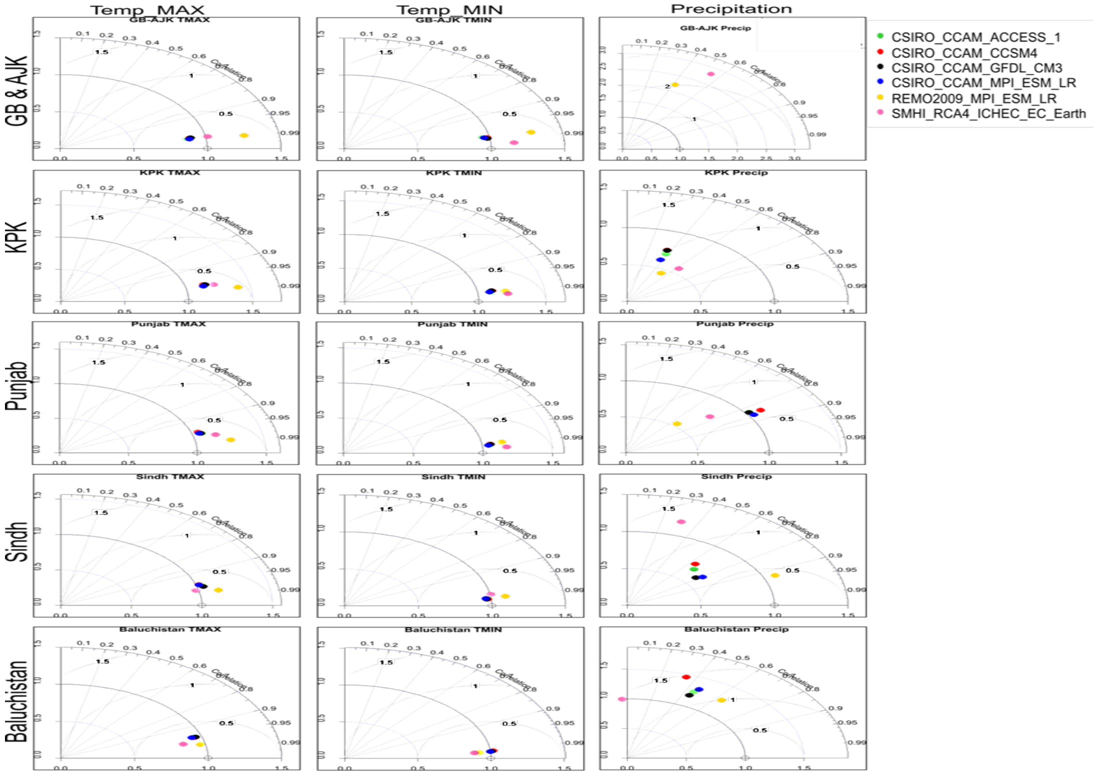
DOWNSCALING DOMAIN

RATIONALE FOR STATISTICAL BIAS CORRECTION OF CORDEX-SOUTH ASIA

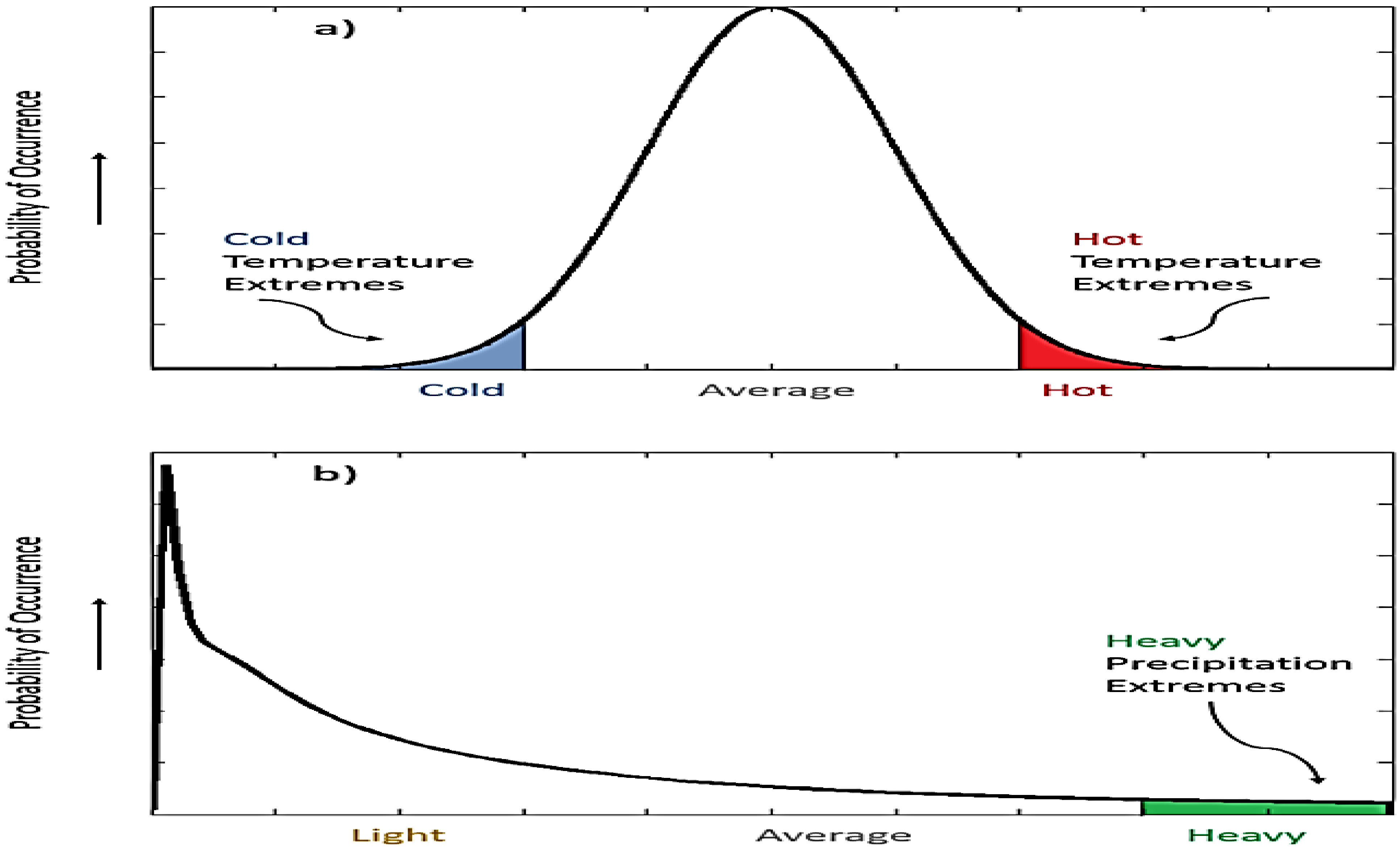
ANNUAL CLIMATOLOGY OF CORDEX BEFORE DOWNSCALING; CLEAR SYSTEMATIC BIASES ARE SEEN ESPECIALLY IN HIGH ALTITUDE REGIONS. PRECIPITATION MAXIMA ARE NOT IN-PHASE WITH OBSERVATIONS, HENCE BIAS CORRECTION IS NEEDED.



TAYLOR STATISTICS OF CORDEX MODELS; TEMPERTURE HAS GOOD PATTERN CORRELATIONS BUT PRECIPITATION HAS VERY WEAK PATTERN CORRELATIONS. ALSO THE ROOT MEAN SQAURE ERROR IS HIGH FOR PRECIPITATION BEFORE DOWNSCALING AND BIAS CORRECTION.



