Tutorial #2 - Using Hydrologic Projections

Introduction

When working with ensembles of hydrologic projections, we need to consider the range in the projections between the different emissions scenarios and global climate models. In this tutorial we will be working with ensembles of streamflow projections produced by PCIC to analyse the range of projected future changes in seasonal streamflow.

Those looking for more background on the study design used to generate PCIC's hydrologic projections, they are encouraged to read the following document https://www.pacificclimate.org/sites/default/files/publications/Revised_Hydro_Scenarios_ENV_Water_Use_Allocation_Report_21Jun2021.pdf

Acquiring projected streamflow data

The Pacific Climate Impact Consortium (PCIC) has two data portals with hydrologic projections from the VICGL Hydrologic Model:

1) Gridded-based Hydrologic Model Output (Runoff, SWE, ET, etc.): https://www.pacificclimate.org/data/gridded-hydrologic-model-output
2) Station-based Hydrologic Model Output (Streamflow): https://www.pacificclimate.org/data/station-hydrologic-model-output

In this tutorial, we will be using data from the Station-based Hydrologic Model Output from the VICGL Hydrologic Model for the Horsefly River Above McKinley Creek, 08KH010.

1) Select 08KH010, under station search, on the modelled streamflow data page, and click on the name Horsefly River above McKinley Creek to download the HORSE.csv.ascii file (Figure 1). Open in excel and delimit by comma only.
2) The file contains daily streamflow data at Horsefly River near McKinley Creek for one historical run (PNWNAmet) from 1945-01-01 to 2012-12-31 and 12 BCCAQv2 downscaled GCM scenarios (6 CMIP5 GCMs for 2 Representative Concentration Pathways (RCPs) 4.5 and 8.5) from 1945-01-01 to 2100-12-31 (Figure 2). Six models were selected to span a wide range in future climate extremes with a cluster initialization algorithm (Cannon, 2015) and each was run under two Representative Concentration Pathways (RCPs), RCP 4.5 and 8.5. The RCP 8.5 scenario is a high emissions scenario, with concentrations in 2100 that are three times those that we see today. The RCP 4.5 scenario represents an intermediate emissions trajectory in which policies are implemented to reduce anthropogenic greenhouse gas emissions and the radiative forcing stabilizes before 2100. (See van Vuuren et al., 2011.) The end-of-century radiative forcing in RCP 4.5 also roughly corresponds to the end-of-century forcing that we would see if the international pledges for the Paris Agreement were to be met.

