DOWNSCALING EXTREMES — A NEW SET OF CLIMATE CHANGE PROJECTIONS FOR CANADA

PACIFIC CLIMATE IMPACTS CONSORTIUM

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Introduction

The need for future projections of extremes is growing, particularly as users planning to adapt to climate change continue to experience record-breaking events (Figure 1). Decision-making demands that such projections possess high spatial resolution. Downscaling has been carried out for Canada by the Pacific Climate Impacts Consortium for the newest Global Climate Model (GCM) and Regional Climate Model (RCM) projections.

Figure 1: *Damage experienced in Bella Coola during 200-year rainfall event in September 2010. Photo credit: BC Ministry of Transportation and Infrastructure.*

Method selection

We compared the performance of eight statistical downscaling methods (Bürger et al. 2013; Cannon et al., in prep.) by training on reanalysis and validating against historical observations, as well as using RCM emulation (Figure 2). We considered metrics of three types: (i) daily sequencing of events, (ii) similarity of distribution of values, and (iii) spatial variation.

Consequently, we modified BCCA, which is a gridded statistical downscaling method that bias-corrects daily climate model output via quantile mapping using observations that are aggregated to the model scale. This is similar to the widely used BCSD method, however BCCA uses a linear combination of historical analogues for daily large-scale anomalies to preserve spatial variability. Finally, our modified version, BCCAQ, includes a post-processing quantile mapping step at high resolution. This gives the method superior performance over North America compared with other gridded methods.

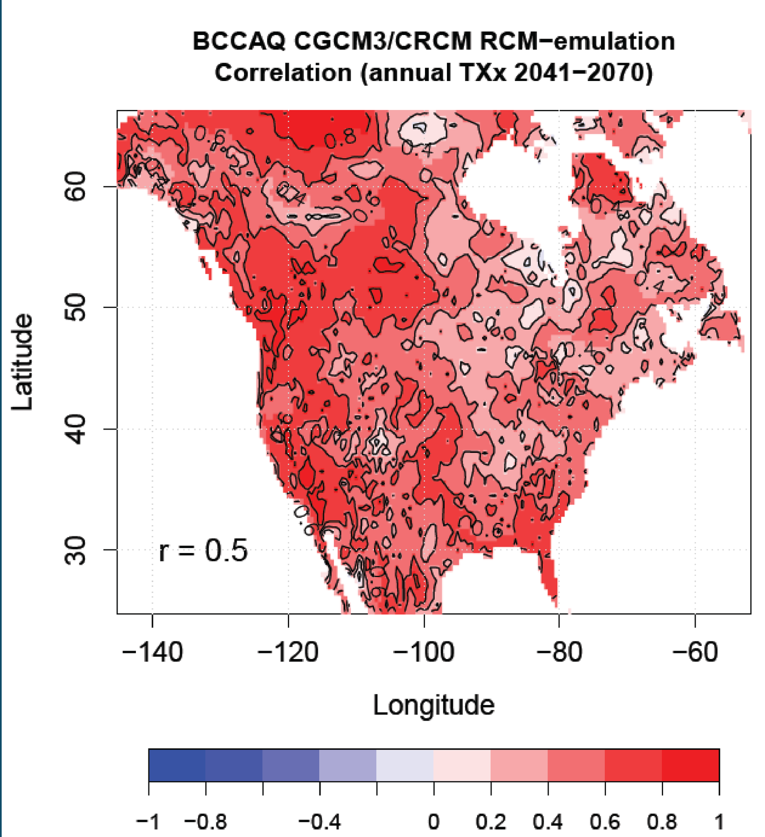

Figure 2: *Correlation of annual TXx (extreme daily maximum temperature) for RCM emulation of the BCCAQ downscaling method. BCCAQ is trained using the past (1971-2000) coarse resolution GCM simulation and the past RCM simulation driven by that GCM. Then the downscaled GCM future projection is compared to the RCM future driven by the GCM. This provides a validation of BCCAQ under future climate. The GCM/RCM pair shown is CGCM3 and CRCM from NARCCAP (A2 emissions). Results are similar for other GCM/RCM pairs.*

