From Snowmelt to Streamflow: Data Portals for Future Hydrologic Conditions

ACCOUNTING FOR CLIMATE CHANGE IMPACTS IN THE DESIGN OF RESOURCE ROAD STREAM CROSSINGS

25th June, 2020

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www.PacificClimate.org

University of Victoria

PACIFIC CLIMATE IMPACTS CONSORTIUM

Our Program

The Pacific Climate Impacts Consortium (PCIC) is a regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada.

We collaborate with climate researchers and regional stakeholders to produce knowledge and tools in support of long-term planning.

The aim of the Hydrologic Impacts (HI) theme at PCIC is to quantify the effect of climate change and climate variability on regional hydrology in order to provide analysis and information relevant to water resources management.

Outline

- **How will peak flows change in the future?**
- **How is PCIC modelling this in BC to give practitioners numbers they can use to get at these changes?**
- **Where can you access this data?**
- **What does this look like for two sites: 25 km^2 and 300 km^2?**

Peak Flow Changes in the Fraser River

Historical:

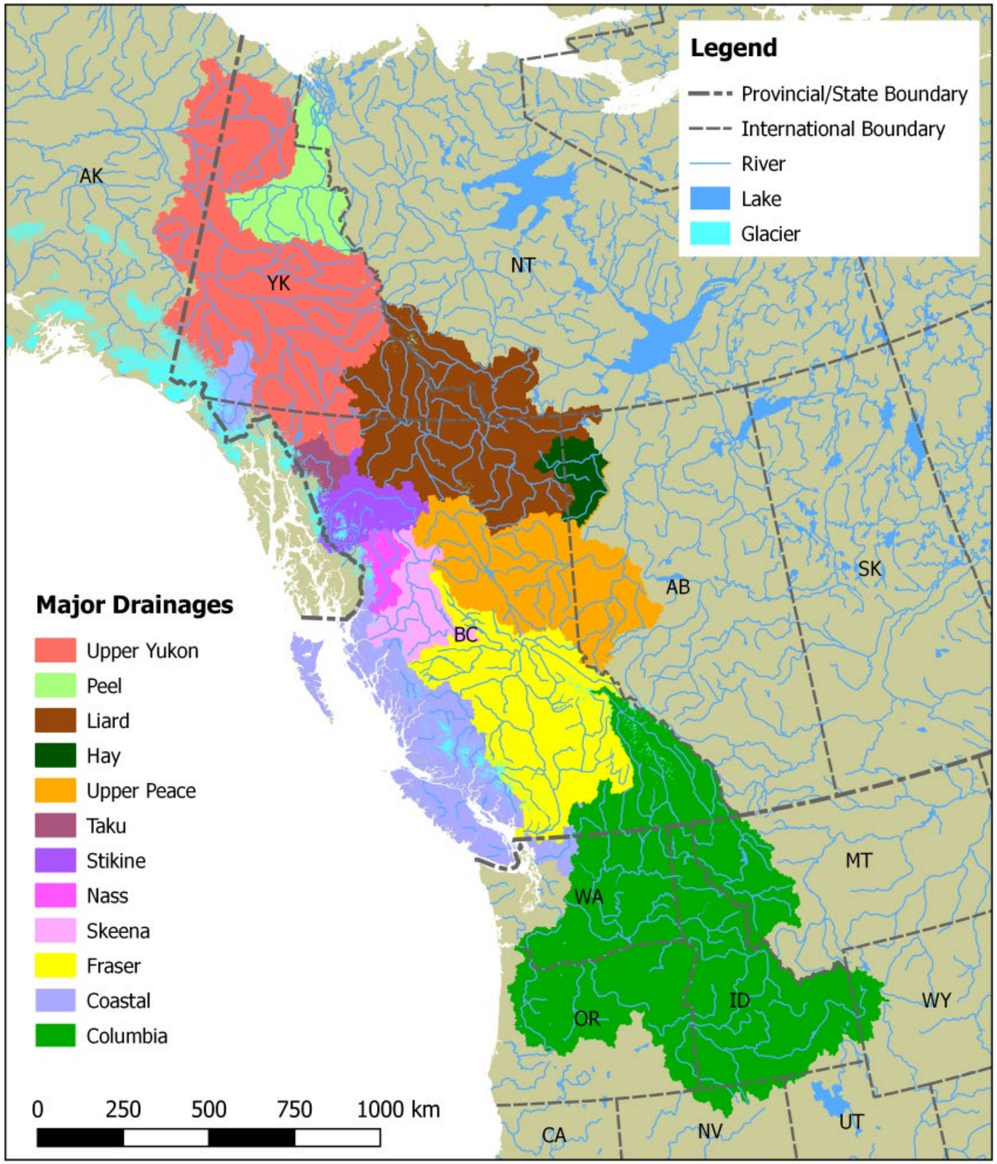
- **Most annual peak flows well correlated with April 1st Snow Water Equivalent (SWE); others likely caused by atmospheric rivers* (Neiman et al. 2011, Curry and Zwiers 2018, Curry et al. 2019).**
- **PIEVC – increased peak flows. FLNRORD.**

Future:

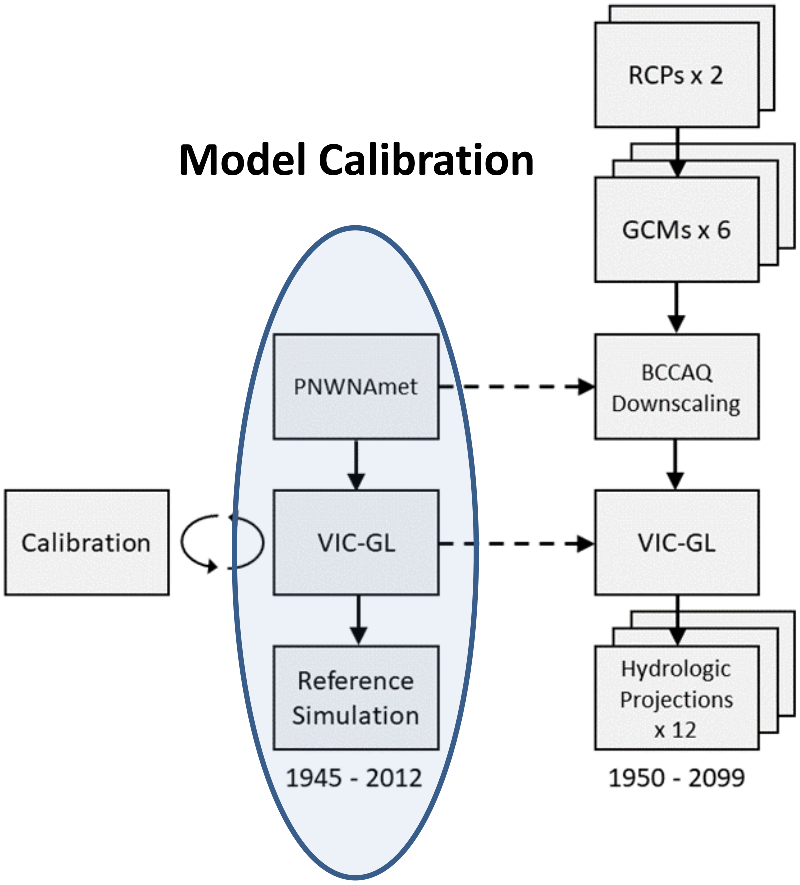
- **Ratio of snow to rain declines. Projected four fold increase in atmospheric rivers. Reduced return period for extreme peak flows (Curry et al. 2018).**
- **Large Ensembles tell us "Intense (precipitation) gets intenser" over most of North America (Li et al. 2019).**

*Atmospheric Rivers are long, meandering plumes of water vapor often originating over the tropical oceans that bring sustained, heavy precipitation to the west coasts of North America and northern Europe.

PCIC's Hydrologic Modelling Domain



Hydrologic Projections – Study Design



PNWNAmet versus NRCANmet (ANUSPLIN)