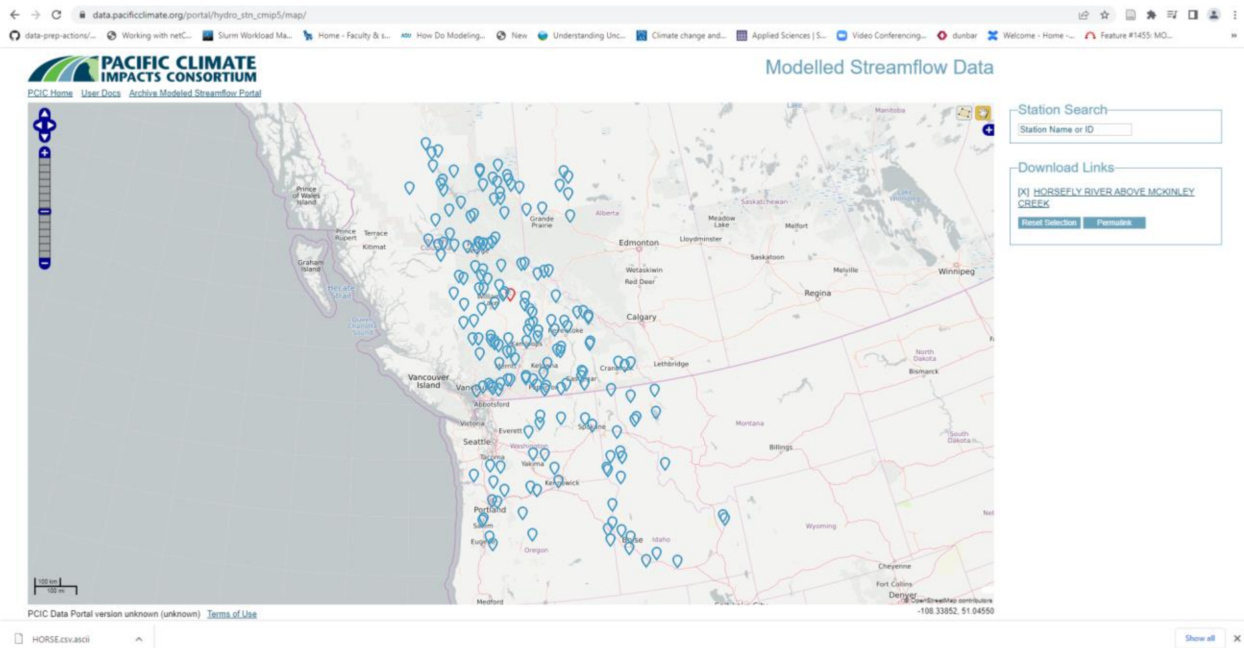
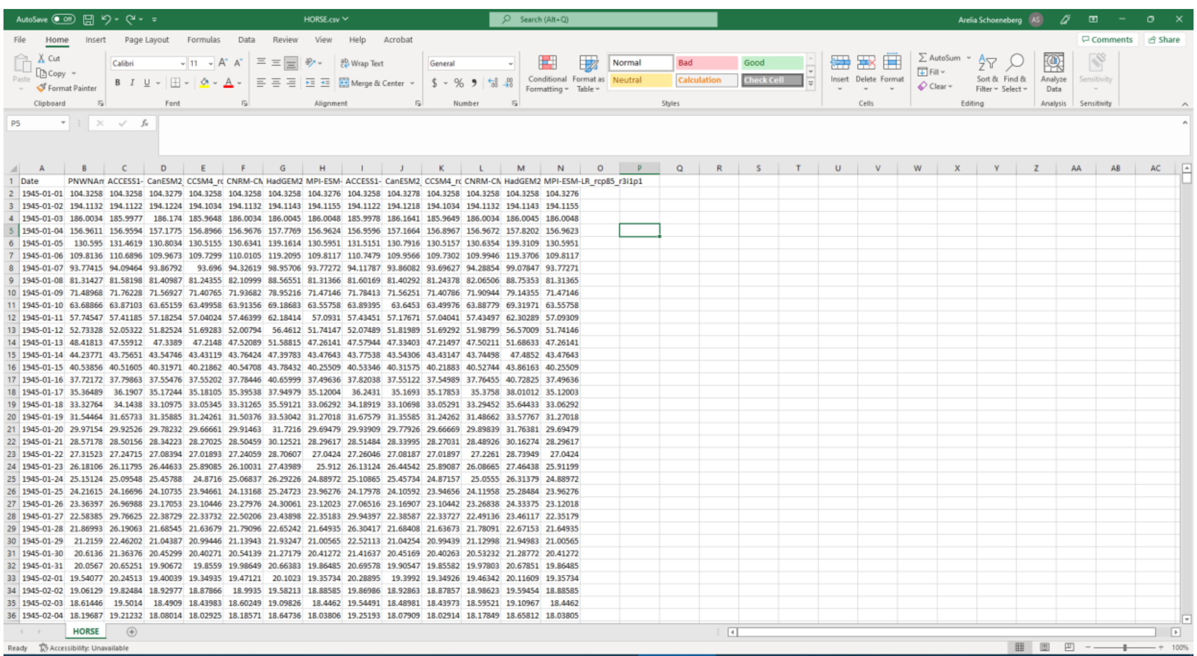