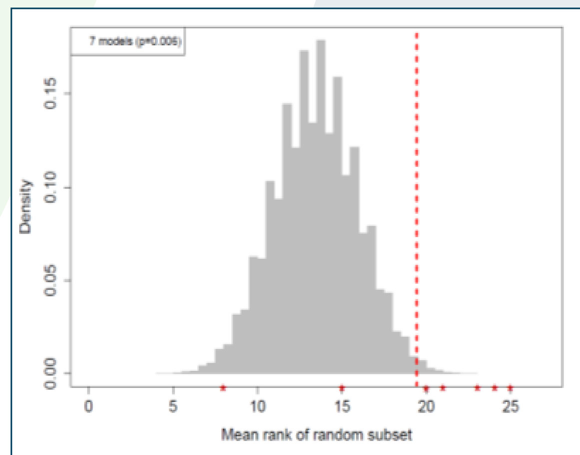

Figure 3: *Rank of projected RCP4.5 2050s and 2080s change for all 27 CLIMDEX indices in Northern Hemisphere Giorgi and Francisco regions. The histogram shows all possible combinations of ensembles with 7 members. The dashed red line shows the ensemble of the 7 models with lowest historical validation. Red asterisks show individual runs in that ensemble.*

Scenarios selection

A subset of CMIP5 simulations was chosen by first eliminating the models with lowest historical skill over the Northern hemisphere for 27 indices of extremes (Sillmann et al. 2013). GCMs that did not reproduce historical extremes tended to project future changes that were relative outliers (Figure 3). The clustering algorithm used to obtain an ordered subset of runs tends to favour those with projections that are most different from their peers. Screening based on skill prior to selection helps avoid choosing outliers. The selected ensemble captures nearly 90% of variation in projected change for 90% of parameters (27 indices of extremes and seasonal mean temperature and precipitation) over Canada. A scatterplot (Figure 4) shows winter temperature and precipitation for Western North America in the selected ensemble (Table 1), compared to all runs.

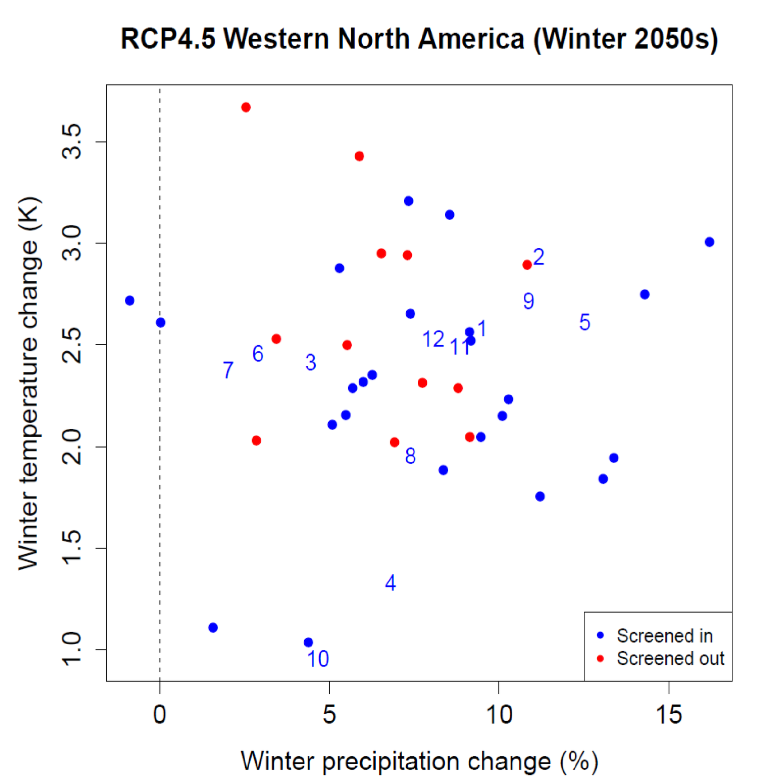

Figure 4: *Scatterplot of 2050s temperature vs. precipitation for winter in Western North America (WNA). The blue numbers show the 12 selected members of the ensemble with the number denoting the ordering for WNA (see Table 1). Blue dots show runs with rank larger than 12. Red dots show runs from models that were screened out.*

Order	WNA
1	CNRM-CM5-r1
2	CanESM2-r1
3	ACCESS1-0-r1
4	inmcm4-r1
5	CSIRO-Mk3-6-0-r1
6	CCSM4-r2
7	MIROC5-r3
8	MPI-ESM-LR-r3
9	HadGEM2-CC-r1
10	MRI-CGCM3-r1
11	GFDL-ESM2G-r1
12	HadGEM2-ES-r1

Table 1: *Selected members of the ordered CMIP5 ensemble for Western North America (WNA). Each run was downscaled for RCP8.5 and RCP4.5. All but inmcm4, ACCESS1-0, and HadGEM2-CC were downcaled for RCP2.6.*

Downscaling

Statistical downscaling with BCCAQ was carried out on all NARCCAP RCMs and the selected subset of CMIP5 GCMs following RCPs 2.6, 4.5, and 8.5. We produced downscaled scenarios over Canada at a daily time resolution and 300 arc second (~10 km) spatial resolution for 1951-2100. The ANUSPLIN gridded daily observations produced by Natural Resources Canada (McKenney et al. 2011) were used to train the statistical downscaling.