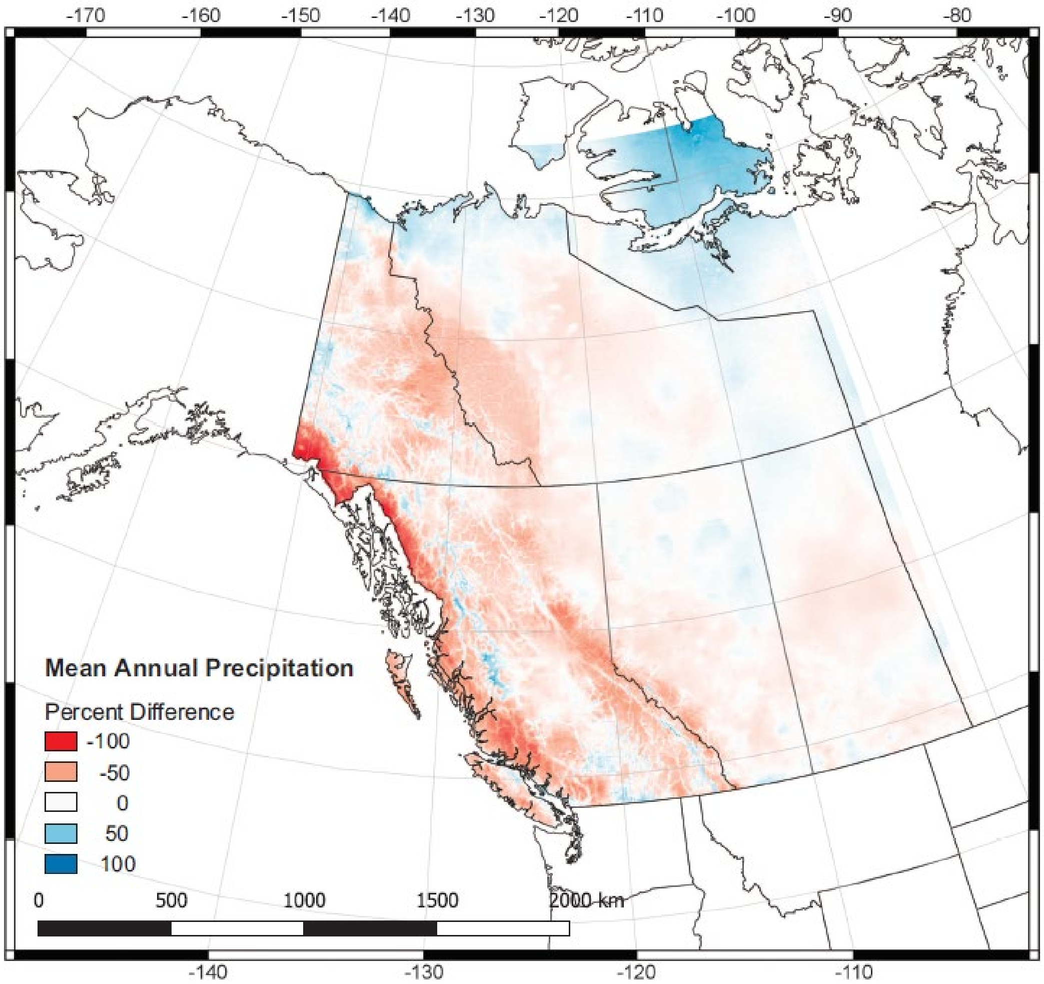
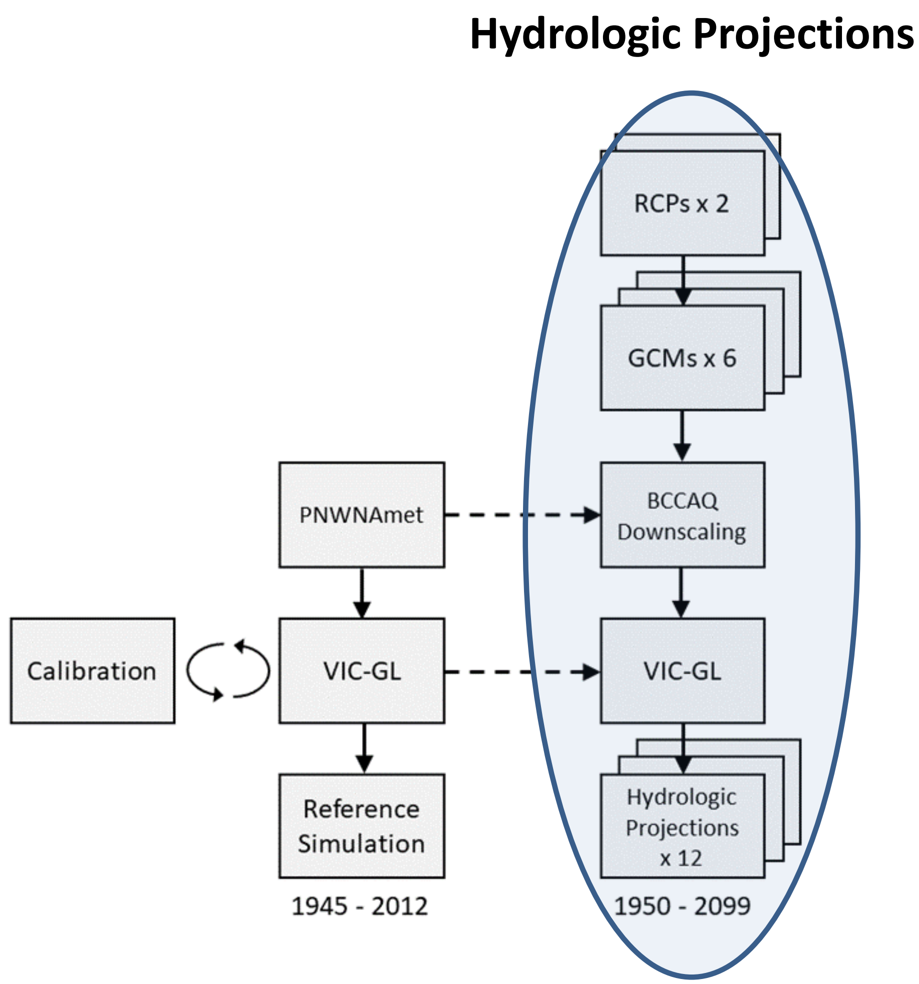


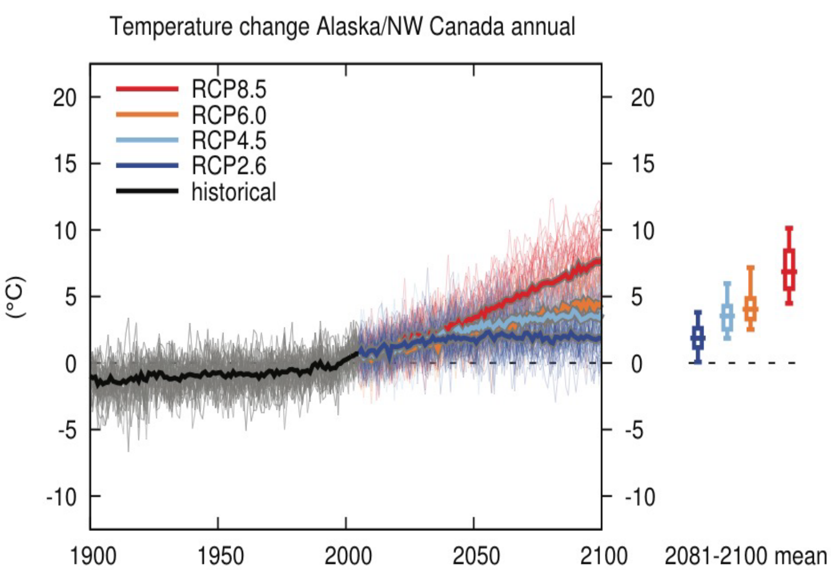
Figure 5. Percent difference in mean annual precipitation for NRCANmet minus PNWNAmet.

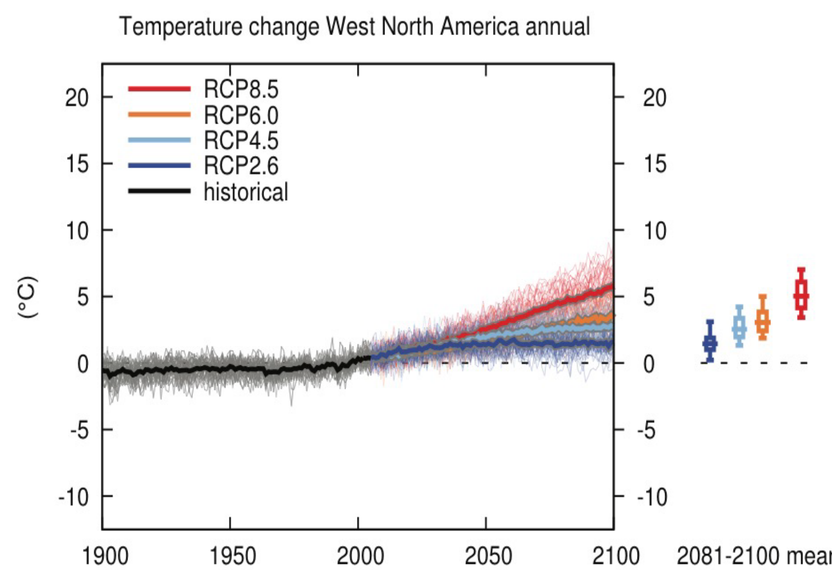
Hydrologic Projections – Study Design



Representative Concentration Pathways (RCPs)

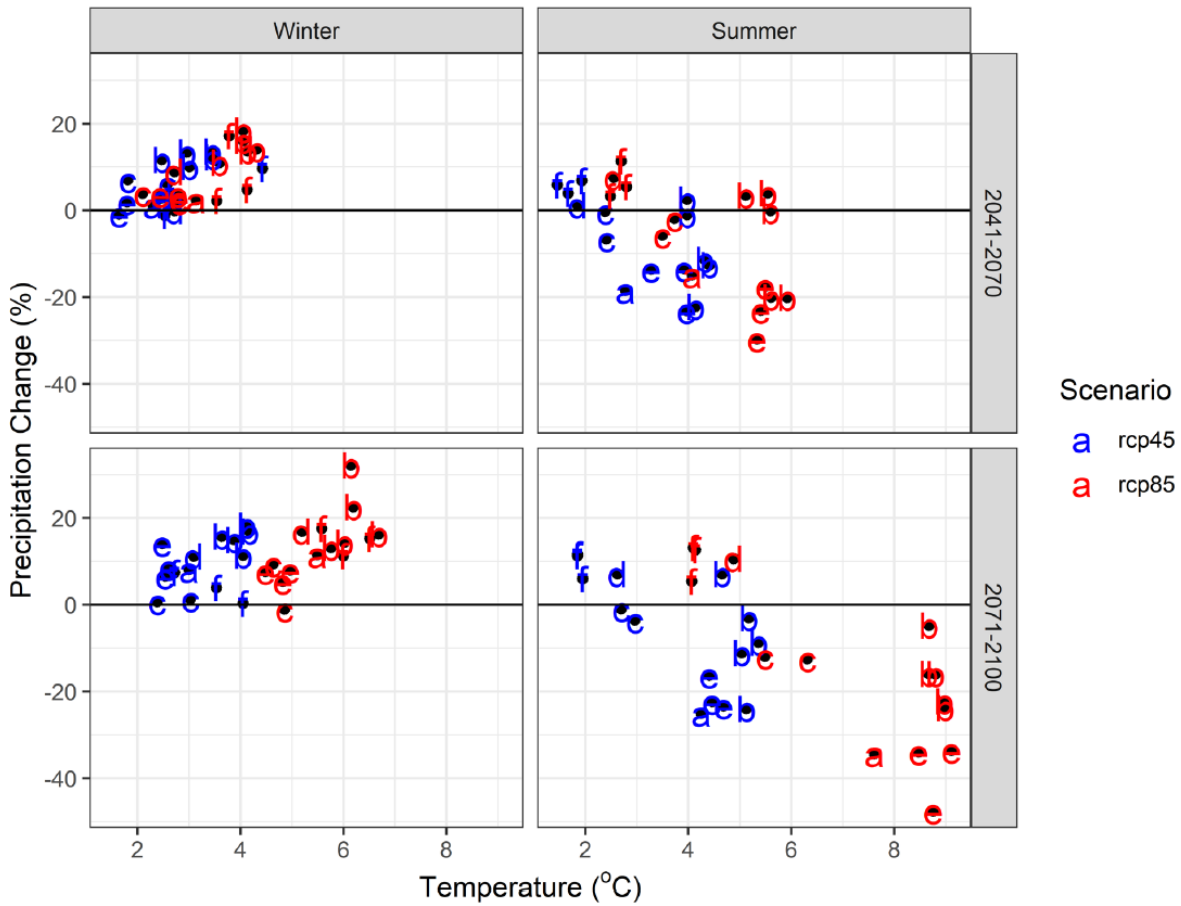
Two RCPs:
RCP 4.5 stabilizes mid-century
RCP 8.5 increases out past 2100