Figure 1 - Screen shot of the Station-based Hydrologic Model Data portal



Date	PNWNAm	ACCESS1-	CanESM2_	CCSM4_rc	CNRM-CN	HadGEM2	MPI-ESM-	ACCESS1-	CanESM2_	CCSM4_rc	CNRM-CN	HadGEM2	MPI-ESM-LR_rcp85_r3i1p1
1945-01-01	104.3258	104.3258	104.3279	104.3258	104.3258	104.3258	104.3276	104.3258	104.3278	104.3258	104.3258	104.3258	104.3276
1945-01-02	194.1132	194.1122	194.1224	194.1034	194.1132	194.1143	194.1155	194.1122	194.1218	194.1034	194.1132	194.1143	194.1155
1945-01-03	186.0034	185.9977	186.174	185.9648	186.0034	186.0045	186.0048	185.9978	186.1641	185.9649	186.0034	186.0045	186.0048
1945-01-04	156.9611	156.9594	157.1775	156.8966	156.9676	157.7769	156.9624	156.9596	157.1664	156.8967	156.9672	157.8202	156.9623
1945-01-05	130.595	131.4619	130.8034	130.5155	130.6341	139.1614	130.5951	131.5151	130.7916	130.5157	130.6354	139.3109	130.5951
1945-01-06	109.8136	110.6896	109.9673	109.7299	110.0105	119.2095	109.8117	110.7479	109.9566	109.7302	109.9946	119.3706	109.8117
1945-01-07	93.77415	94.09464	93.86792	93.696	94.32619	98.95706	93.77272	94.11787	93.86082	93.69627	94.28854	99.07847	93.77271
1945-01-08	81.31427	81.58198	81.40987	81.24355	82.10999	88.56551	81.31366	81.60169	81.40292	81.24378	82.06506	88.75353	81.31365
1945-01-09	71.48968	71.76228	71.56927	71.40765	71.93682	78.95216	71.47146	71.78413	71.56251	71.40786	71.90944	79.14355	71.47146
1945-01-10	63.68866	63.87103	63.65159	63.49958	63.91356	69.18683	63.55758	63.89395	63.6453	63.49976	63.88779	69.31971	63.55758
1945-01-11	57.74547	57.41185	57.18254	57.04024	57.46399	62.18414	57.0931	57.43451	57.17671	57.04041	57.43497	62.30289	57.09309
1945-01-12	52.73328	52.05322	51.82524	51.69283	52.00794	56.4612	51.74147	52.07489	51.81989	51.69292	51.98799	56.57009	51.74146
1945-01-13	48.41813	47.55912	47.3389	47.2148	47.52089	51.58815	47.26141	47.57944	47.33403	47.21497	47.50211	51.68633	47.26141
1945-01-14	44.23771	43.75651	43.54746	43.43119	43.76424	47.39783	43.47643	43.77538	43.54306	43.43147	43.74498	47.4852	43.47643
1945-01-15	40.53856	40.51605	40.31971	40.21862	40.54708	43.78432	40.25509	40.53346	40.31575	40.21883	40.52744	43.86163	40.25509
1945-01-16	37.72172	37.79863	37.55476	37.55202	37.78446	40.65999	37.49636	37.82038	37.55122	37.54989	37.76455	40.72825	37.49636
1945-01-17	35.36489	36.1907	35.17244	35.18105	35.39538	37.94979	35.12004	36.2431	35.1693	35.17853	35.3758	38.01012	35.12003