Understanding Extremes



Methodology

- Following Piani et al. (2010), a transformation can is formulated as

$$V_o = c(V_m) \tag{1}$$

- Statistical transformations are an implementation of the probability integral transform (Angus, 1994) and if the distribution of the variable is known, the transformation is defined as

$$V_o = F_o^{-1}(F_m(V_m)) \tag{2}$$

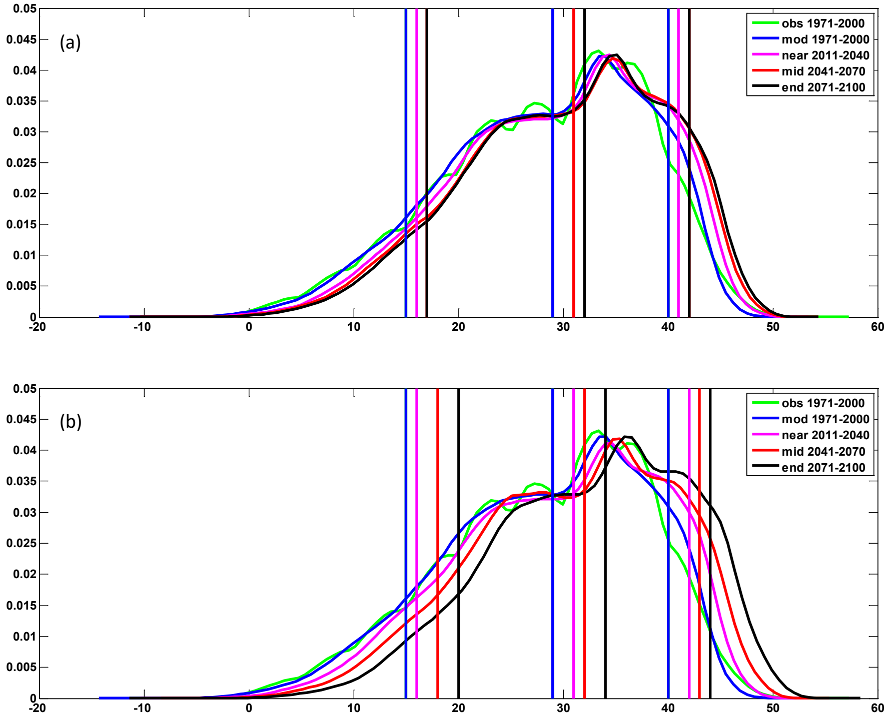
- Here F_m is the CDF of V_m and F_o^{-1} is the inverse CDF (or quantile function) corresponding to V_o.
- The practical challenge is to find a suitable approximation for c and different approaches have been suggested in the literature.

Statistical transformations adopted for post–processing

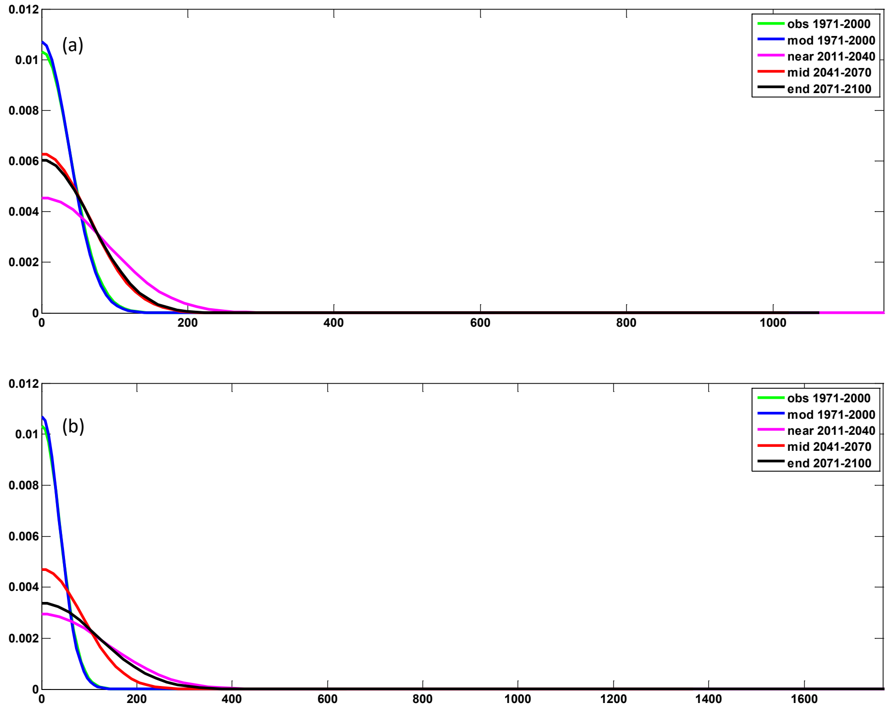
Sr. No.	Statistical Distribution	Description
1	PTF	Quantile mapping using parametric transformations
2	DIST	Quantile mapping using distribution derived transformations
3	RQUANT	Nonparametric quantile mapping using robust empirical quantiles
4	QUANT	Nonparametric quantile mapping using empirical quantiles
5	SSPLIN	Quantile mapping using a smoothing spline

Baseline and Projected Probability Density Functions of SMHI RCA4 CORDEX Downscaled over Pakistan

Shifts in PDFs of projected TMAX (°C) under (a) RCP4.5 and (b) RCP8.5 emission scenarios. The three sets of vertical lines in each panel represent P10, P50, and P90 of each of the representative 30–year time slices.



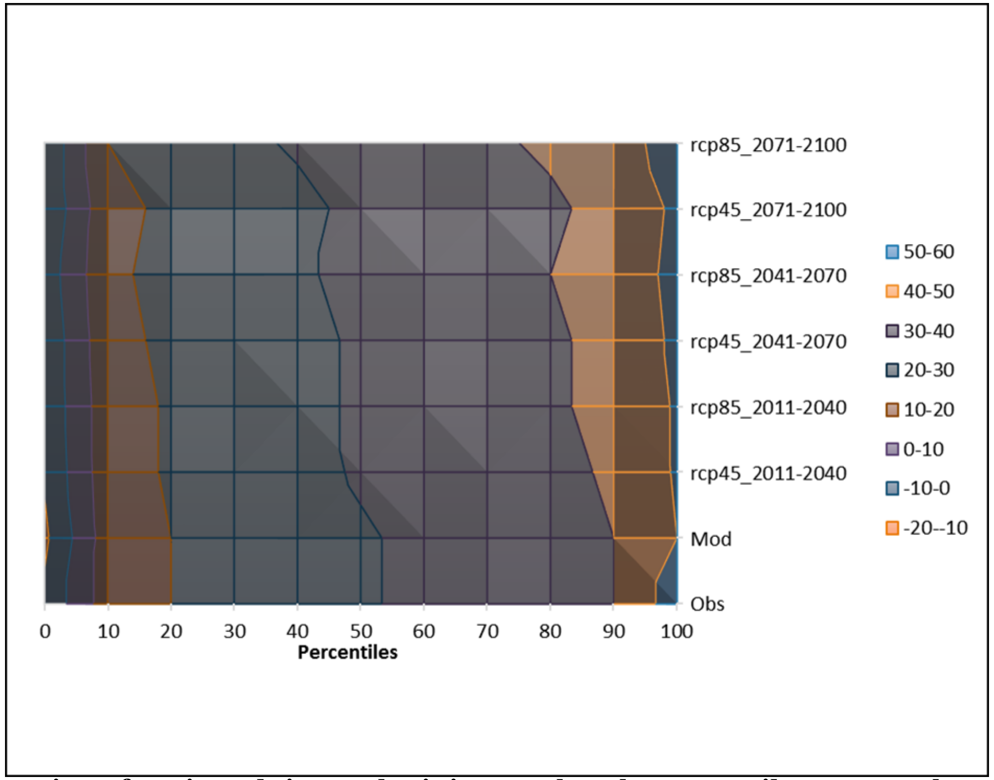
Shifts in PDFs of historical and projected PRECIPITATION (mm) under (a) RCP4.5 and (b) RCP8.5 emission scenarios.