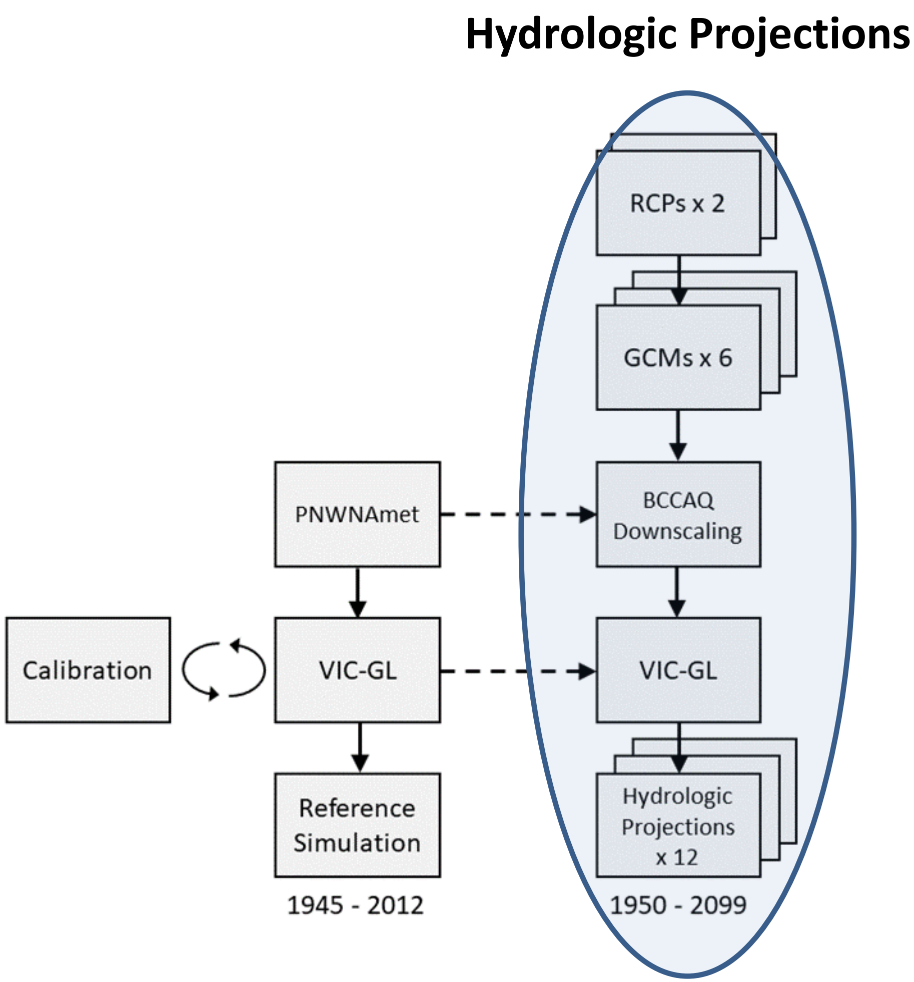


Global Climate Models (GCMs) from CMIP5

GCMs from the fifth Coupled Model Intercomparison Project (CMIP5), selected to cover a wide range in future temperature and precipitation.