Applications

The dataset has been used to provide climate information for adaptation. Certain stretches of British Columbia highway have experienced extreme precipitation events resulting in substantial damage. The BC Ministry of Transportation and Infrastructure considered three case studies, including Bella Coola (Figure 1). Table 2 shows estimated risk to infrastructure components based on projected climate change. Projected changes in extremes (Figure 5) tend to be relatively larger than seasonal (Figure 6) and annual precipitation change itself (Table 3).

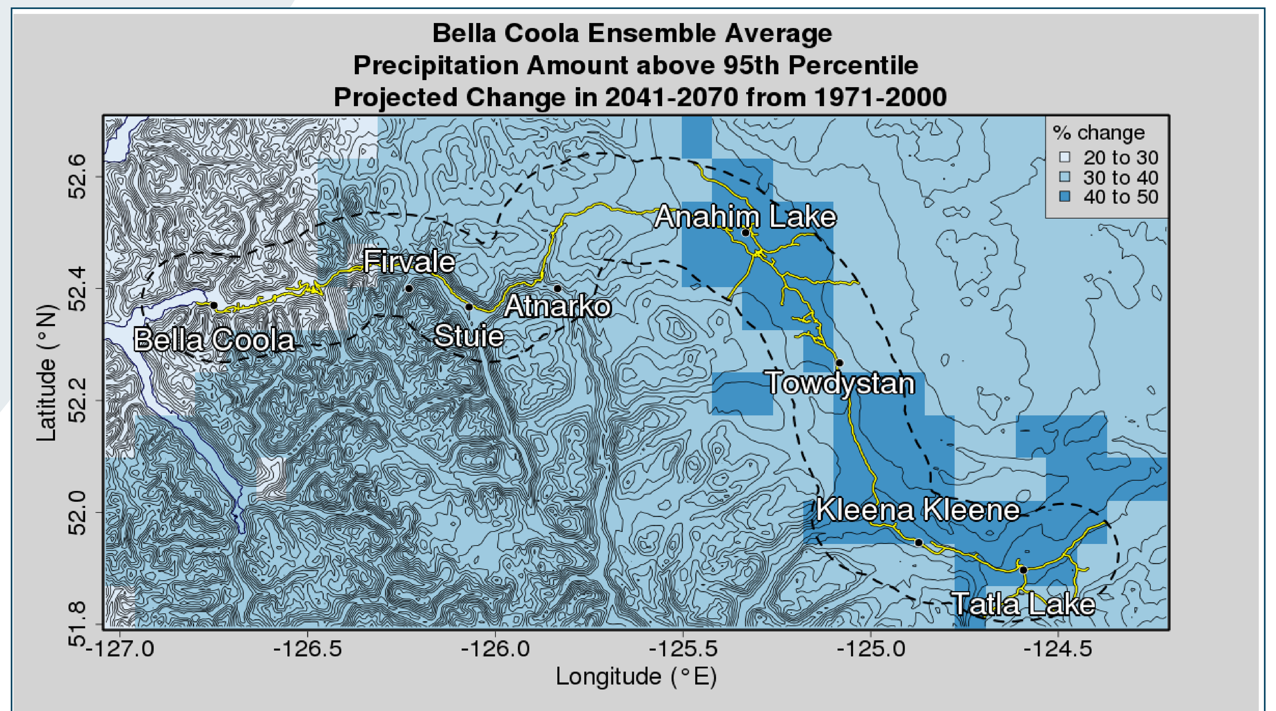

Figure 5: *Ensemble average (10 NARCCAP runs) downscaled 10 km future (2041-2070) projected change in CLIMDEX index R95pTOT: annual total precipitation during wet days, where wet days are those with precipitation equal or greater to the 95th percentile of daily precipitation during the historical (1971-2000) period. The 10 km resolution allows for representation of topographic features.*