1945-01-18	33.32764	34.1438	33.10975	33.05345	33.31265	35.59121	33.06292	34.18919	33.10698	33.05291	33.29452	35.64433	33.06292
1945-01-19	31.54464	31.65733	31.35885	31.24261	31.50376	33.53042	31.27018	31.67579	31.35585	31.24262	31.48662	33.57767	31.27018
1945-01-20	29.97154	29.92526	29.78232	29.66661	29.91463	31.7216	29.69479	29.93909	29.77926	29.66669	29.89839	31.76381	29.69479
1945-01-21	28.57178	28.50156	28.34223	28.27025	28.50459	30.12521	28.29617	28.51484	28.33995	28.27031	28.48926	30.16274	28.29617
1945-01-22	27.31523	27.24715	27.08394	27.01893	27.24059	28.70607	27.0424	27.26046	27.08187	27.01897	27.2261	28.73949	27.0424
1945-01-23	26.18106	26.11795	26.44633	25.89085	26.10031	27.43989	25.912	26.13124	26.44542	25.89087	26.08665	27.46438	25.91199
1945-01-24	25.15124	25.09548	25.45788	24.8716	25.06837	26.29226	24.88972	25.10865	25.45734	24.87157	25.0555	26.31379	24.88972
1945-01-25	24.21615	24.16696	24.10735	23.94661	24.13168	25.24723	23.96276	24.17978	24.10592	23.94656	24.11958	25.28484	23.96276
1945-01-26	23.36397	26.96988	23.17053	23.10446	23.27976	24.30061	23.12023	27.06516	23.16907	23.10442	23.26838	24.33375	23.12018
1945-01-27	22.58385	29.76625	22.38729	22.33732	22.50206	23.43898	22.35183	29.94397	22.38587	22.33727	22.49136	23.46117	22.35179
1945-01-28	21.86993	26.19063	21.68545	21.63679	21.79096	22.65242	21.64935	26.30417	21.68408	21.63673	21.78091	22.67153	21.64935
1945-01-29	21.2159	22.46202	21.04387	20.99446	21.13943	21.93247	21.00565	22.52113	21.04254	20.99439	21.12998	21.94983	21.00565
1945-01-30	20.6136	21.36376	20.45299	20.40271	20.54139	21.27179	20.41272	21.41637	20.45169	20.40263	20.53232	21.28772	20.41272
1945-01-31	20.0567	20.65251	19.90672	19.8559	19.98649	20.66383	19.86485	20.69578	19.90547	19.85582	19.97803	20.67851	19.86485
1945-02-01	19.54077	20.24513	19.40039	19.34935	19.47121	20.1023	19.35734	20.28895	19.3992	19.34926	19.46342	20.11609	19.35734
1945-02-02	19.06129	19.82484	18.92977	18.87866	18.9935	19.58213	18.88585	19.86986	18.92863	18.87857	18.98623	19.59454	18.88585
1945-02-03	18.61446	19.5014	18.4909	18.43983	18.60249	19.09826	18.4462	19.54491	18.48981	18.43973	18.59521	19.10967	18.4462
1945-02-04	18.19687	19.21232	18.08014	18.02925	18.18571	18.64736	18.03806	19.25193	18.07909	18.02914	18.17849	18.65812	18.03805