Hydrologic Projections – Study Design



2 RCPs

6 GCMs

12 Hydrologic Projections

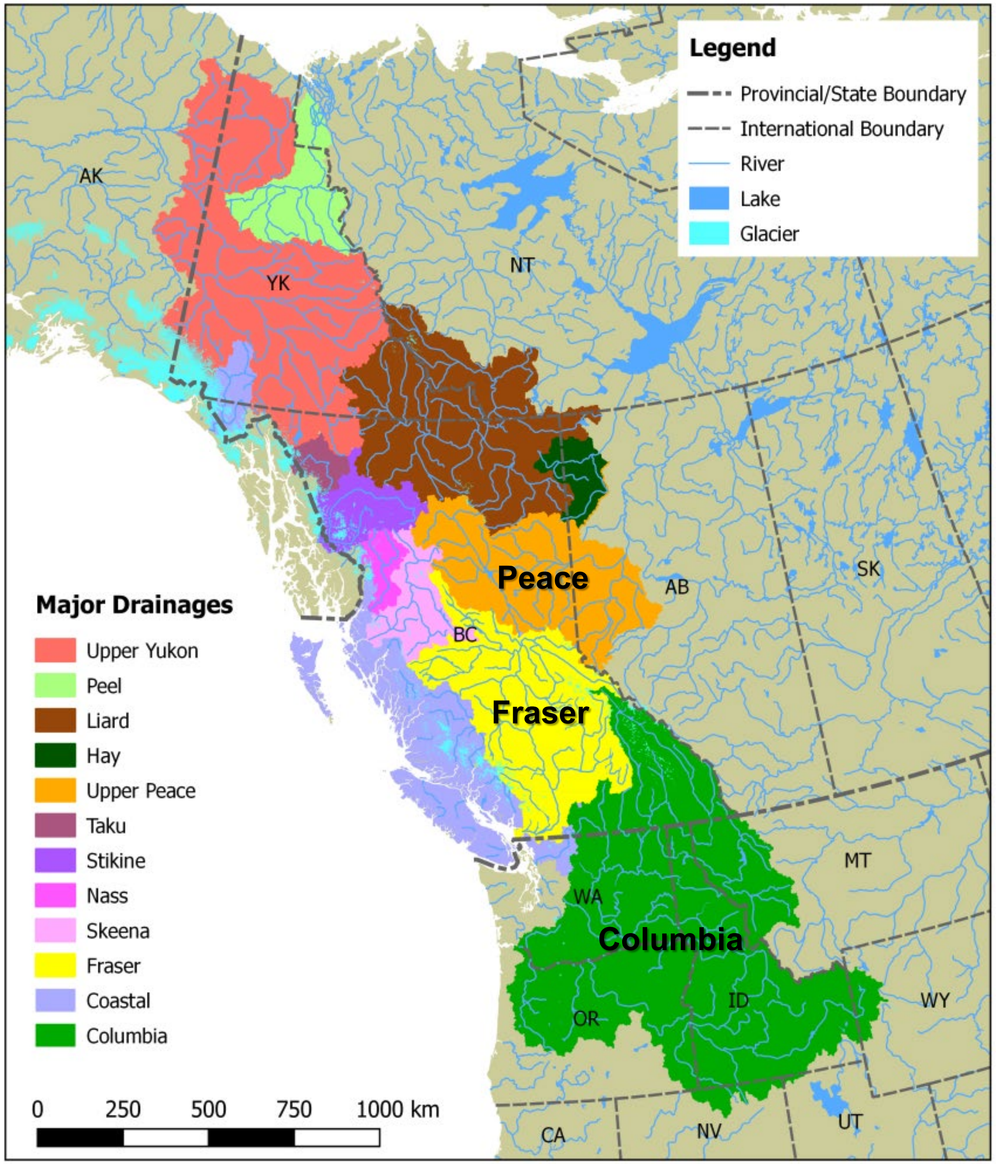
Current VIC-GL Domain

Peace:
- 203,969 km^2
- 7,485 cells
- 101,348 HRUs

Fraser:
- 250,238 km^2
- 8,452 cells
- 144,643 HRUs

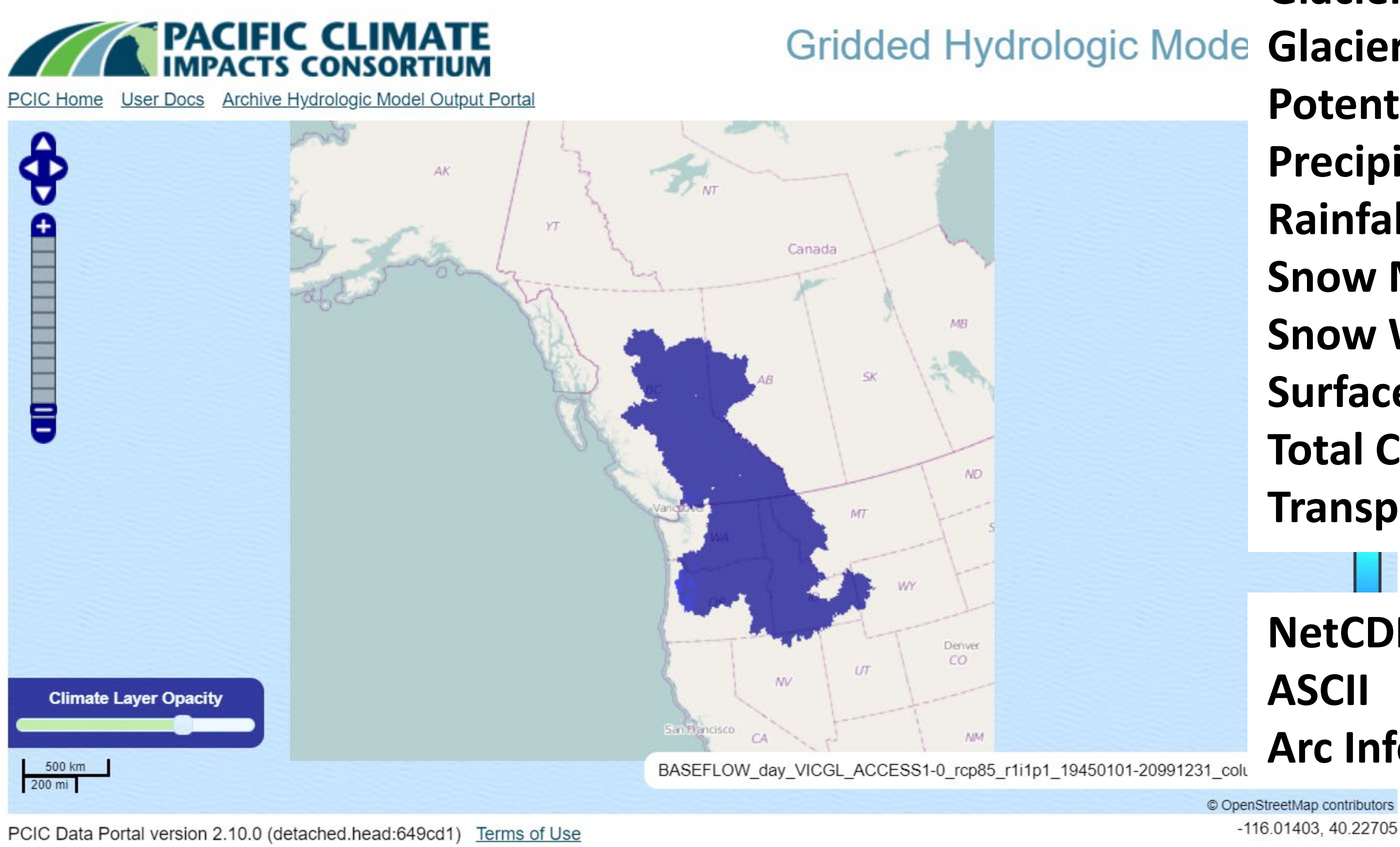
Columbia:
- 696,417 km^2
- 20,814 cells
- 267,299 HRUs

Total:
- 1,150,624 km^2
- 36,751 cells
- 513,290 HRUs



VIC-GL – Gridded Hydrologic Model Fluxes – 1/16°

PNWNAmet = Reference Simulation
2 RCPs x 6 GCMs = 12 Hydrologic Projections

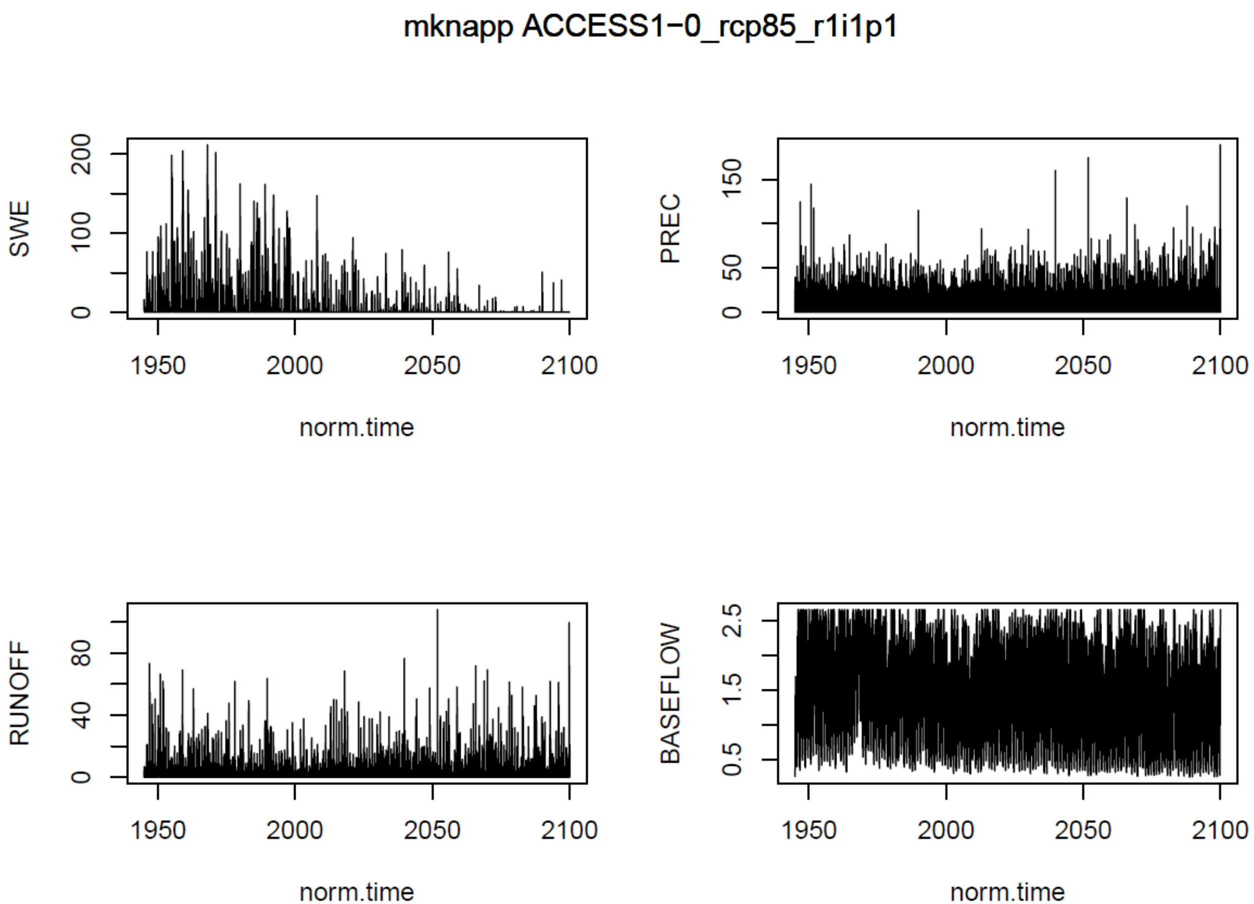


Baseflow
Evapotranspiration
Glacier Area
Glacier Mass Balance
Glacier Outflow
Potential Evapotranspiration
Precipitation
Rainfall
Snow Melt
Snow Water Equivalent
Surface Runoff
Total Column Soil Moisture
Transpiration

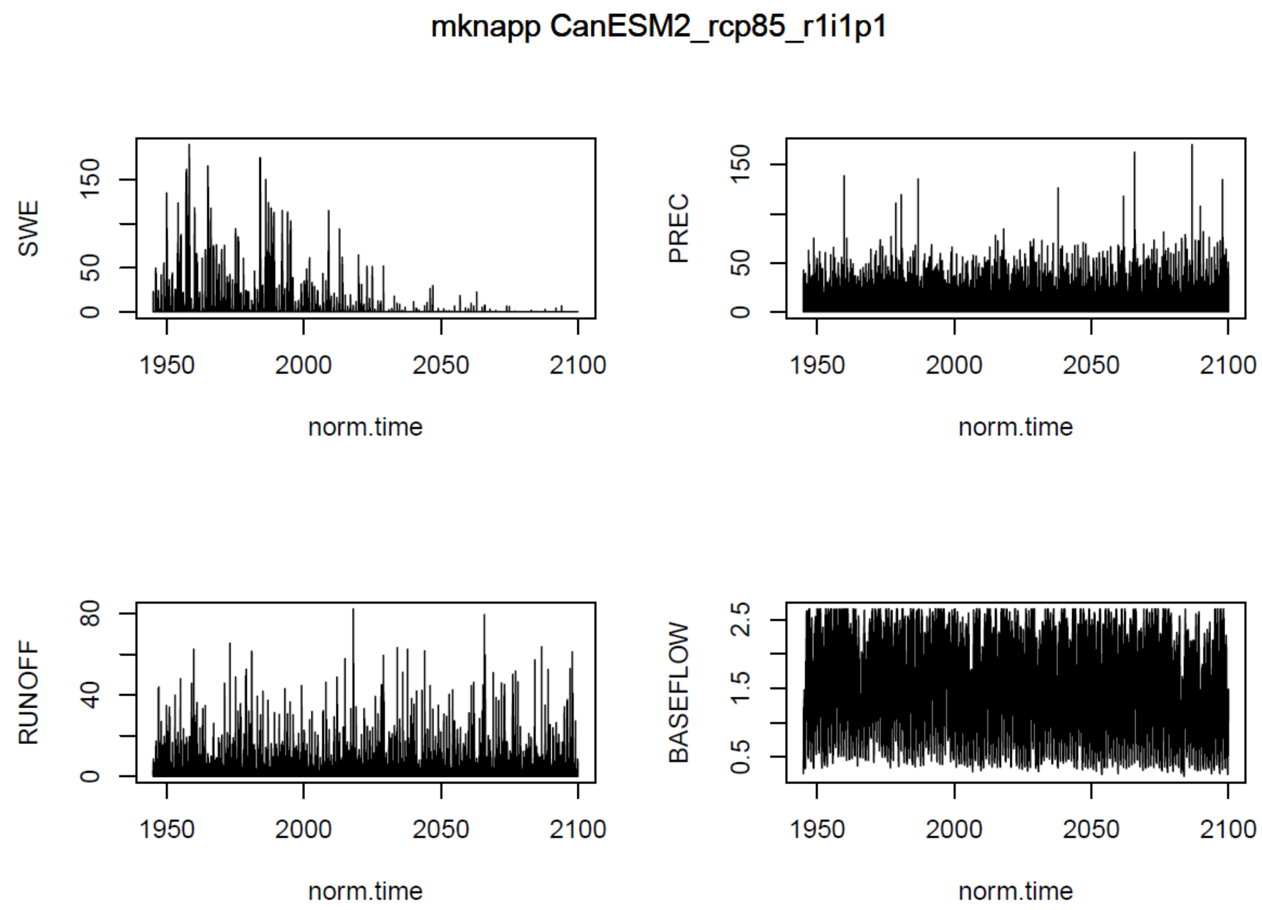
NetCDF
ASCII
Arc Info ASCII Grid

https://www.pacificclimate.org/data/gridded-hydrologic-model-output
https://data.pacificclimate.org/portal/docs/raster.html#download-multiple-variables
Open-source Project for a Network Data Access Protocol (OPeNDAP)

