Evaluation of increasing spatial resolution in downscaled climate projections and the effect on extreme precipitation

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Introduction

Recent extreme precipitation events in British Columbia that resulted in flooding and damage to infrastructure have lead to requests for high resolution projections of extreme precipitation in a changing climate. Statistical downscaling [Wilby, 2004] offers methods to obtain the detailed projections needed for impacts assessments, however questions remain about how downscaling can affect the size of future extreme values. Our goal is to measure the effect of statistical downscaling on the signal of projected change from large scale models to determine if downscaling influences the magnitude of those future changes.

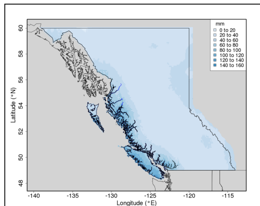

Figure 1. Map of B.C. 10-year return period precipitation from ANUSPLIN observations (1951-2000).

Experimental Design

We compare four precipitation indices computed from global and regional climate models (GCMs [Taylor, 2012] and RCMs [Mearns, 2009]) at different spatial resolutions to identify any spatial dependence on precipitation type.

Table 1. Indices of precipitation extremes compared at 50 km and 150 km resolution.

ID	Indicator name	Definitions	UNITS
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm
R95p	Very wet days	Annual total PRCP when RR>95th percentile	mm
RP10	10-Year Return Period	Daily precipitation amount that is expected to occur once every 10 years	mm
RP20	20-Year Return Period	Daily precipitation amount that is expected to occur once every 20 years	mm

Downscaling - Bias Correction/Constructed Analogues with Quantile Mapping (BCCAQ) [Cannon, 2014]

•Produces precipitation simulations through historical analogues and quantile mapping calibrated with gridded 10 km daily ANUSPLIN observations [McKenney, 2011].

Aggregation and Comparison

Precipitation indices are computed from both coarse scale and from downscaled precipitation aggregated to lower resolution. Aggregation is performed multiple ways to test whether the order of averaging affects the resulting comparison. Indices are evaluated using Kolmogorov-Smirnov and Walker field significance tests.

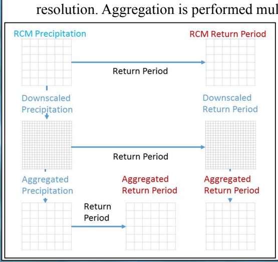

Figure 2. Schematic of the downscaling, aggregation and comparison steps used to measure the effect of downscaling on RCM projected return periods.

Validation

Downscaled models are calibrated and validated using the historical period of 1951-2005 with future projections obtained for the 2050s (2041-2070). When compared at common resolutions of 50 km for RCMs and 150 km for GCMs we find that downscaling using BCCAQ (bias correction, constructed analogues and quantile mapping) significantly improves spatial and temporal representation of average and extreme precipitation events in British Columbia.

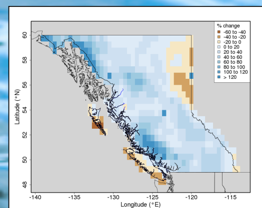

Figure 3. Difference map of 10-year precipitation return periods at 50km resolution. Return periods are calculated from the NARCCAP ensemble of 11 regional climate models, and from ANUSPLIN observations aggregated to 50km resolution. The image highlights the bias in the RCM return periods.

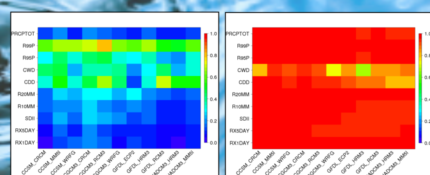

Figure 4. Fraction of grid cells that pass Kolmogorov-Smirnov tests for 11 RCMs (left) and the same RCMs downscaled to 10 km and aggregated to 50 km resolution (right), both tested against observations. The cells are evaluated using 10 CLIMDEX [Zhang, 2011] indices over the test period of 1971-2000.

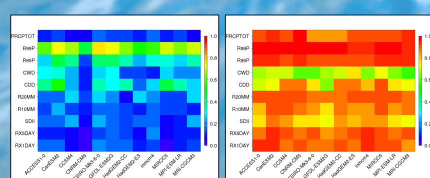

Figure 5. Fraction of grid cells that pass Kolmogorov-Smirnov tests for 12 GCMs (left) and the same GCMs downscaled to 10 km and aggregated to 150 km resolution (right), both tested against observations. The cells are evaluated using 10 CLIMDEX [Zhang, 2011] indices over the test period of 1971-2000.

