Evaluating the role of increasing spatial resolution in climate projections for highway impacts assessments in British Columbia

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Introduction

Recent extreme precipitation events have resulted in flooding and damage to several highways in British Columbia. Rebuilding and redesigning these roadways requires detailed information about future precipitation extremes to plan effectively for a changing climate in the Pacific Northwest. Statistical downscaling [Wilby, 2004] offers methods to obtain the high resolution projections needed for vulnerability assessments, however downscaling can affect the size of future projections. Our goal is to measure this effect and determine if it influences the results of a highway risk assessment.

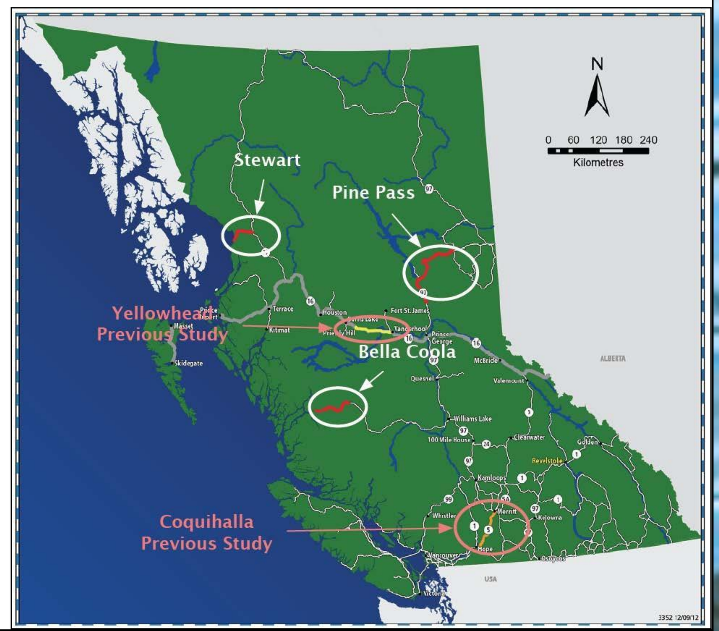

Figure 1. Map of B.C. highlighting past and present locations of highway vulnerability assessments.

Experimental Design

We compare three precipitation indices computed from regional climate models (RCMs) [Mearns, 2009] at different spatial resolutions to test whether downscaling is altering the size of precipitation projections and to see if any differences would change the results of the risk assessment.

Table 1. Indices of precipitation extremes compared at RCM and 10 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

Downscaling - Bias Correction/Constructed Analogues with Quantile Mapping (BCCAQ) [Cannon, 2014]
•Produces precipitation simulations through historical analogues and quantile mapping calibrated with ANUSPLIN observations [McKenney, 2011].

Aggregation and Comparison
Precipitation indices are computed from both RCMs and from downscaled precipitation aggregated to RCM 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.

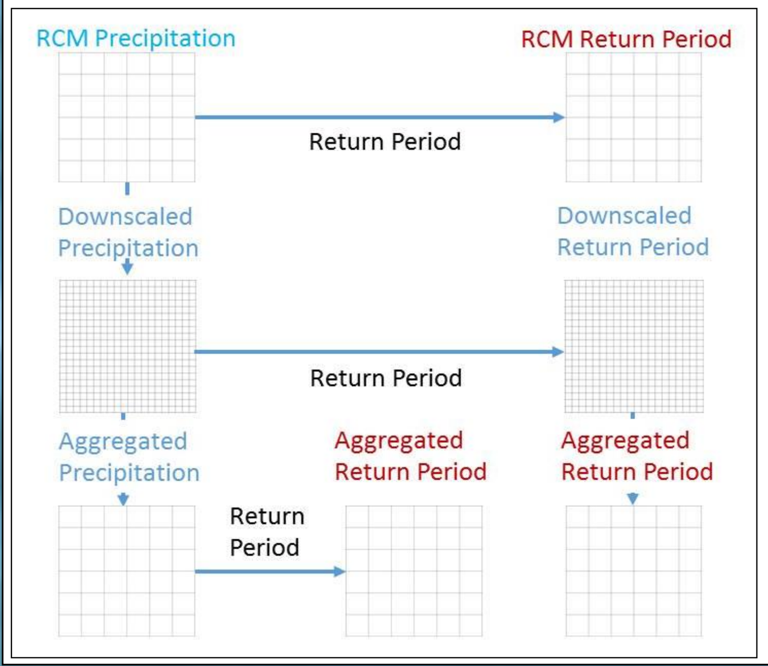

Figure 2. Schematic of the downscaling, aggregation and comparison steps used to measure the effect of downscaling on RCM projected return periods.