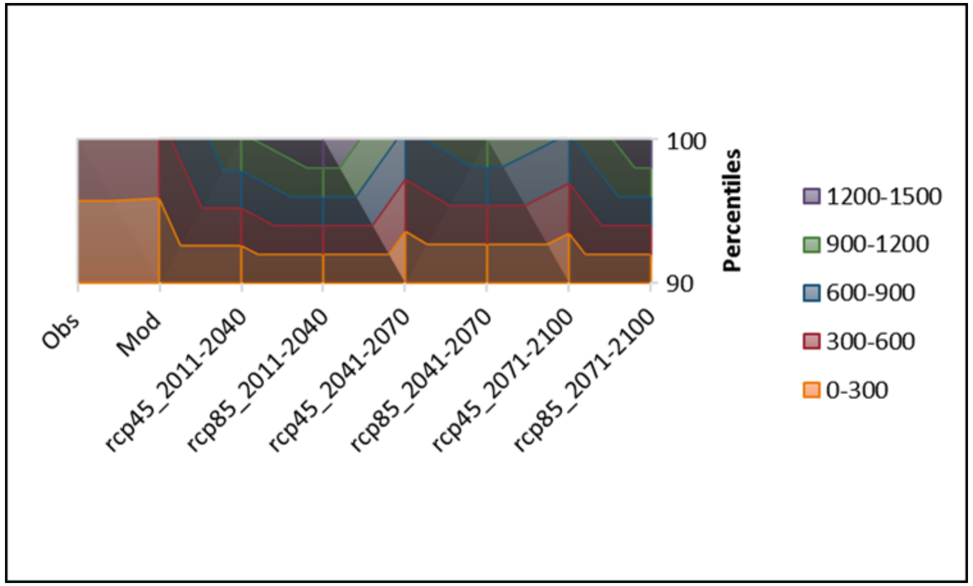
- **More occurrences of hot extreme weather attributed to significant shifts in temperature extremes.**
- **Higher probability of more than 250 mm/day precipitation extremes in 2011-2040 projections.**

Projected Shifts in Percentiles of SMHI RCA4 CORDEX Downscaled over Pakistan

Projected shifts in percentiles of TMAX (°C) under RCP4.5 and RCP8.5 with respect to observations. Surface is colour coded with a 10°C bin size which shows clear shifting and/or expansion of percentiles to higher degrees of bins.



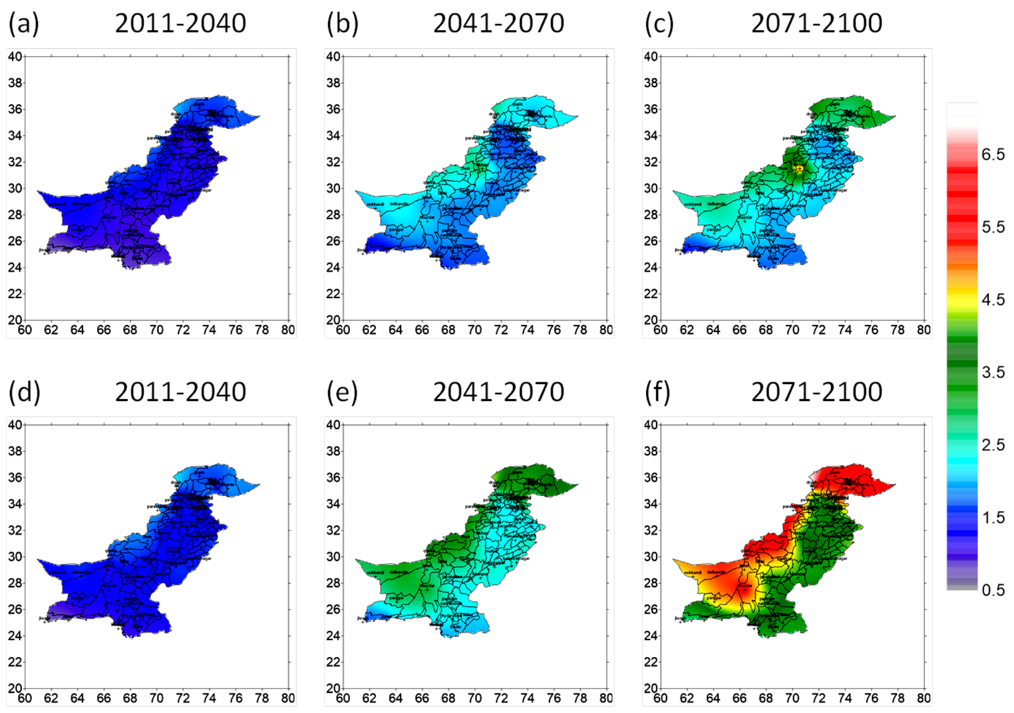
Projected shifts in percentiles of PRECIPITATION (mm) under RCP4.5 and RCP8.5 with respect to observations. Surface is colour coded with a 300 mm bin size which shows clear expansion and inclusion of high magnitude extremes in projected timescales.



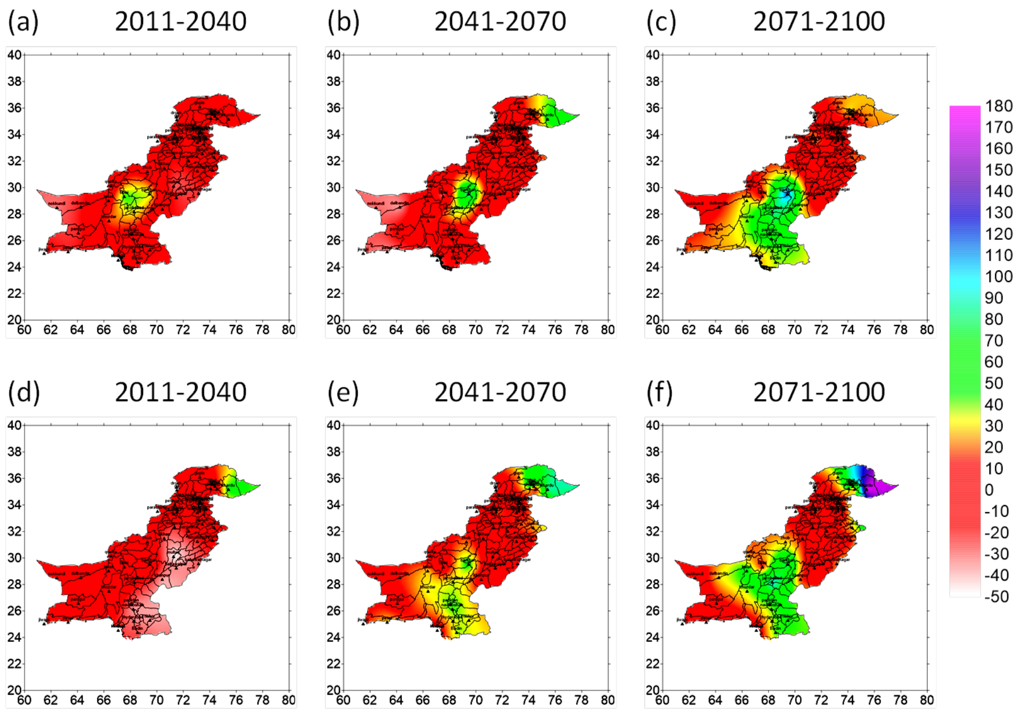
- With progression of projected timescales it is seen that the percentiles greater than 90 have expanded their 40-60°C TMAX bins to 70th percentile by the end of 21st century, which means that current temperate days would be shifted to extreme hot days in the projected periods.
- The Precipitation percentiles greater than 90 project high magnitude extremes with both the RCP4.5 and the RCP8.5 emission scenarios, which means that "heavy precipitation" extremes would be shifted to "very heavy" precipitation extremes in the projected periods.