Figure 2 - Screen shot of the Horse.csv

Exercises

Using the information found on the data portal landing page and the downloaded streamflow data itself, see if you can answer the following questions:

1) What is the gridded observational dataset used to calibrate (a) the hydrologic model and (b) the BCCAQv2 statistical downscaling?
2) What is the ensemble size?
3) How well does the simulation of streamflow using the gridded historical meteorological dataset compare to observational data from the WSC gauge (08KH010)?
4) What is the range in spring streamflow change between GCMs in the 2050s (mid-century) versus the 2080s (end-century)? Are the changes all in the same direction?
5) What is the degree of consensus for the median change in seasonal flow for a) spring (MAM) in the 2080s for RCP8.5, and b) for fall (SON) in the 2080s (end-century) for RCP4.5

See Appendix A for results for Horsefly River Above McKinley Creek, 08KH010, that will help answer some of the above questions.

Appendix A – Exercise Results for Horsefly River above McKinley Creek

Verification of PNWNAmet streamflow versus observations, calculated using the hydroGOF R package, are presented in Figure 3. Projected changes in seasonal streamflow versus the Baseline period are shown graphically in Figure 4 and summarised in Table 1 (absolute change) and Table 2 (relative change).

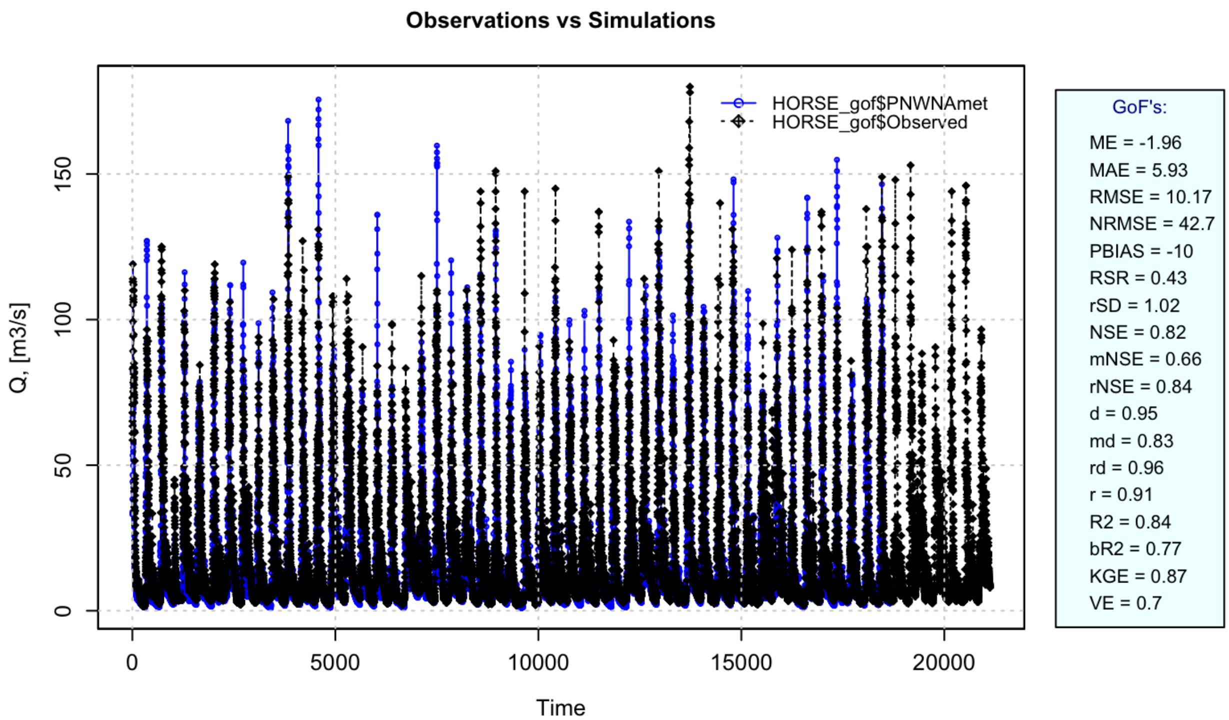


Figure 3 - Daily hydrograph comparison and goodness-of-fit metrics for the Horsefly River near McKinley Creek. ME - Mean Error (m^3/s), MAE - mean absolute error (m3/s), RMSE – root mean square error (m^3/s), NRMSE – normalized RMSE (-), PBIAS – percent bias (%), RSR - ratio of RMSE to the standard deviation of the observations (-), rSD – ratio of standard deviations (-), NSE – Nash-Sutcliffe Efficiency (-), mNSE - modified Nash-Sutcliffe efficiency (-), rNSE - relative Nash-Sutcliffe efficiency (-), d – index of agreement (-), md – modified index of agreement (-), rd – relative index of agreement (-), r – correlation coefficient (-), R2 - coefficient of determination (-), bR2 - coefficient of determination (R2) multiplied by the slope of the regression line between sim and obs (-), KGE – Kling-Gupta Efficiency (-), and VE – volumetric efficiency (-)