Grid Cell: lat 49.28125 lon -122.59375



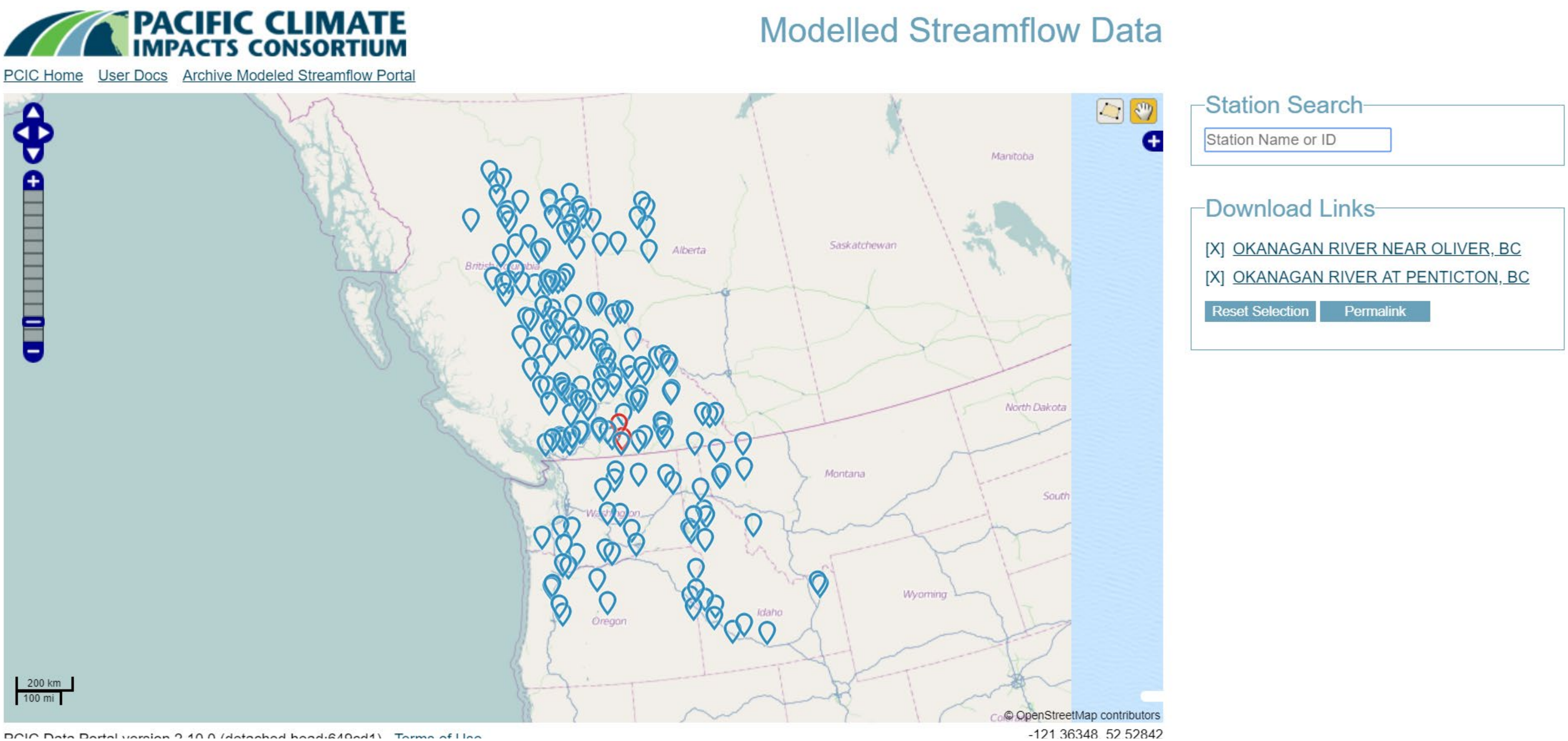
Grid Cell: lat 49.28125 lon -122.59375



VIC-GL – Station Hydrologic Model Output

PNWNAmet = Reference Simulation
2 RCPs x 6 GCMs = 12 Hydrologic Projections

Runoff + Baseflow through RVIC
→ Routed Streamflow



https://www.pacificclimate.org/data/station-hydrologic-model-output

VIC-GL – Station Hydrologic Model Output

CHILLIWACK RIVER AT VEDDER CROSSING

CHILLI.csv.ascii - Excel

F4 | 156.157241821

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	sequence														
2	Date	PNWNAmet	ACCESS1-0_rcp45_r1i1p1	CanESM2_rcp45_r1i1p1	CCSM4_rcp45_r2i1p1	CNRM-CM5_rcp45_r1i1p1	HadGEM2-ES_rcp45_r1i1p1	MPI-ESM-	ACCESS1-(	CanESM2_	CCSM4_rc	CNRM-CN	HadGEM2	MPI-ESM-LR_rcp85_r3i1p	
3	1945-01-01	76.1674881	76.09169006	79.83068085	76.05882263	76.45066071	76.06692505	76.81494	76.09187	79.82663	76.05882	76.45042	76.06921	76.80325	
4	1945-01-02	155.6299591	155.9913483	164.9237518	155.3673553	156.1572418	169.5400848	159.0303	155.9952	164.915	155.3674	156.1604	169.5825	158.9811	
5	1945-01-03	170.7541351	172.3549042	182.6290283	170.2595215	171.2668762	183.9529877	184.6008	172.3825	182.6448	170.2595	171.269	183.9675	184.5733	
6	1945-01-04	178.6806335	178.4470215	185.010498	169.822525	183.4362793	181.7512665	181.0787	178.5135	185.0176	169.8225	183.4361	181.7535	181.1039	
7	1945-01-05	188.7642365	184.5742035	193.6243591	165.8587036	177.4099274	207.1727142	168.1578	184.6826	193.6122	165.8587	177.3912	207.195	168.1647	
8	1945-01-06	209.2238159	175.760849	180.2976532	160.9930573	180.7414856	191.9483795	161.4763	175.8368	180.2812	160.9932	180.7883	191.9626	161.4775	
9	1945-01-07	236.4706116	161.7905121	173.4884949	155.989502	186.3611298	171.3206482	156.0947	161.7978	173.4857	155.9903	186.4013	171.3431	156.0947	

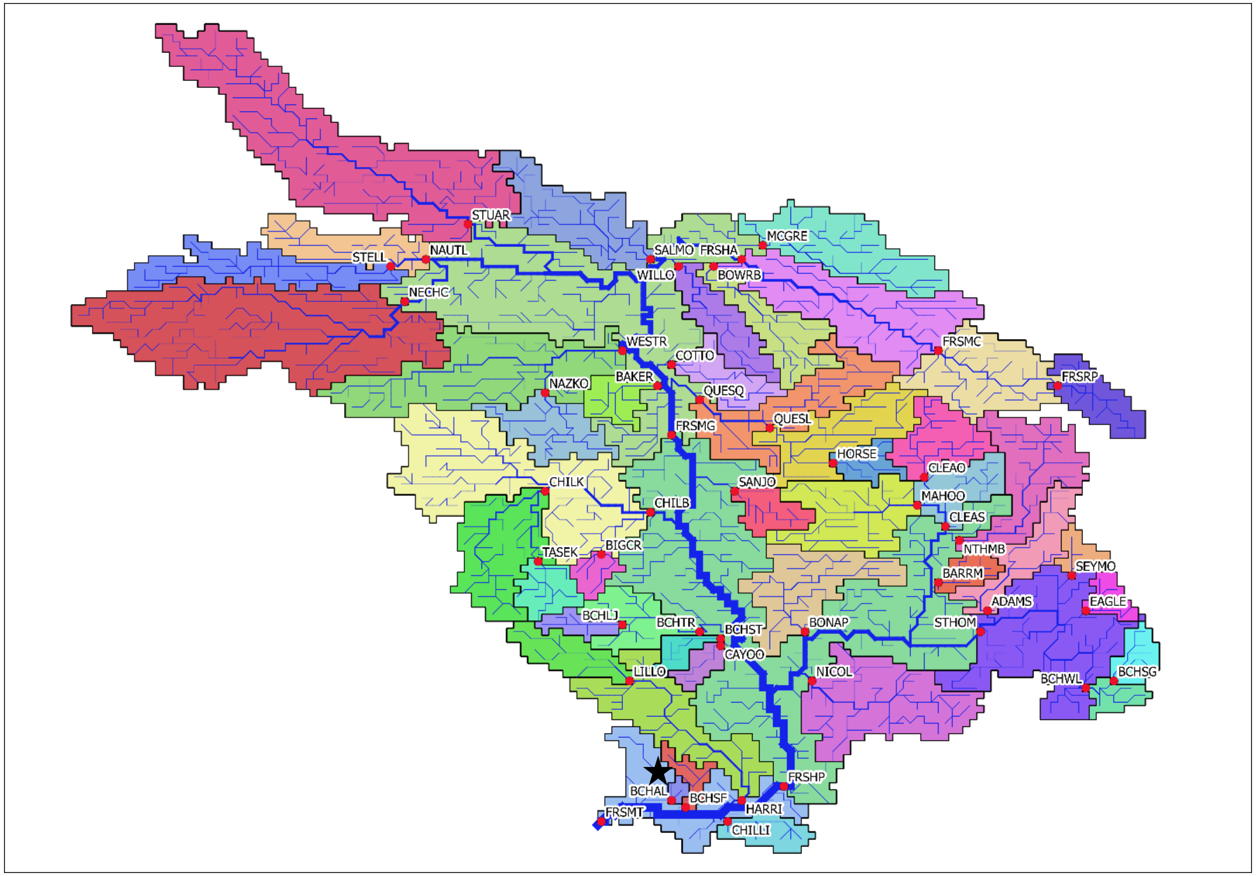
Daily Streamflow (m^3s^{-1})