Projected Changes in TMAX (°C) and PRECIP (mm)
Top Row (RCP4.5), Bottom Row (RCP8.5)

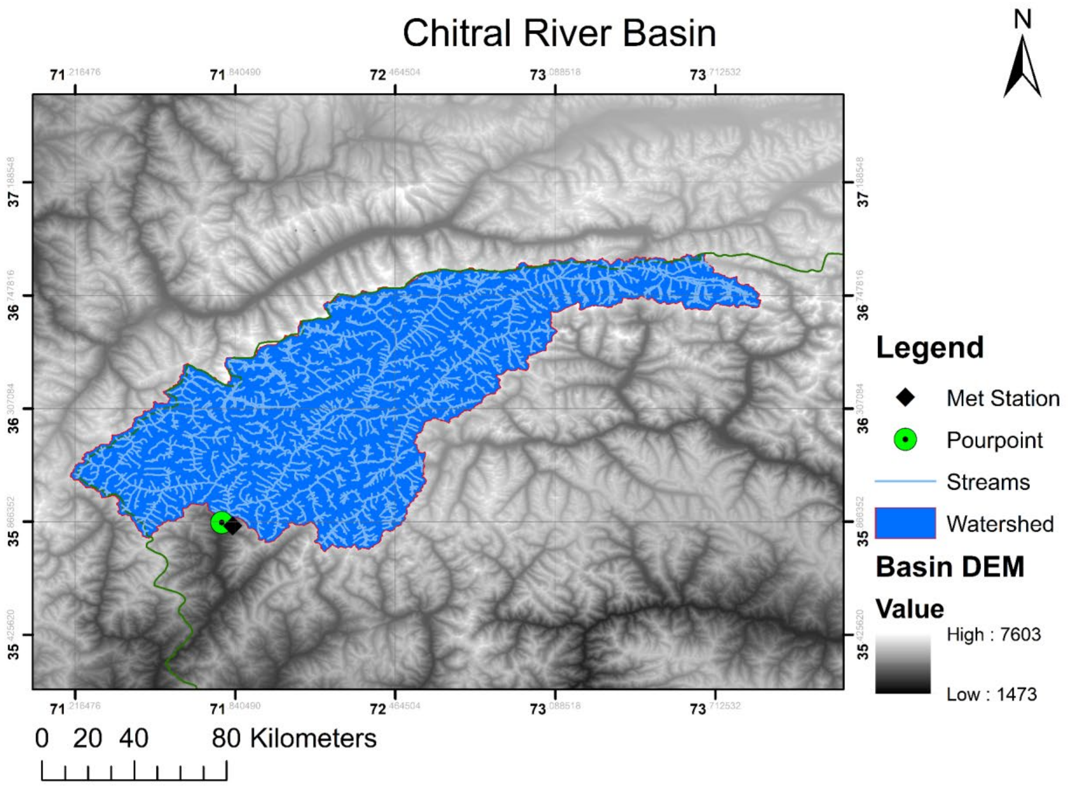
TMAX (°C). PROJECTED TEMPERATURE IS SEEN TO AFFECT ITS HIGHEST TOWARDS NORTH-WESTERN REGIONS (SPECIALLY CHITRAL BASIN, HINDUKUSH) WITH UP TO 6.5°C INCREASE BY THE END OF CENTURY UNDER THE RCP8.5 EMISSION SCENARIO

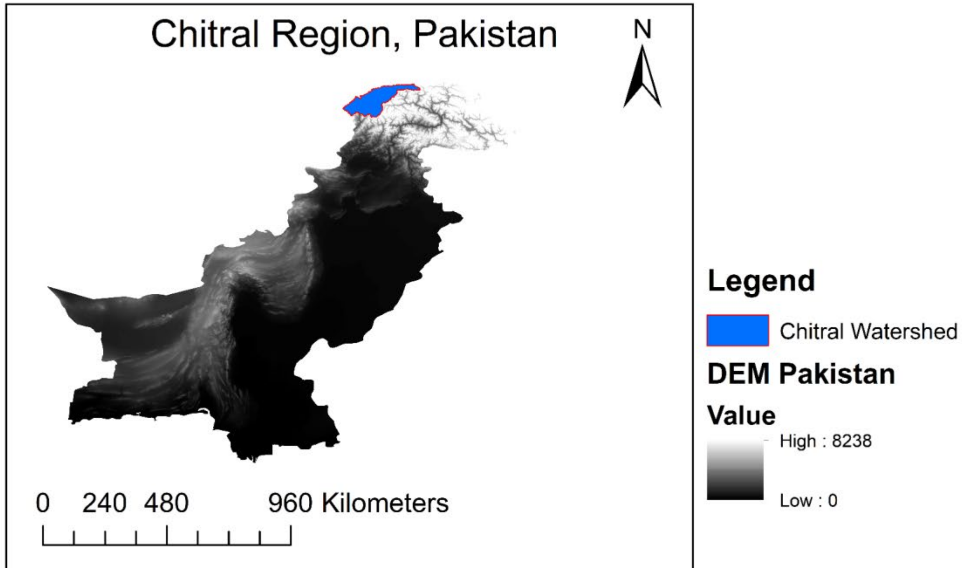


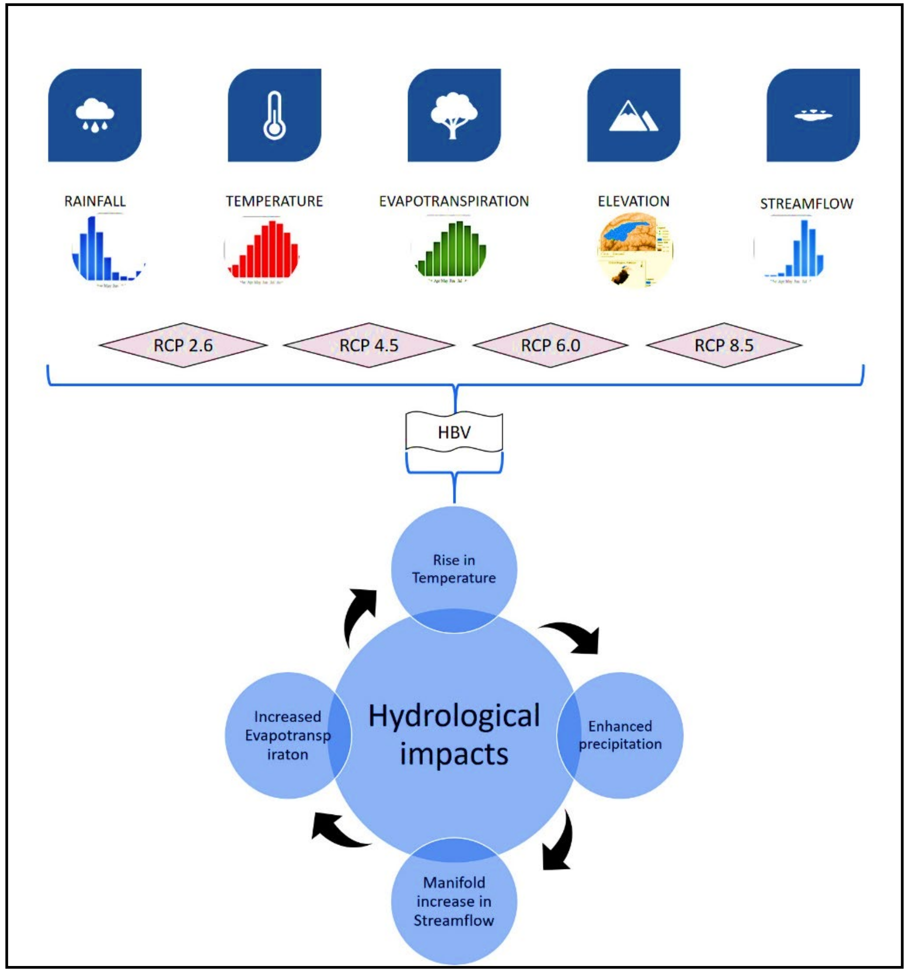
PRECIPITATION(mm). INITIALLY DRY BUT PROGRESSIVELY WET CONDITIONS ARE PROJETCED AT THE CONJUNCTION OF SINDH, PUNJAB, KPK AND BALUCHISTAN PROVINCES WITH UP TO 100% INCREASE. MOREOVER, NORTH-EASTERN SIDES OF THE DOMIAN INCLUDING HIMALAYAS PROJECT UP TO 180% INCREASE BY THE END OF CENTURY.