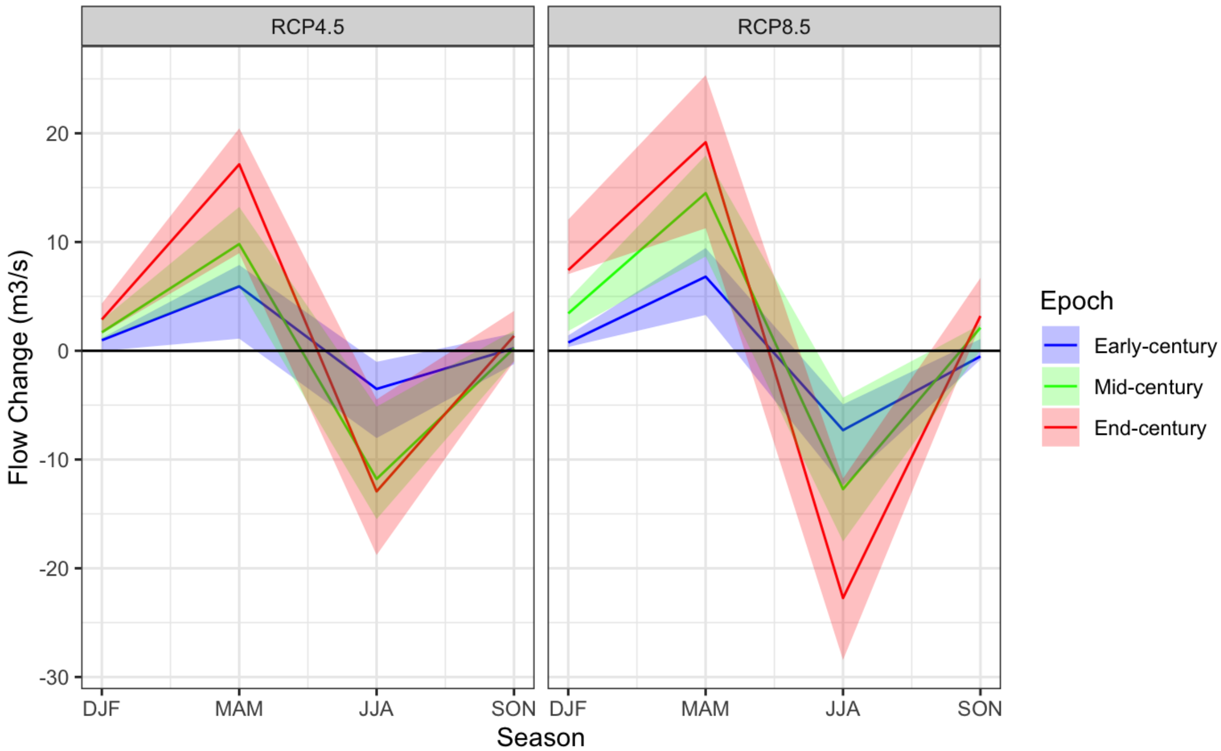


Figure 4. Projected change in seasonal flow for the Horsefly River above McKinley Creek for Early-, Mid-, and End-century for the RCP4.5 (left panel) and RCP8.5 (right panel) emissions scenarios.

Table 1. Summary of ensemble of projected seasonal flow changes from baseline, given as the ensemble median and range (minimum and maximum)

Scen	Period	Projected Changes in seasonal flow (m^3/s)											
		Minimum				Median				Maximum			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
RCP4.5	Early-century	0.0	1.1	-8.0	-1.2	1.0	5.9	-3.5	0.2	1.2	7.9	-1.0	1.6
	Mid-century	1.1	5.9	-15.5	-0.9	1.7	9.8	-11.8	0.2	2.8	13.2	-5.1	1.9
	End-century	1.6	9.0	-18.8	-1.0	2.9	17.1	-12.9	1.4	4.3	20.4	-4.5	3.7
RCP8.5	Early-century	0.3	3.3	-12.4	-0.8	0.8	6.8	-7.3	-0.5	1.4	9.4	-4.9	1.1
	Mid-century	1.8	8.7	-17.5	0.1	3.4	14.5	-12.7	2.1	4.7	18.0	-4.3	2.4
	End-century	7.1	11.3	-28.4	2.4	7.4	19.2	-22.7	3.2	12.1	25.3	-11.7	6.7

Table 2. Summary of ensemble of projected relative seasonal flow changes from baseline, given as the ensemble median and range (minimum and maximum)

Scen	Period	Projected Relative Changes in seasonal flow (%)											
		Minimum				Median				Maximum			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
RCP4.5	Early-century	-0.4	4.5	-22.4	-17.6	26.6	26.8	-10.4	3.1	33.3	39.8	-3.1	22.7
	Mid-century	27.6	27.5	-43.2	-11.5	48.5	45.2	-34.4	3.1	74.5	65.1	-13.8	26.1
	End-century	49.4	36.2	-52.5	-14.6	77.1	77.8	-38.5	17.1	114.5	103.2	-13.3	51.4
RCP8.5	Early-century	10.1	13.2	-34.6	-11.1	21.1	31.1	-21.1	-7.1	37.1	44.2	-14.7	15.2
	Mid-century	57.2	38.9	-49.0	0.7	93.2	66.1	-37.9	28.6	124.7	90.0	-12.8	32.3
	End-century	193.2	45.2	-79.4	34.6	216.5	92.8	-65.3	42.7	318.3	112.8	-34.9	94.0