PIEVC Risk Assessment

The PIEVC process [Lapp, 2013] combines engineering expertise with projections of climate change to determine levels of risk for individual pieces of infrastructure. Each piece of infrastructure (e.g. bridge or road) is assigned a risk value based on the probability of a particular climate event occurring and on the severity of damage to the infrastructure should that event occur. This enables engineers, managers and designers to identify where vulnerabilities are highest.

$$\boldsymbol{R}isk = \boldsymbol{P}robability \times \boldsymbol{S}everity$$

Probability and Severity are both rated on a scale from 0 to 7.

Components	Score	Result
Probability	0	Climate event will not cause an adverse effect
	7	Very certain of an adverse effect
Severity	0	No negative consequences if event occurs
	7	Significant failure if event occurs

The resulting risk score identifies infrastructure with low, medium and high risk values to specific climate events.

Risk Range	Threshold	Response
< 12	Low Risk	No immediate action needed
12 – 36	Medium Risk	Action and analysis may be needed
> 36	High Risk	Immediate action required

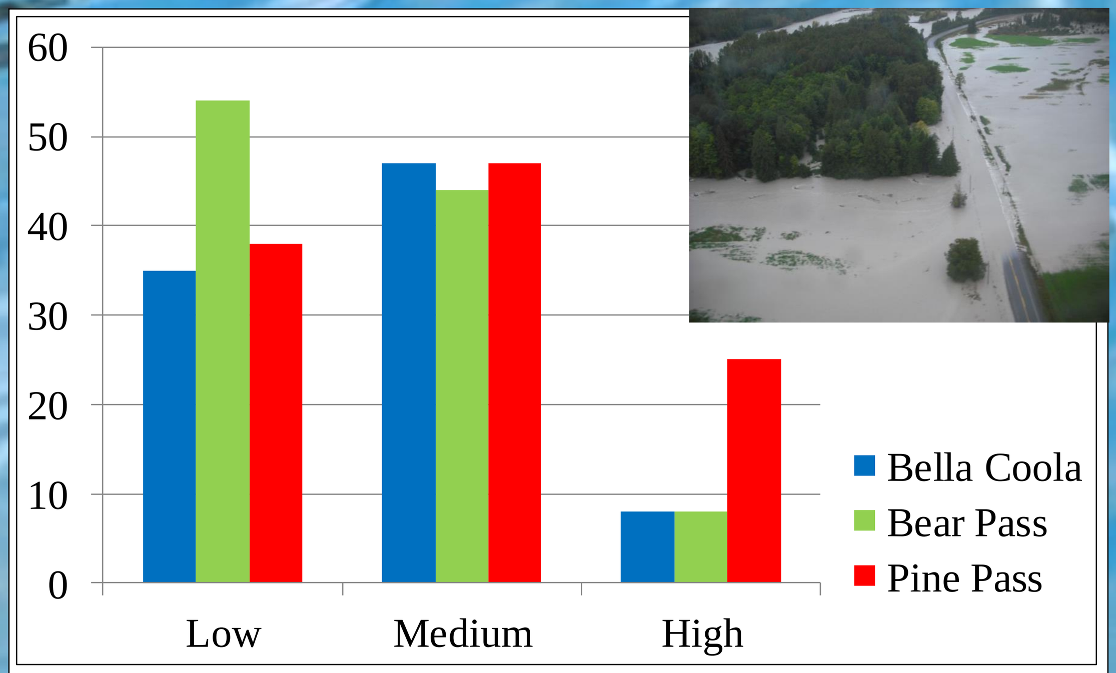

Figure 3. Risk scores for the three highway regions obtained by following the PIEVC risk assessment process. Pine Pass possesses the greater 'high risk' elements due to the age of the highway and its vulnerability to flooding. The inset photo illustrates an occurrence of a 'high risk' event at Bella Coola.