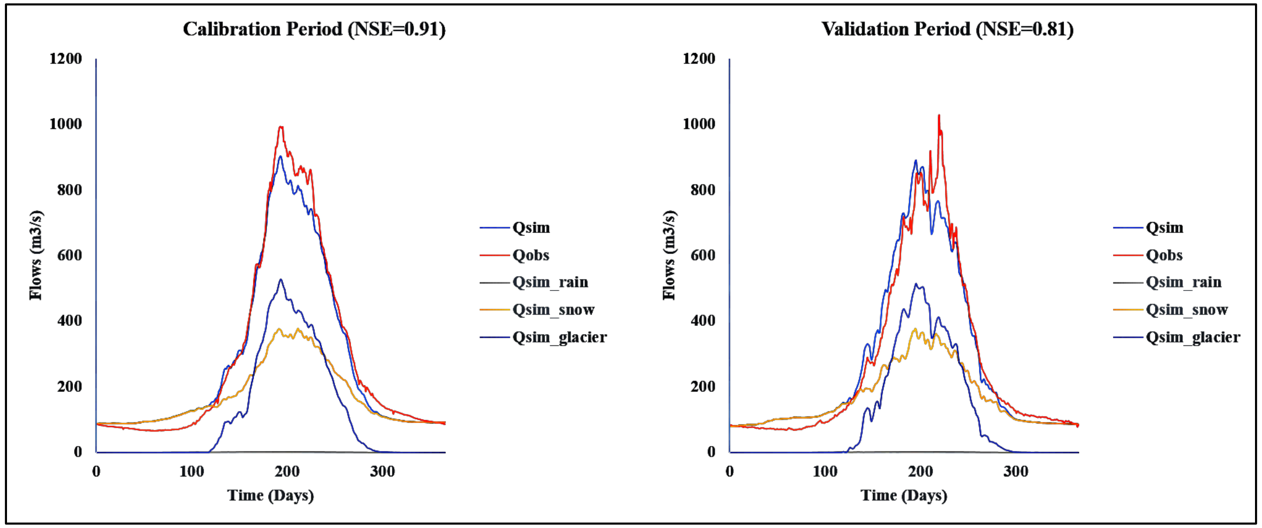


Prognosis of hydro meteorological attributes based on simulation and projection of stream flow under AR5 emission scenarios in Chitral River Basin (CRB)


Chitral River Basin
N
Legend
Met Station
Pourpoint
Streams
Watershed
Basin DEM
Value
High : 7603
Low : 1473
0 20 40 80 Kilometers

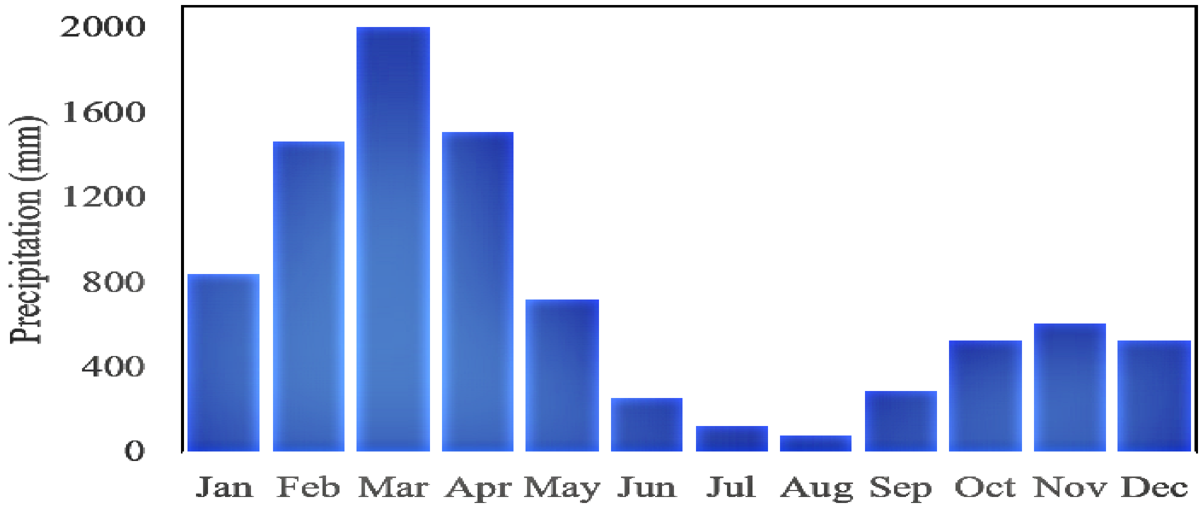

Chitral Region, Pakistan
N
Legend
Chitral Watershed
DEM Pakistan
Value
High : 8238
Low : 0
0 240 480 960 Kilometers

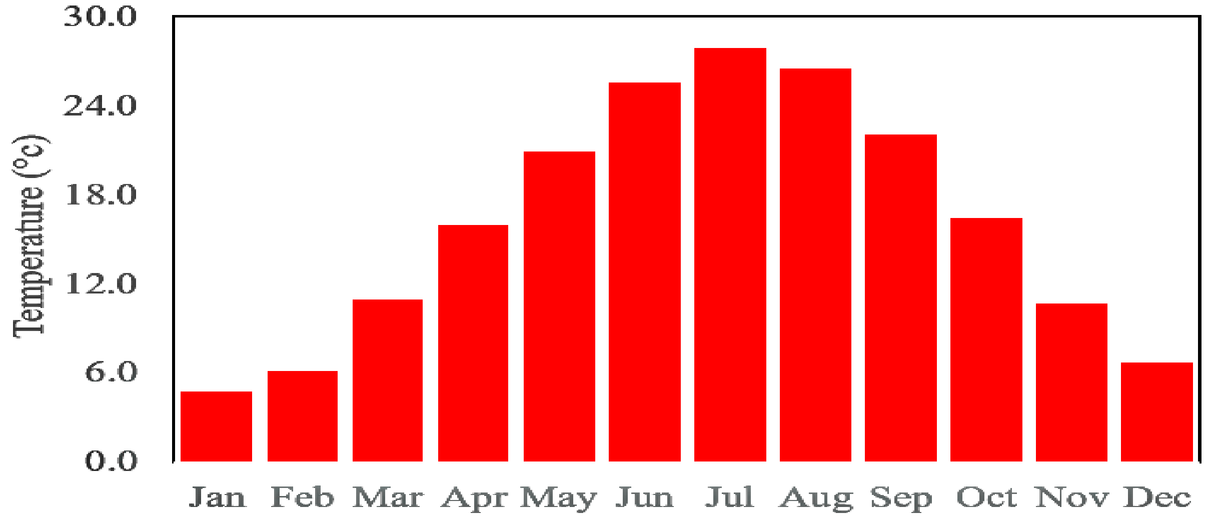

RAINFALL
TEMPERATURE
EVAPOTRANSPIRATION
ELEVATION
STREAMFLOW
RCP 2.6
RCP 4.5
RCP 6.0
RCP 8.5
HBV
Rise in Temperature
Enhanced precipitation
Manifold increase in Streamflow
Increased Evapotransp iraton
Hydrological impacts