Reference Simulation = PNWNAmet (1945 to 2012)
6 GCMs RCP 4.5 and RCP 8.5 (12 Hydrologic Projections – 1945 to 2099)

Date, PNWNAmet, ACCESS1-0_rcp45_r1i1p1, CanESM2_rcp45_r1i1p1, CCSM4_rcp45_r2i1p1, CNRM-CM5_rcp45_r1i1p1, HadGEM2-ES_rcp45_r1i1p1, MPI-ESM-LR_rcp45_r3i1p1, ACCESS1-0_rcp85_r1i1p1, CanESM2_rcp85_r1i1p1, CCSM4_rcp85_r2i1p1, CNRM-CM5_rcp85_r1i1p1, HadGEM2-ES_rcp85_r1i1p1, MPI-ESM-LR_rcp85_r3i1p1

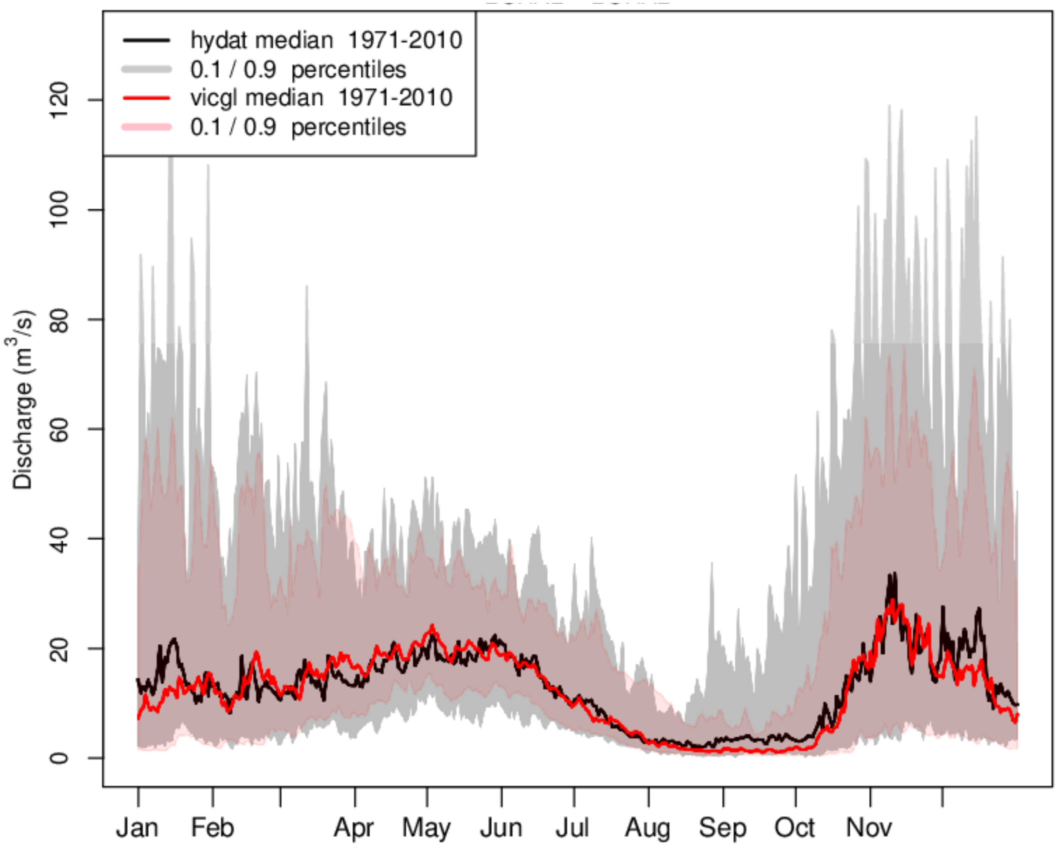
https://www.pacificclimate.org/data/station-hydrologic-model-output

Calibration of VIC-GL in the Fraser River Basin



VIC-GL – PNWNAmet vs. Observations

Alouette River at Alouette Dam – 283 km²



VIC-GL – PNWNAmet vs. Observations

Alouette River at Alouette Dam – 283 km^2

Percentiles – 1971-2000

	obs	mod	%diff
0%	0	0	0
10%	2	1	-33
20%	4	3	-18
30%	6	6	-5
40%	9	8	-2
50%	12	12	3
60%	16	16	-2
70%	21	20	-7
80%	30	26	-13
90%	47	36	-23
100%	452	233	-48

Reference Simulation or PNWNAmet run allows us to verify the model.

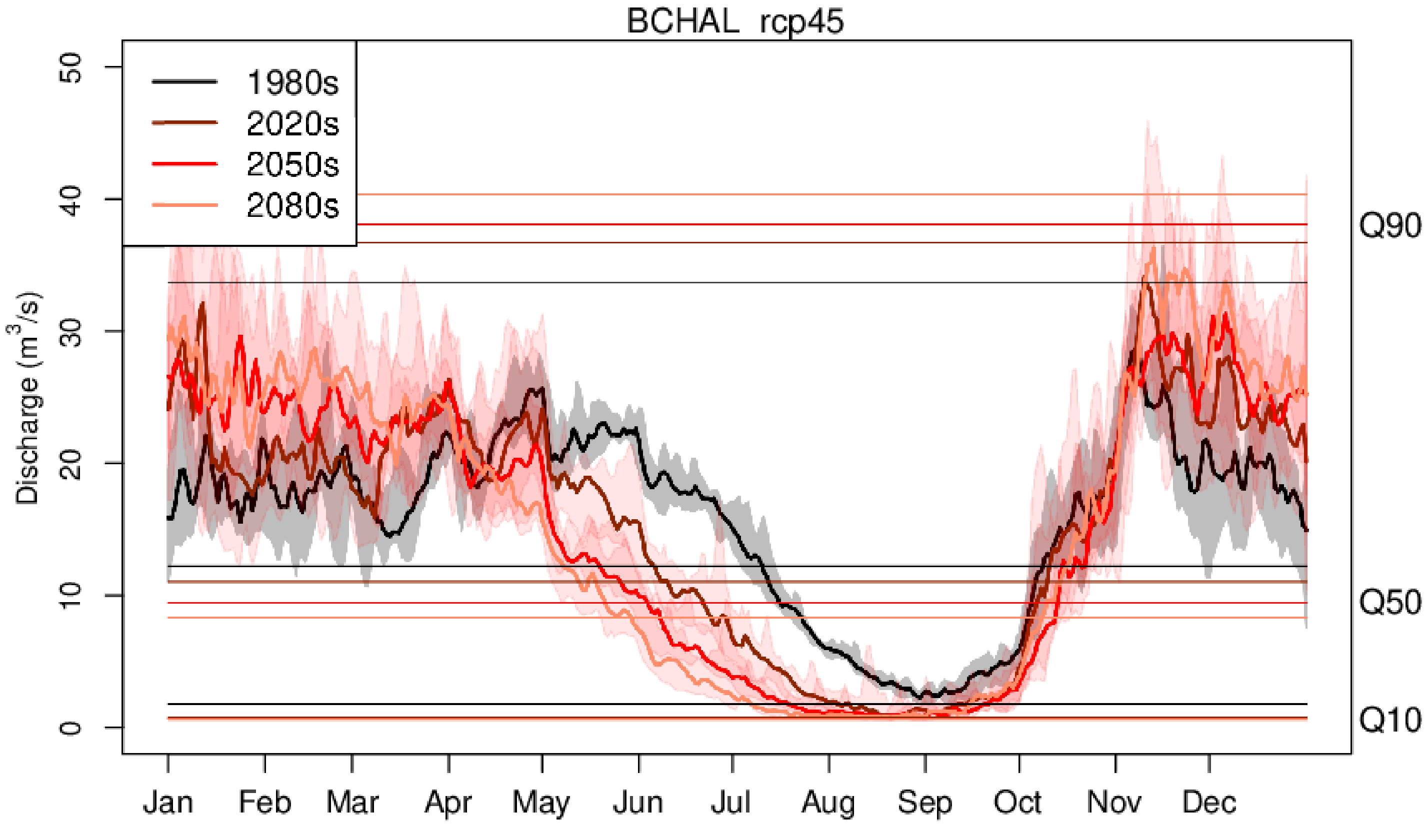
Seasonal – 1971-2000

	obs	mod	%diff
Spring - MAM	23	21	-8
Summer - JJA	12	10	-14
Fall - SON	23	15	-34
Winter - DJF	28	20	-30