Validation & Results

The key findings are:

1) Downscaling with bias correction and quantile mapping improves spatial and temporal representation of average and extreme precipitation events in B.C.
2) The order of aggregation to RCM scale does not make a statistically significant difference for the vast majority of models and amounts to between 0 % and 4 % on average.
3) Downscaling does not alter projected changes in average and moderate precipitation events but does change the size of projected extremes from some models.
4) The differences in RCM and downscaled projections of return periods are large enough in some cases to change the probability scores for extreme precipitation. This can increase the risk ratings in the highway vulnerability assessment for specific pieces of infrastructure.

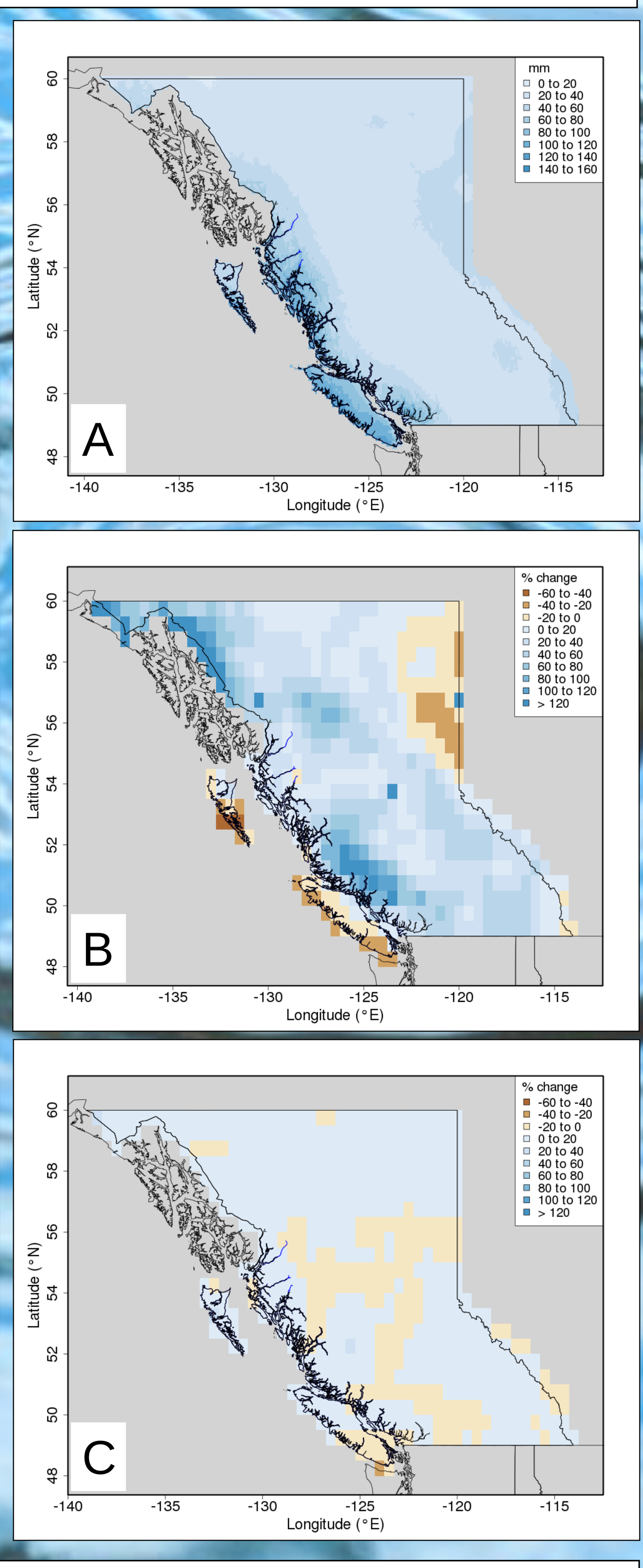

Figure 4. Maps of 10-year precipitation return periods at 10 km and 50 km resolution. The top map (**A**) shows return periods from ANUSPLIN during 1951-2000. The lower two images display the differences between RCM and ANUSPLIN 10-year return periods for British Columbia. Return periods are calculated from the NARCCAP ensemble of 11 regional climate models (**B**) and from the same RCMs downscaled and then aggregated back to RCM resolution (**C**). The added information included as part of the downscaling process from observations improves the simulation of return periods over British Columbia. This also occurs for the total and wet day precipitation indices as well.