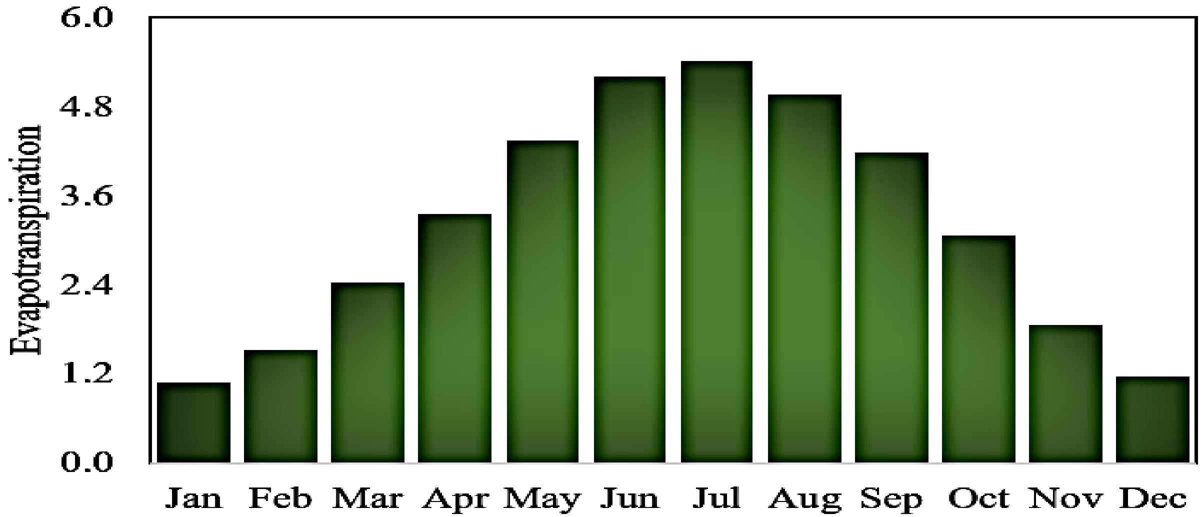


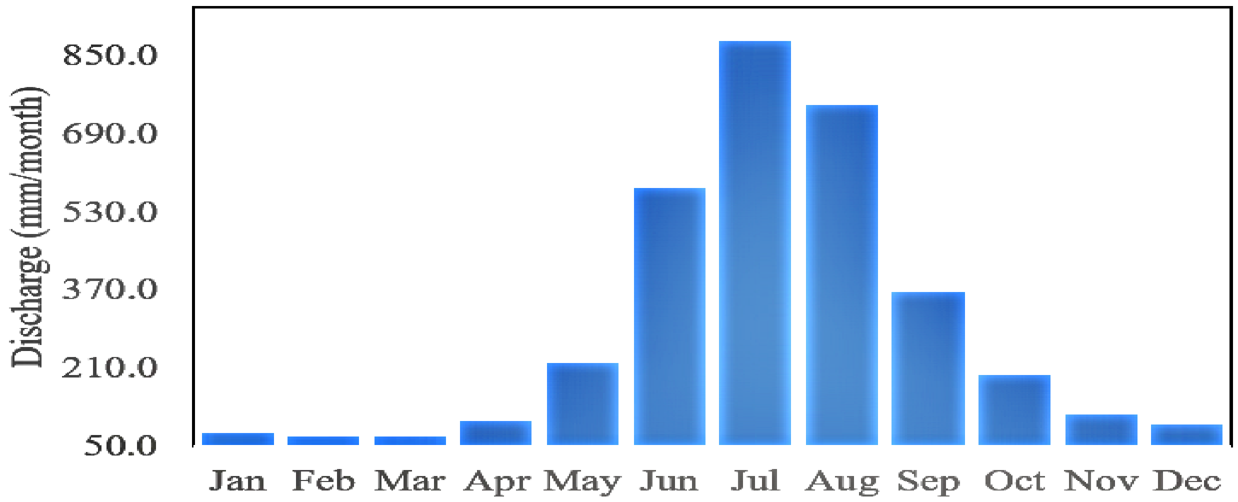
Calibration Period (NSE=0.91)
Validation Period (NSE=0.81)
Flows (m3/s)
Time (Days)
0
100
200
300
400
600
800
1000
1200
Qsim
Qobs
Qsim_rain
Qsim_snow
Qsim_glacier