Response to Climate Forcings – RCP 4.5

Alouette River at Alouette Dam – 283 km²

Min, Median and Max for 6 GCM run under RCP 4.5

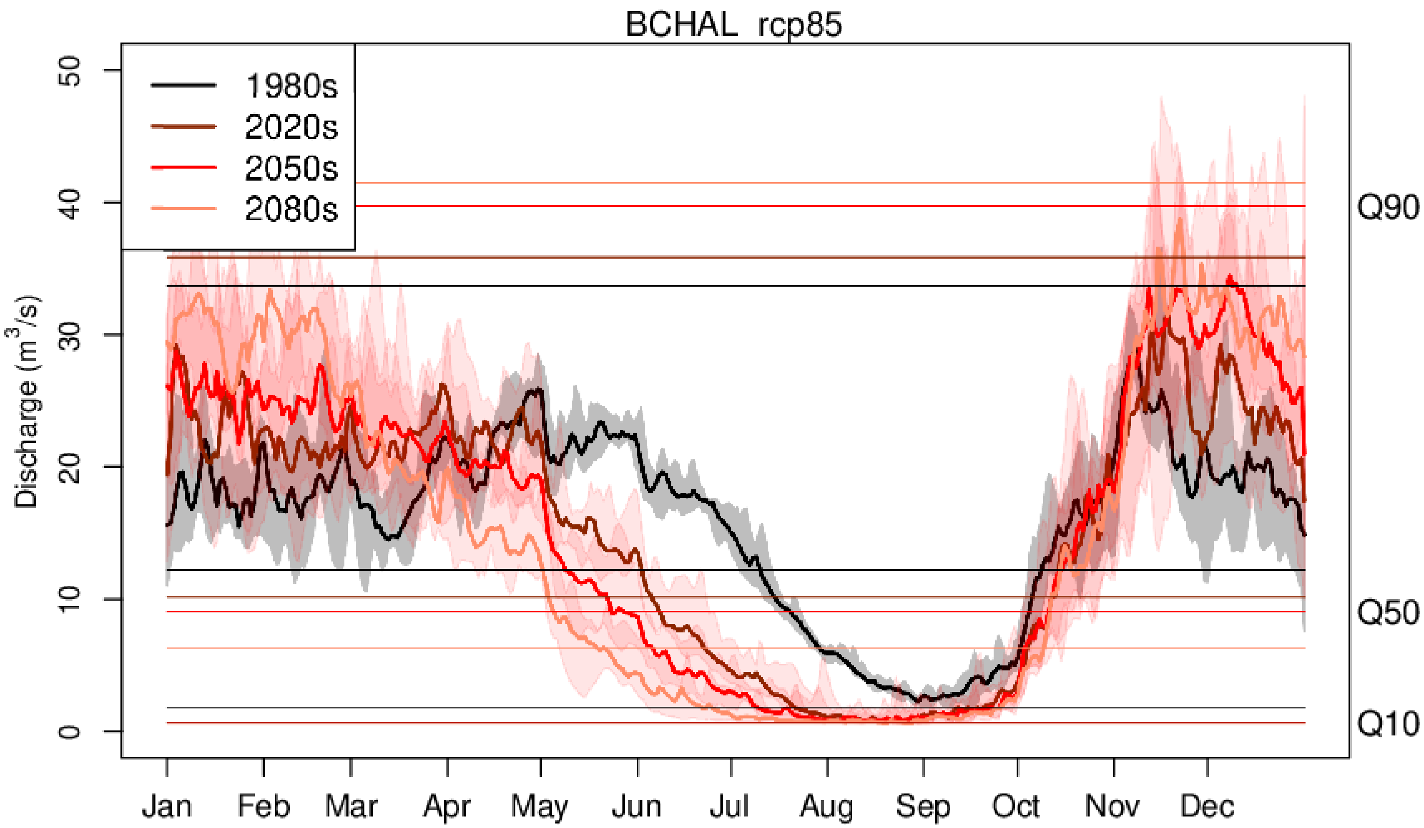


https://www.pacificclimate.org/data/station-hydrologic-model-output

Response to Climate Forcings – RCP 8.5

Alouette River at Alouette Dam – 283 km²

Min, Median and Max for 6 GCM run under RCP 8.5



https://www.pacificclimate.org/data/station-hydrologic-model-output

Low, Median and High Streamflow RCP 4.5

Alouette River at Alouette Dam – 283 km^2

	Mean of Ensemble			Min of Ensemble			Max of Ensemble		
	Q10	**Q50**	**Q90**	**Q10**	**Q50**	**Q90**	**Q10**	**Q50**	**Q90**
	Low	**Median**	**High**	**Low**	**Median**	**High**	**Low**	**Median**	**High**
med.dat.1980	2	12	34	2	12	33	2	13	35
med.dat.2020	1	10	36	1	9	33	1	12	42
med.dat.2050	1	9	40	1	8	37	1	10	41
med.dat.2080	1	6	41	1	5	37	1	8	47
med.per.diff.2020	**-61**	**-17**	**9**	**-64**	**-29**	**-4**	**-46**	**-3**	**20**
med.per.diff.2050	**-64**	**-28**	**19**	**-68**	**-39**	**5**	**-55**	**-15**	**22**
med.per.diff.2080	**-66**	**-50**	**25**	**-68**	**-58**	**12**	**-61**	**-33**	**33**

https://www.pacificclimate.org/data/station-hydrologic-model-output

Low, Median and High Streamflow RCP 8.5

Alouette River at Alouette Dam – 283 km^2

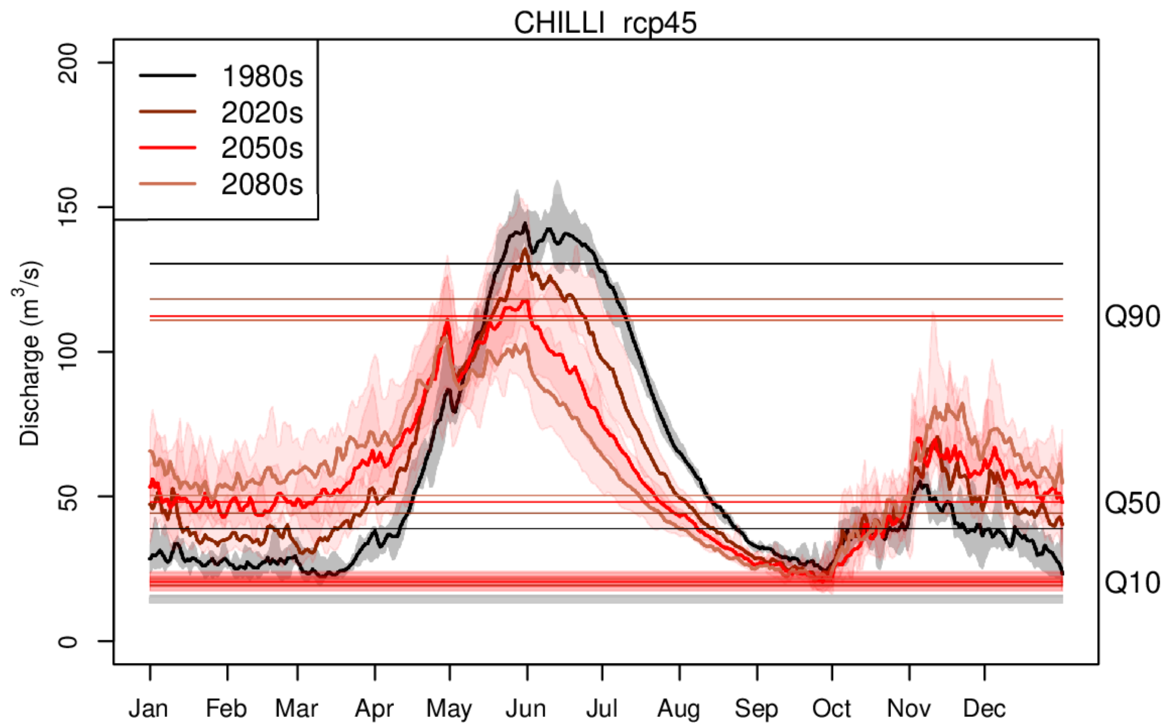
	Mean of Ensemble			Min of Ensemble			Max of Ensemble		
	Q10	Q50	Q90	Q10	Q50	Q90	Q10	Q50	Q90
	Low	Median	High	Low	Median	High	Low	Median	High
med.dat.1980	2	12	34	2	12	33	2	13	35
med.dat.2020	1	11	37	1	10	36	1	12	39
med.dat.2050	1	9	38	1	9	37	1	10	41
med.dat.2080	1	8	40	1	8	38	1	12	43
med.per.diff.2020	**-54**	**-9**	**10**	**-63**	**-24**	**4**	**-47**	**-3**	**14**
med.per.diff.2050	**-63**	**-24**	**13**	**-68**	**-28**	**8**	**-59**	**-21**	**20**
med.per.diff.2080	**-64**	**-32**	**18**	**-70**	**-35**	**10**	**-57**	**-4**	**27**

https://www.pacificclimate.org/data/station-hydrologic-model-output

Response to Climate Forcings – RCP 4.5

CHILLIWACK RIVER AT VEDDER CROSSING – 1230 km²

Min, Median and Max for 6 GCM run under RCP 4.5



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Response to Climate Forcings – RCP 8.5