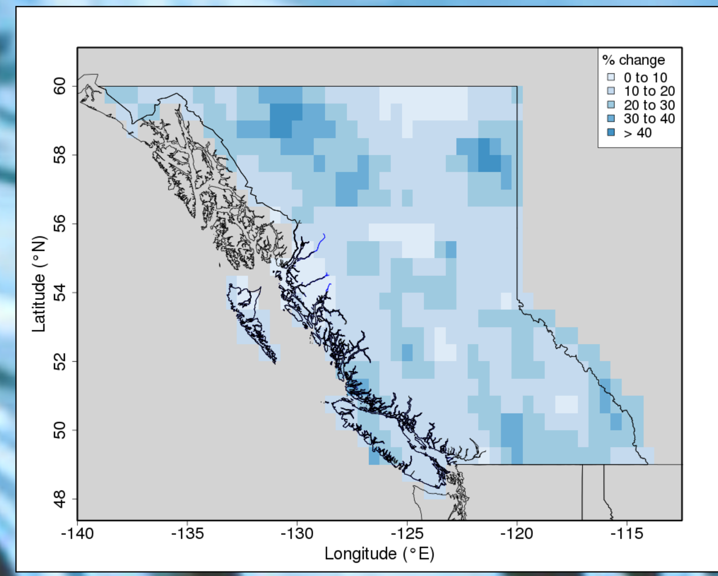

Figure 5. The difference in percent between projected change in 10-year precipitation return period between the downscaled RCMs at 50 km and the driving RCMs. Downscaling tends to inflate the change in return periods.

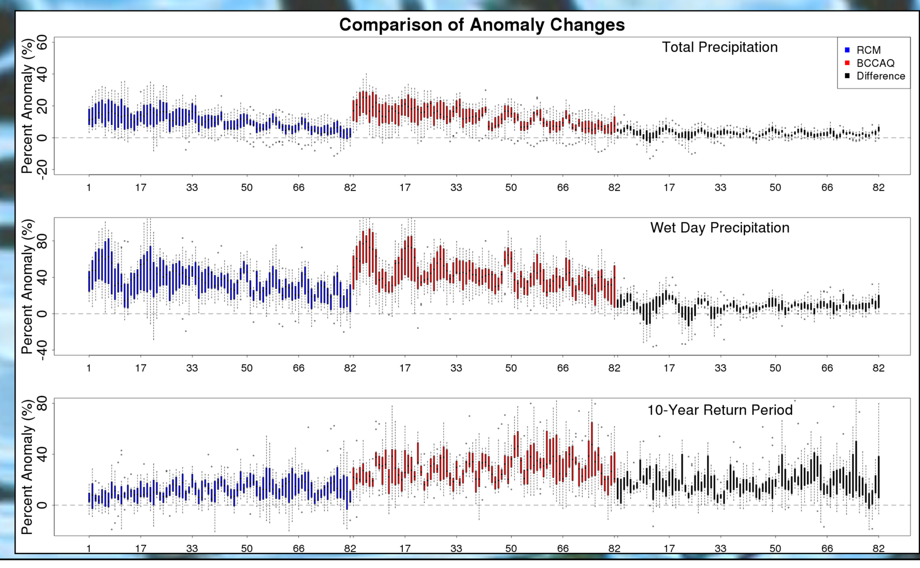

Figure 6. Boxplots illustrating the range of projected change from the ensemble of 11 regional climate models at each grid cell within B.C. for the three precipitation indices. Blue boxplots denote the RCM projections, red plots show the downscaled projections and black plots show the difference.

Table 2. A subset of risk scores for Bella Coola highway from the assessment.

Infrastructure Components	Annual Rainfall	Extreme Rainfall	Sustained Rainfall	Snow	Rain on Snow	Peak Streamflow
Shoulders		24	7	3		24
Ditches		12	7	3	15	18
Embankments	8	18	7		5	36
Slope Stability	10	24	7		5	36
Armoring	6	30	7		20	42
Culverts <3m		24	7		15	36
Culverts >3m		30	7		15	18
Bridge End Fill		36			25	42

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 regional climate models. In locations where the difference between observations and RCMs is large, bias correction tends to inflate the magnitude of projected extremes. Differences in projections between the RCMs and downscaled simulations can be large enough to affect the PIEVC Risk Assessment process, leading to higher risk values. 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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