Infrastructure Components	Total Annual Rainfall	Extreme High Rainfall	Light Sustained Rainfall	Heavier Sustained Rainfall	Snow (Frequency)	Snow Accumulation	Rain on Snow	Rain on Frozen Ground	Rapid Snow Melt	Snowmelt Driven Peak Flow Events	Magnitude of Storm Driven Peak Flow Events	Frequency of Storm Driven Peak Flow Events	Ice / Ice Jams
Above Ground													
Shoulders (Including Gravel)		24	7	20	3	12					24		
Ditches		12	7	10	3	12	15		0	18	18	15	
Embankments / Cuts	8	18	7	15		12	5		0	12	36	30	
Natural Hillside/Slope Stability	10	24	7	20		12	5		0	12	36	30	
Protection Works / Armoring	6	30	7	25		12	20		0	30	42	35	1
Engineered Stabilization Works	4					12			0	6	6	5	
Structures that Cross Streams		24					20		0	24	18	15	1
Below Ground													
Road Sub-Base											36	30	
Culverts < 3 meters		24	7	20			15	4	0	24	36	30	1
Culverts >3 meters		30	7	25			15	4	0	18	18	15	1
Bridge End Fill		36		30			25		0	36	42	35	

Table 2: *Summary of infrastructure risk to various climate events for Bella Coola following the Public Infrastructure Engineering Vulnerability Committee (PIEVC) risk assessment protocol of Engineers Canada. Low risk, less than 12, indicates no immediate action is necessary. Medium risk, 12-36, is shaded yellow and suggests that action or more in depth engineering analysis may be required. High risk, greater than 36, indicates that immediate action is needed. Numerical values are assigned using expert opinion in a workshop setting to estimate vulnerability to projected climate change.*