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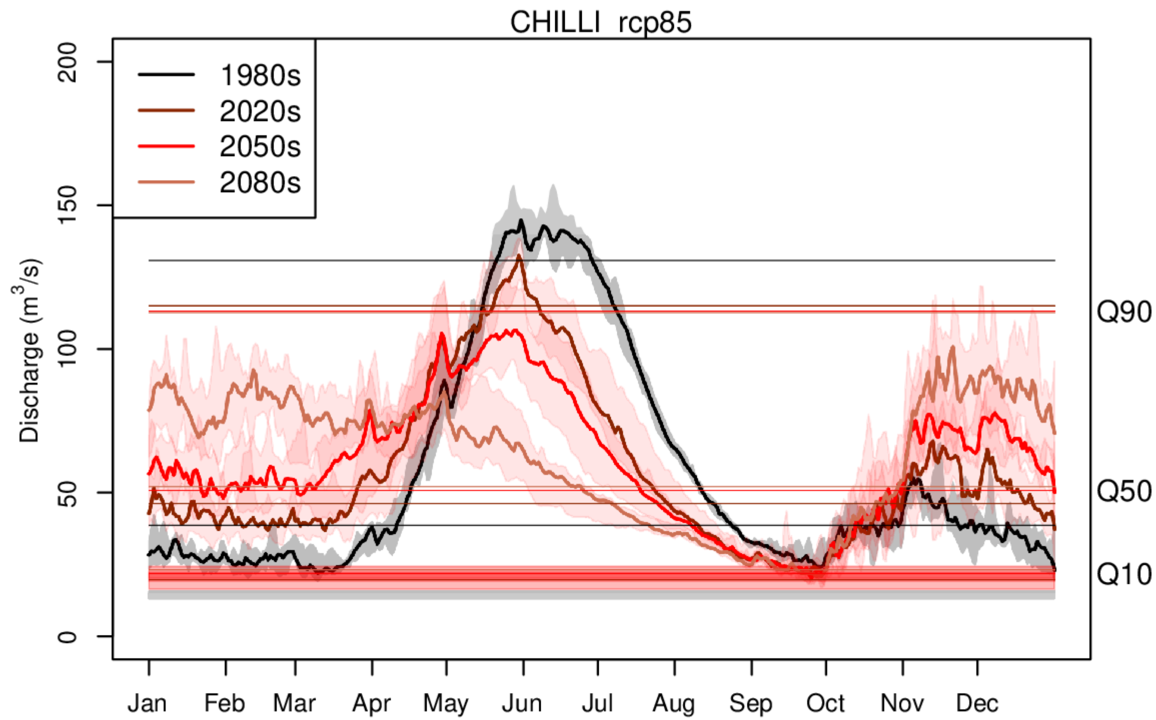


https://www.pacificclimate.org/data/station-hydrologic-model-output

Low, Median and High Streamflow RCP 8.5

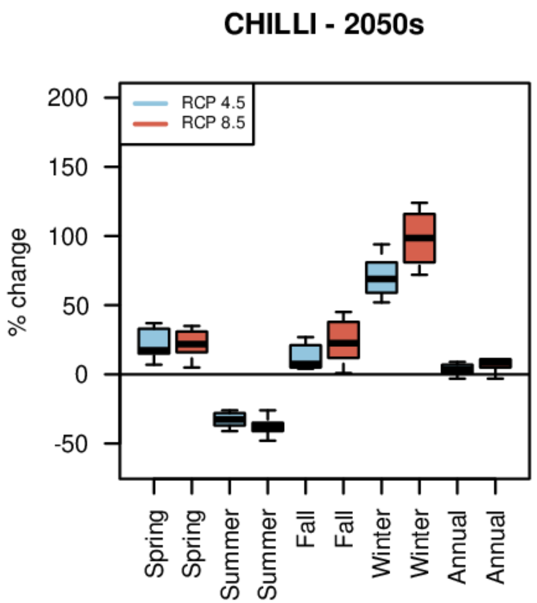
			Median			Minimum			Maximum		
			Low	Median	High	Low	Median	High	Low	Median	High
Chilliwack	*Streamflow (m^3s^{-1})*	***1980s***	15	39	131	13	37	126	16	41	132
		2020s	20	46	115	16	42	113	22	50	125
		2050s	22	51	113	19	47	106	23	57	119
		2080s	23	52	113	20	47	101	24	57	117
	Change vs 1980s (%)	***2020s***	**33**	**22**	**-11**	**14**	**3**	**-14**	**50**	**29**	**-5**
		2050s	**47**	**35**	**-14**	**26**	**15**	**-20**	**63**	**45**	**-6**
		2080s	**55**	**37**	**-13**	**33**	**17**	**-23**	**84**	**46**	**-10**

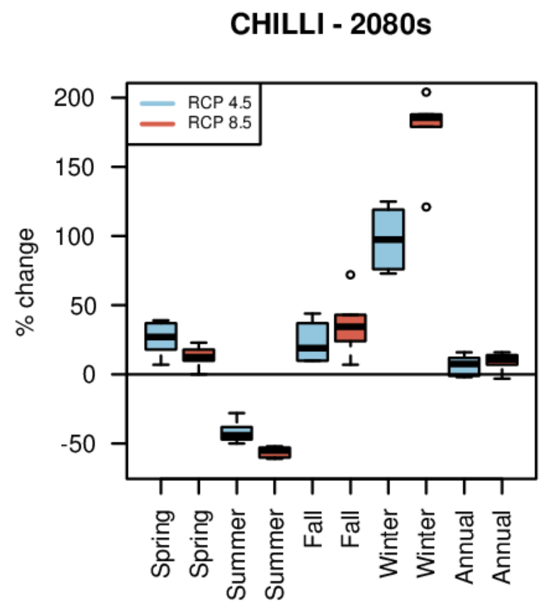
https://www.pacificclimate.org/data/station-hydrologic-model-output

GCM Agreement and RCP 4.5 versus 8.5 Response

CHILLIWACK RIVER AT VEDDER CROSSING

There is a range in response between GCMs. High confidence in direction of change in all seasons. Moderate confidence only annually because sign of change is different.





https://www.pacificclimate.org/data/station-hydrologic-model-output

Median Seasonal and Annual Streamflow Change

CHILLIWACK RIVER AT VEDDER CROSSING

RCP 4.5 **RCP 8.5**

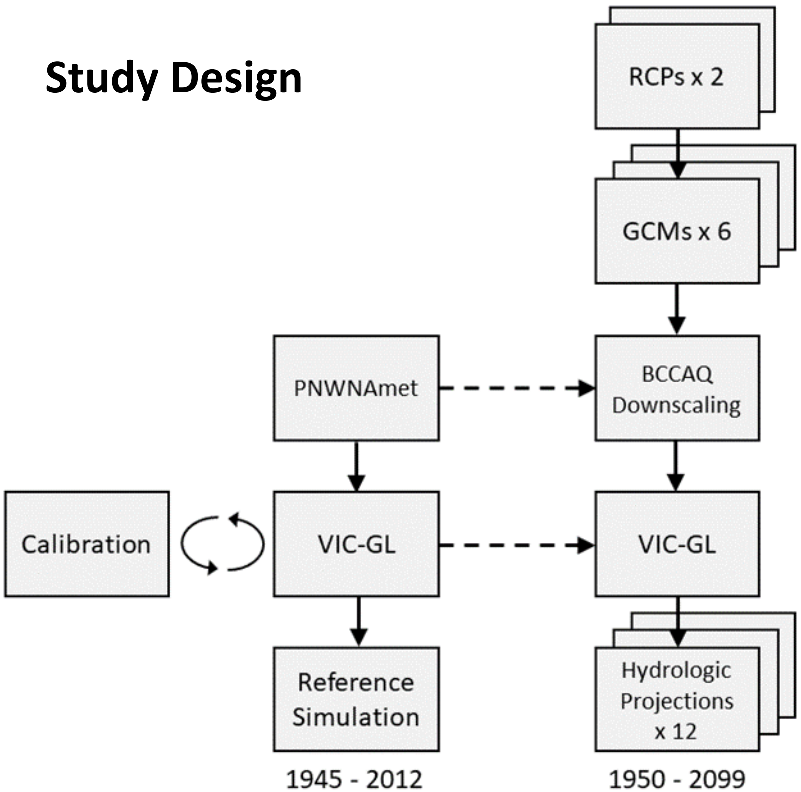
		Median RCP 4.5 Ensemble						Median RCP 8.5 Ensemble				
		Spr.	Sum.	Fall	Win.	Annual		Spr.	Sum.	Fall	Win.	Annual
Streamflow (m^3s^{-1})	*1980s*	65	94	37	31	57		65	94	37	30	57
	2020s	75	78	40	41	58		78	70	40	42	58
	2050s	77	62	42	50	59		80	58	46	58	61
	2080s	82	54	44	58	61		72	43	49	86	63
Change vs 1980s (%)	*2020s*	14	-18	8	33	1		19	-24	7	42	3
	2050s	17	-32	7	69	4		22	-38	23	98	9
	2080s	27	-44	19	97	7		12	-55	35	186	11

Projected increases in spring, fall, winter and annually based on the median of six GCMs. Decreases projected for summer.

https://www.pacificclimate.org/data/station-hydrologic-model-output

Hydrologic Projections – Study Design + Portals

Study Design



Data Portals

https://www.pacificclimate.org/data/daily-gridded-meteorological-datasets

https://www.pacificclimate.org/data/statistically-downscaled-climate-scenarios

https://www.pacificclimate.org/data/gridded-hydrologic-model-output

https://www.pacificclimate.org/data/station-hydrologic-model-output

Current Directions – HI Theme

- Completion and analysis of large ensemble VIC-GL simulations
- Application of VIC-GL to study of
  - flow and water temperature in coastal basins
  - flow and water temperature in the Nechako watershed
  - large basin calibration procedures
- Couple RAVEN to dynamic glacier model; initial application to
  - Mica and Cheakamus basins
  - Somass basin (flow and water temperature)
- Hydrologic tool development for PCIC Data Portal
  - Routing to any point in modelling domain (MOTI)
- Percent increase in precipitation with degree of warming

PCIC's Hydrologic Projection Portals

Questions?

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