Observed hydro-climate attributes of CRB

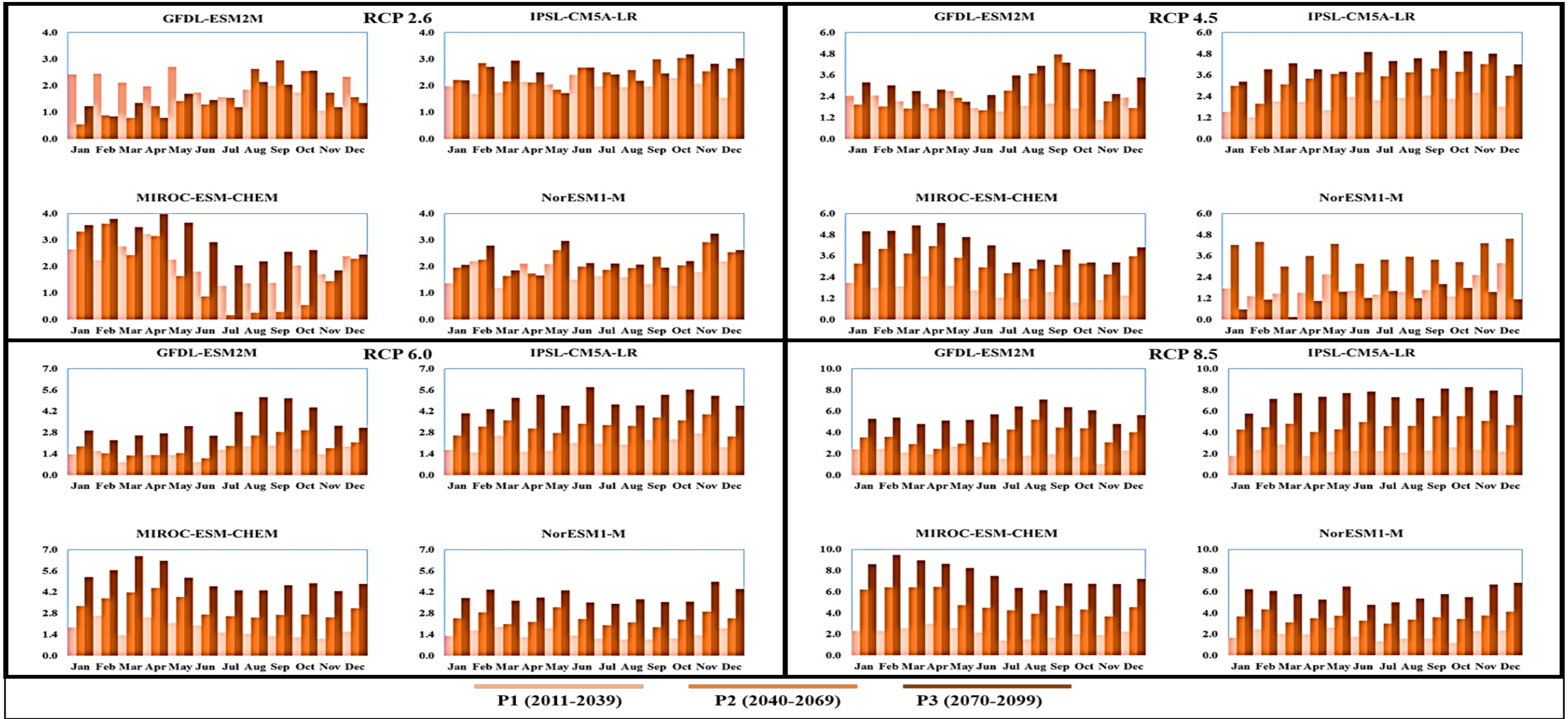




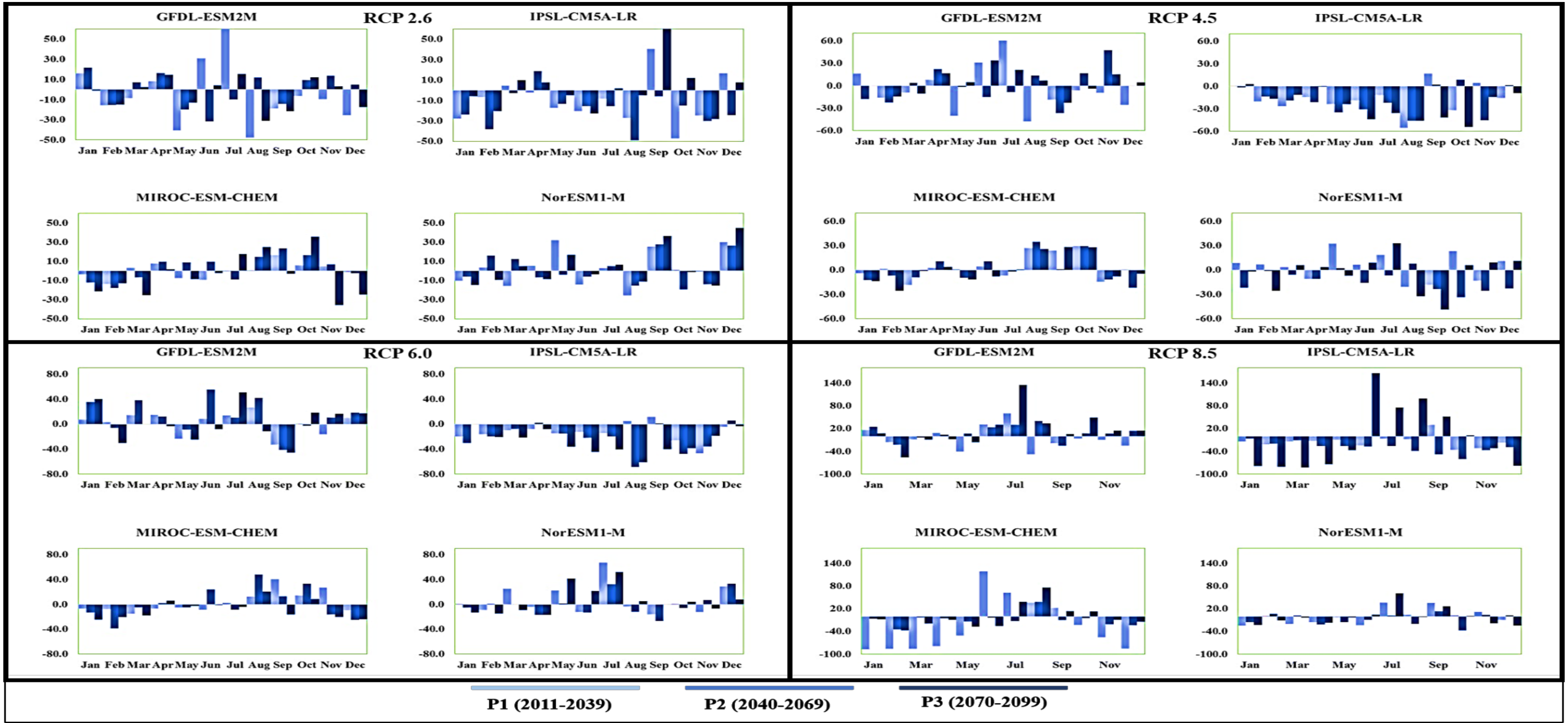




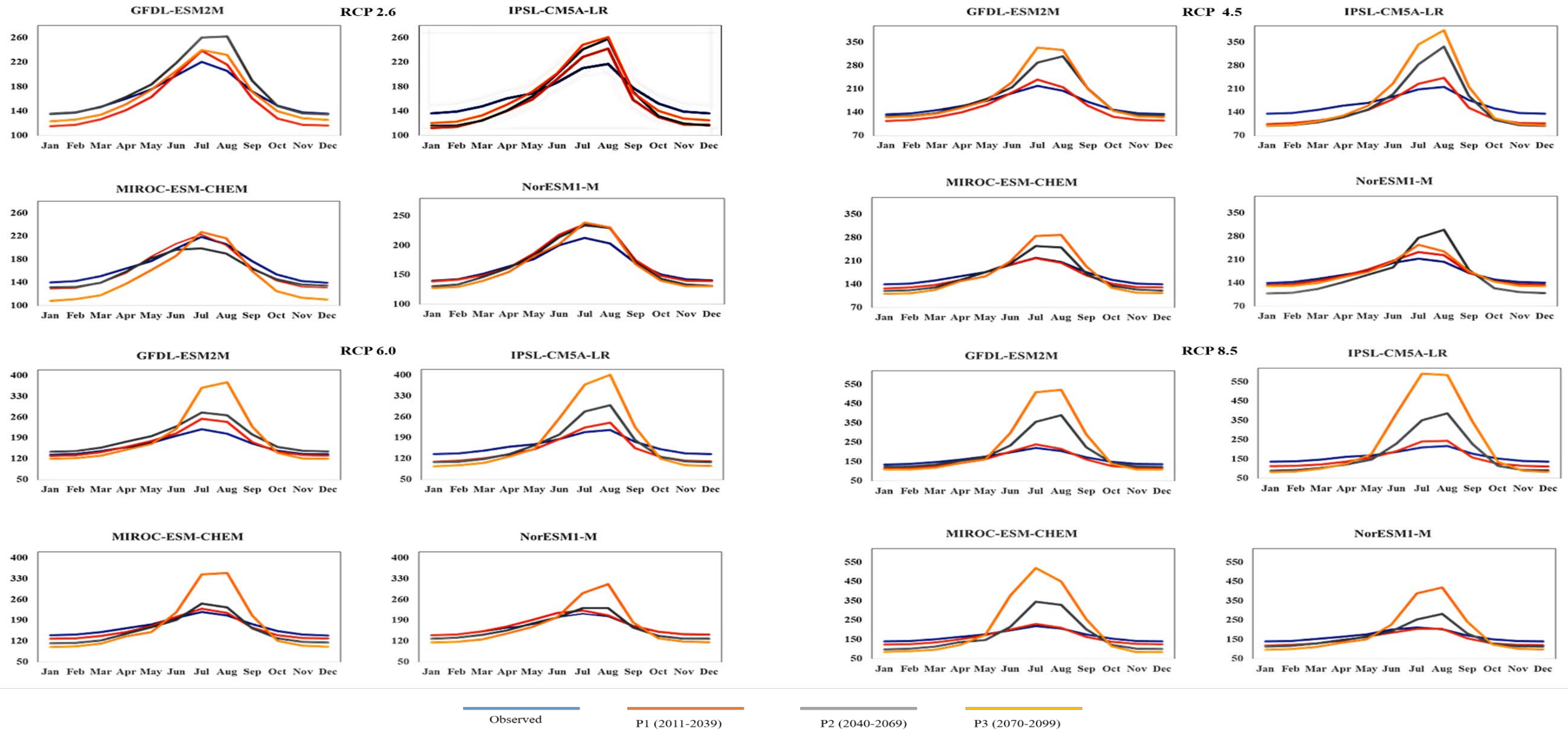
Temperature projections of CRB



Precipitation projections of CRB



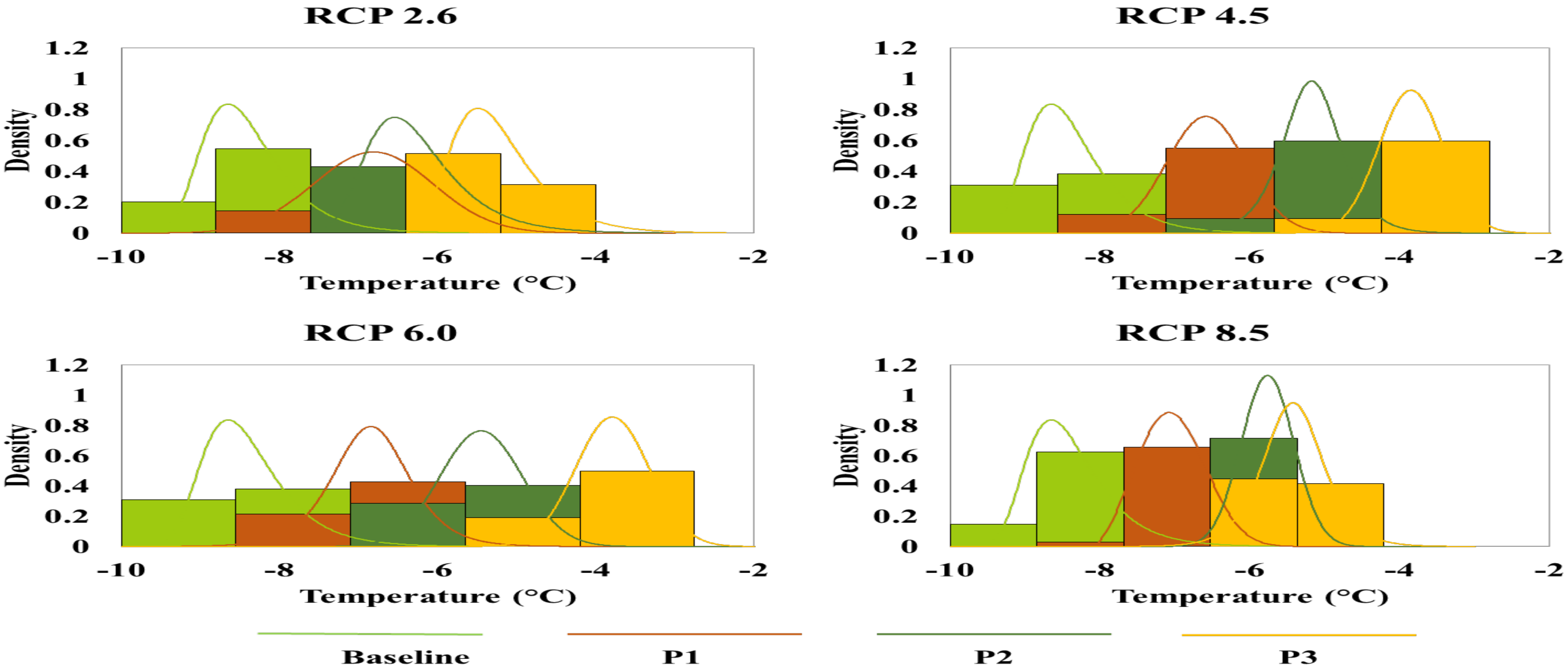
Projected streamflow of CRB



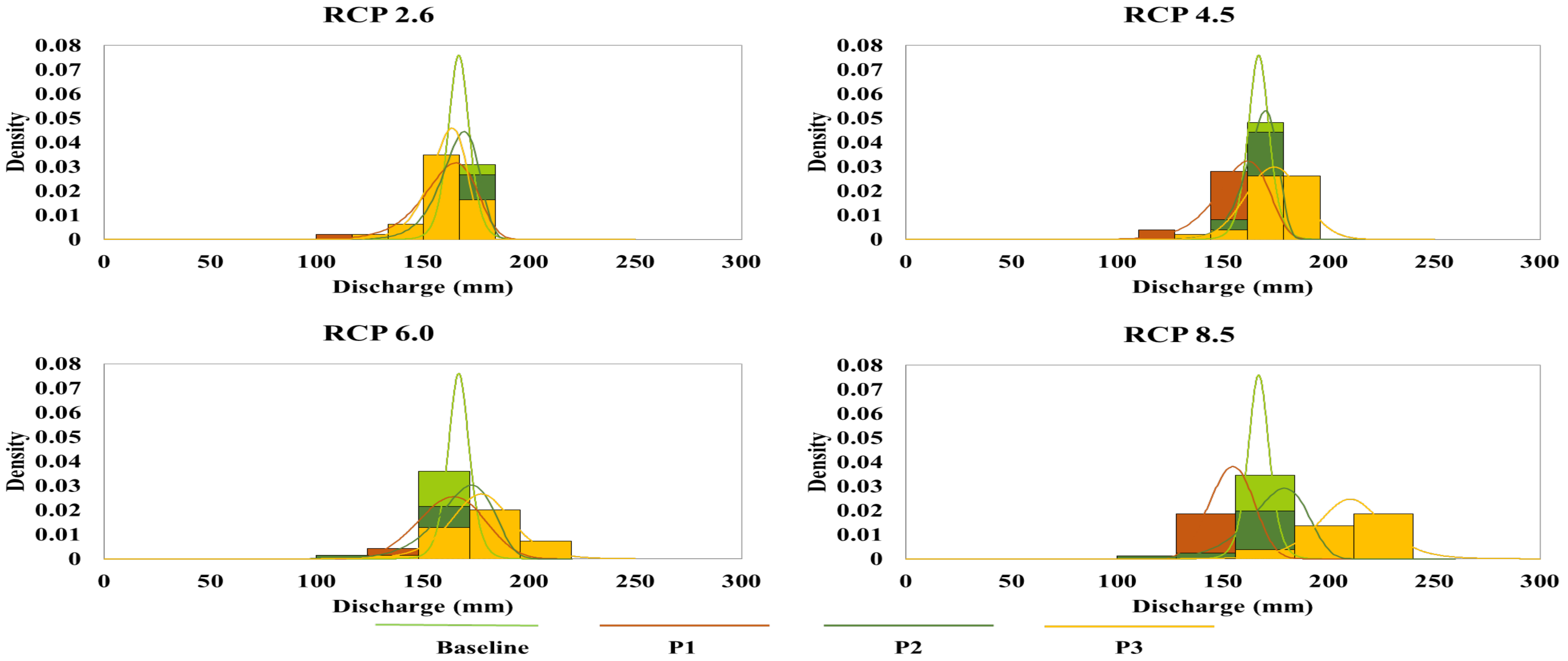
Significant increase (decrease) in summer (winter) flows of CRB

			P1 (2010–2039)				P2 (2040–2069)				P3 (2070–2099)			
		Obs	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
GFDL–ESM2M	Jan	135	115	115	130	115	136	129	144	124	123	126	122	110
	Feb	137	117	117	133	118	138	130	147	126	126	128	124	110
	Mar	147	126	126	143	126	147	139	159	134	134	137	132	117
	Apr	160	141	141	162	141	163	157	178	155	151	155	152	141
	May	175	163	163	181	163	184	182	197	174	175	176	172	162
	Jun	198	200	200	206	201	219	216	230	233	206	231	221	299
	July	220	238	238	256	239	261	289	277	357	240	334	360	508
	Aug	206	215	215	245	216	262	309	267	391	232	328	379	522
	Sep	172	160	160	178	161	190	211	203	225	171	210	230	291
	Oct	149	127	127	145	128	148	146	161	143	140	145	141	138
	Nov	138	117	117	134	118	136	133	148	125	129	129	122	109
	Dec	136	116	116	132	116	135	131	146	124	126	127	121	108
IPSL–CM5A–LR	Jan	136	112	106	111	113	116	100	110	90	120	102	96	83
	Feb	139	114	108	114	114	117	103	111	93	123	104	99	86
	Mar	148	125	116	122	122	125	111	120	103	133	114	107	100
	Apr	161	140	127	135	136	141	125	136	122	150	130	129	125
	May	169	159	149	152	158	164	149	166	148	172	161	154	176
	Jun	187	193	181	187	191	201	195	202	231	202	227	257	387
	July	210	228	227	226	241	241	285	279	350	248	344	369	592
	Aug	217	242	244	241	245	258	338	301	387	261	387	402	586
	Sep	178	158	154	156	158	171	190	183	227	170	217	226	345