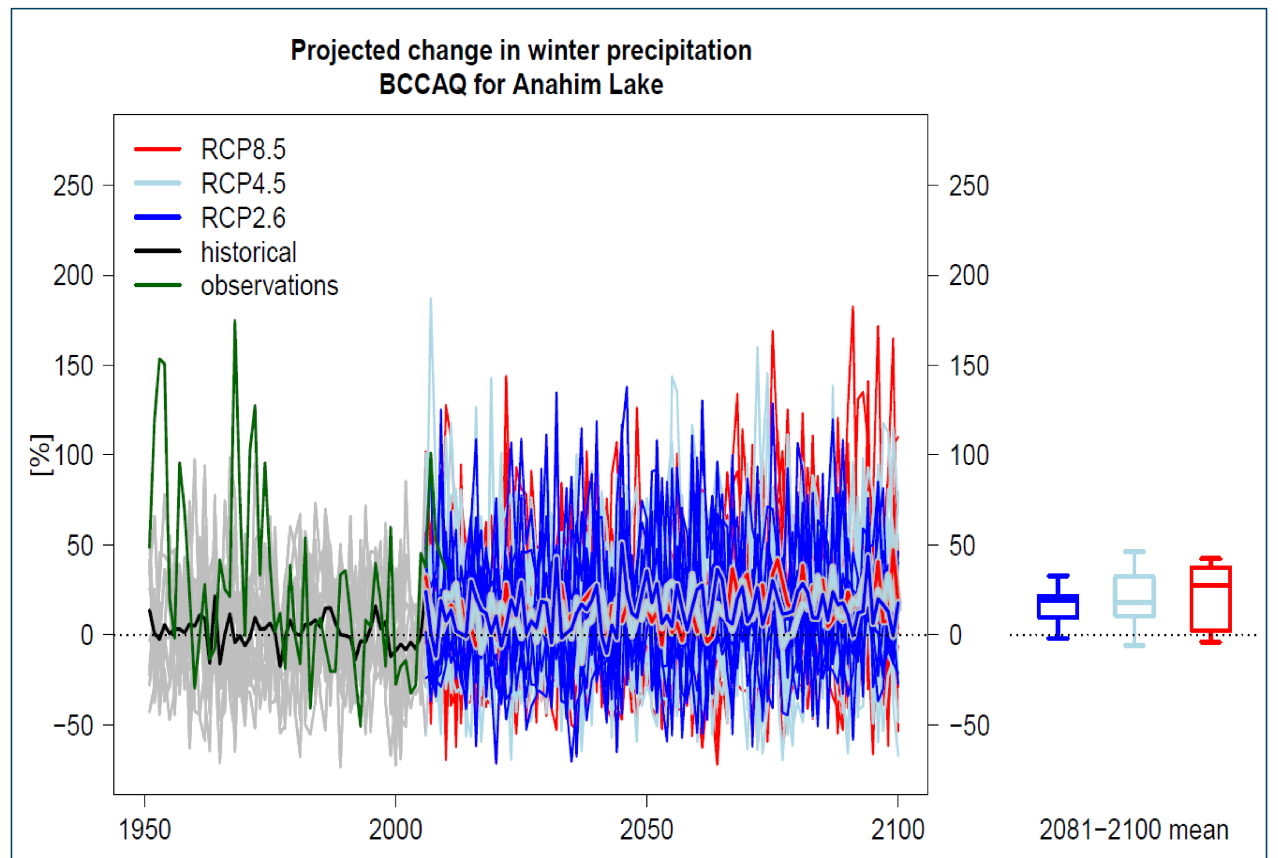

Figure 6: *Winter precipitation at Anahim Lake (see Figure 5). The green line shows historical ANUSPLIN observations (McKenney et al., 2011). Large variability is due to changing station density with time and small region size (-125.5°E to -125.1°E, 52.4°N to 52.6°N). The black line shows ensemble average downscaled past (12 CMIP5 runs; see Table 1), while grey shading shows simulated variability among members. Red, light blue, and dark blue show future projections for RCPs 8.5, 4.5, and 2.6 (ensemble averages and simulated variability). Box plots at right display ensemble median (horiztonal line), 25th to 75th percentiles (box), and 5th to 95th percentiles (whiskers) of projected change for the 2090s (2081-2100). The median projected increase in winter precipitation is larger by the 2090s following RCP8.5 than 4.5 or 2.6, and for all emissions pathways projected increases are considerably less than projected changes in extremes.*

Indicator	Past ('71-2000)	Future (2041-'70)	Change
Annual Total	673 mm	744 mm	11%
R95pTOT	131 mm	177 mm	36%
RX5day	56 mm	67 mm	20%
10-year return period	36 mm	47 mm	31%
25-year return period	44 mm	60 mm	36%

Table 3: *Ensemble average (10 NARCCAP runs) of projected change in precipitation indices for Bella Coola highway region (black outline in Figure 5).*

Works cited

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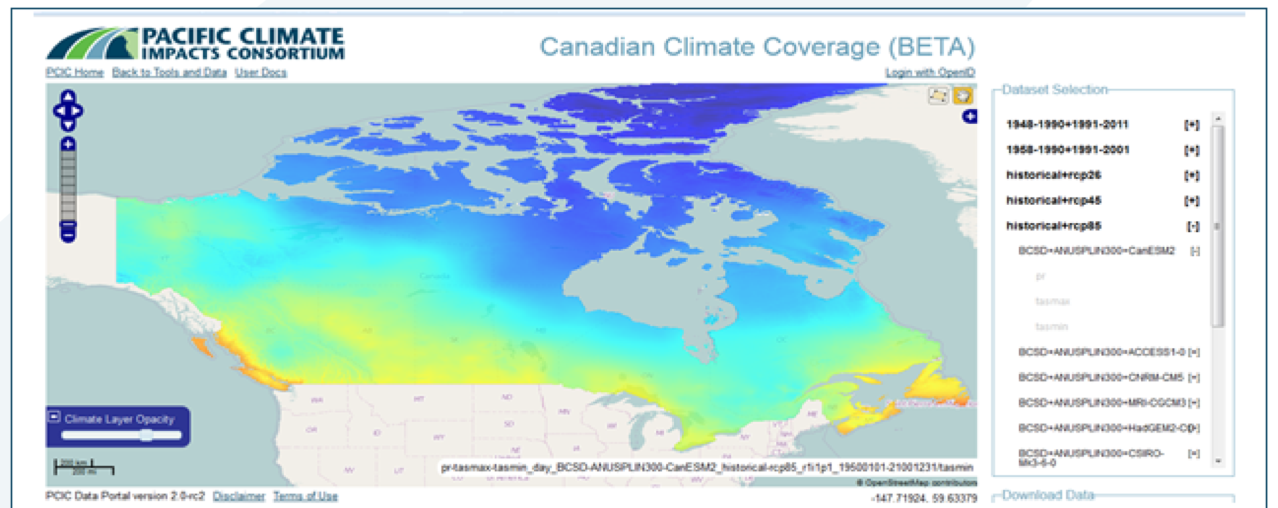

Figure 7: *The downscaled data will be made available on the PCIC data portal (www.PacificClimate.org). Shown is the beta portal viewing the download window for minimum temperature from CanESM following RCP8.5.*

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