Results

The key findings are:

1) Downscaling improves representation of average and extreme precipitation events in British Columbia with greater improvement in RCM indices.

2) The order of aggregation to RCM or GCM scale is not statistically significant for the vast majority of models and the difference amounts to between 0 % and 4 % on average.

3) Downscaling does not alter projected changes in average and moderate precipitation events.

4) The differences between driving model and downscaled projections of return periods are statistically significant for a subset of the model ensembles. The inflating effect on extreme events increases as event frequency decreases.

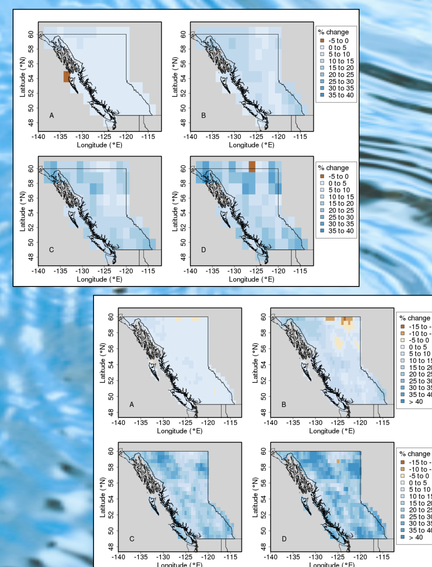

Figure 6. Maps of annual total (**A**), very wet day (**B**), 10-year return period (**C**) and 20-year return period (**D**) precipitation at 150 km (top) and 50 km (bottom) resolution. Both images display absolute differences in projected percent changes between the models downscaled and then aggregated back to the resolution of the driving models, and the original models (GCM or RCM) at coarse scale.

Table 2. The list of global and regional climate models used in this study.

ID	GCM Name	ID	GCM Name	ID	RCM Name	ID	RCM Name
A	ACCESS1-0	G	HadGEM2-CC	M	CCSM-CRCM	S	GFDL-ECP2
B	CanESM2	H	HadGEM2-ES	N	CCSM-MM5i	T	GFDL-HRM3
C	CCSM4	I	inmcm4	O	CCSM-WRFg	U	GFDL-RCM3
D	CNRM-CM5	J	MIROC5	P	CGCM3-CRCM	V	HADCM3-HRM3
E	CSIRO-Mk3-6-0	K	MPI-ESM-LR	Q	CGCM3-RCM3	W	HADCM3-MM5i
F	GFDL-ESM2G	L	MRI-CGCM3	R	CGCM3-WRFg		

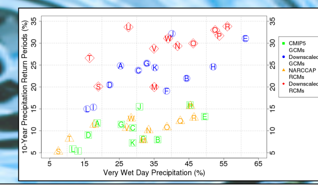

Figure 7. Projected changes in percent of 10-year precipitation return period and annual very wet day precipitation (R95p) averaged over British Columbia. The indices are obtained both from GCMs and RCMs at coarse resolution, and their downscaled outputs aggregated to coarse resolution.

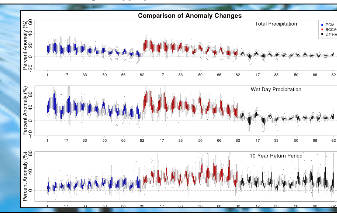

Figure 8. Boxplots illustrating the range of projected change from the ensemble of 11 regional climate models at each grid cell within B.C. for the three precipitation indices. Blue boxplots denote the RCM projections, red plots show the downscaled projections and black plots show the difference.

Conclusions

For terrestrial British Columbia, precipitation averages and extremes can be simulated more accurately within individual regions by using gridded downscaling to increase the resolution of both global and regional climate models. In locations where the difference between observations and model simulations is large, bias correction tends to inflate the magnitude of high resolution projected extremes. The effect is minimal for average indices but is statistically significant in a subset of models for projected changes of 10 and 20-year return periods. Future work will focus on correcting the inflation of extremes in the downscaling method and extending the analysis to additional regions.

Literature cited

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Acknowledgments

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