	Oct	152	130	120	127	126	132	118	127	115	140	124	121	136
	Nov	139	118	108	114	114	120	103	112	94	128	105	99	90
	Dec	137	117	107	112	112	116	101	110	91	125	103	96	84
MIROC–ESM–CHEM	Jan	140	129	128	128	124	131	120	114	99	108	111	100	86
	Feb	142	130	130	130	126	132	122	114	102	111	113	102	89
	Mar	151	139	138	137	135	139	131	122	112	118	123	112	98
	Apr	164	156	153	151	151	158	152	145	136	137	149	137	122
	May	176	184	177	171	172	181	177	167	148	161	164	151	174
	Jun	198	207	200	202	202	196	202	191	215	185	209	217	378
	July	219	223	218	228	230	199	254	246	345	227	284	345	519
	Aug	206	204	205	215	211	190	250	234	329	216	288	350	449
	Sep	177	165	167	165	164	164	172	164	204	160	194	207	255
	Oct	154	143	142	140	137	145	136	129	122	125	129	122	115
	Nov	142	132	132	131	128	136	124	117	103	113	115	105	85
	Dec	139	130	130	129	125	134	121	115	101	110	114	102	84
NorESM1–M	Jan	140	139	133	140	118	130	108	128	113	128	131	115	97
	Feb	143	142	136	142	121	133	111	132	116	129	131	118	100
	Mar	152	149	147	153	130	146	122	141	128	140	140	126	112
	Apr	164	162	161	170	143	162	141	157	148	154	157	146	133
	May	177	186	181	192	165	183	164	179	164	181	173	167	151
	Jun	200	218	206	215	185	214	187	200	193	202	205	200	227
	July	213	236	233	223	204	234	275	231	253	239	255	282	388
	Aug	203	229	223	206	205	230	299	231	283	230	234	312	420
	Sep	170	175	171	172	156	171	179	165	181	168	175	184	242
	Oct	150	148	145	151	129	144	125	138	127	140	144	129	123
	Nov	142	140	137	143	121	133	112	128	115	131	132	119	102
	Dec	141	139	134	142	120	131	110	128	113	130	131	117	98

Shifts in temperature regimes from low magnitude bins to high ones in CRB under RCPs emission scenarios



Shifts in stream flow regimes from low magnitude bins to high ones in CRB under RCPs emission scenarios



Thank you