DOWNSCALING INTERCOMPARISON PROJECT

SUMMARY REPORT

PACIFIC CLIMATE IMPACTS CONSORTIUM

DOWNSCALING INTERCOMPARISON PROJECT

Method tests and future climate projections

The Pacific Climate Impacts Consortium (PCIC) recently tested a variety of downscaling techniques for their ability to simulate climate extremes in British Columbia. The objective of this downscaling intercomparison project (DIP) was to evaluate methods that can be used to bring information from global climate models to local and regional scales.

The DIP project showed that:

- Most of the techniques tested show some skill at representing past climate extremes and produced consistent future climates.
- Temperature extremes were better represented by the downscaling methods than were precipitation extremes.
- None of the downscaling methods tested could reliably simulate more complex, multi-day extreme events, such as the duration of warm spells.
- Annual sums, such as the number of sunny days or total amount of precipitation in a given year, were better simulated than extreme events, such as annual extreme daily precipitation amount.
- For those downscaling techniques that perform best at reproducing historical observed climate, the largest source of uncertainty in projecting future climate change at fine scales comes from the choice of global climate model that is to be downscaled.
- The two main downscaling techniques used by PCIC, "Bias Correction and Spatial Disaggregation" (BCSD), and "Expanded Downscaling" (XDS) showed the best performance.

PCIC'S DOWNSCALING INTERCOMPARISON PROJECT EVALUATED THE ABILITY OF DIFFERENT STATISTICAL DOWNSCALING METHODS TO REPRODUCE HISTORICAL CLIMATE EXTREMES AND COMPARED THEIR PROJECTIONS OF FUTURE CLIMATE EXTREMES

THE TWO MAIN DOWNSCALING METHODS USED BY PCIC SHOWED THE BEST PERFORMANCE

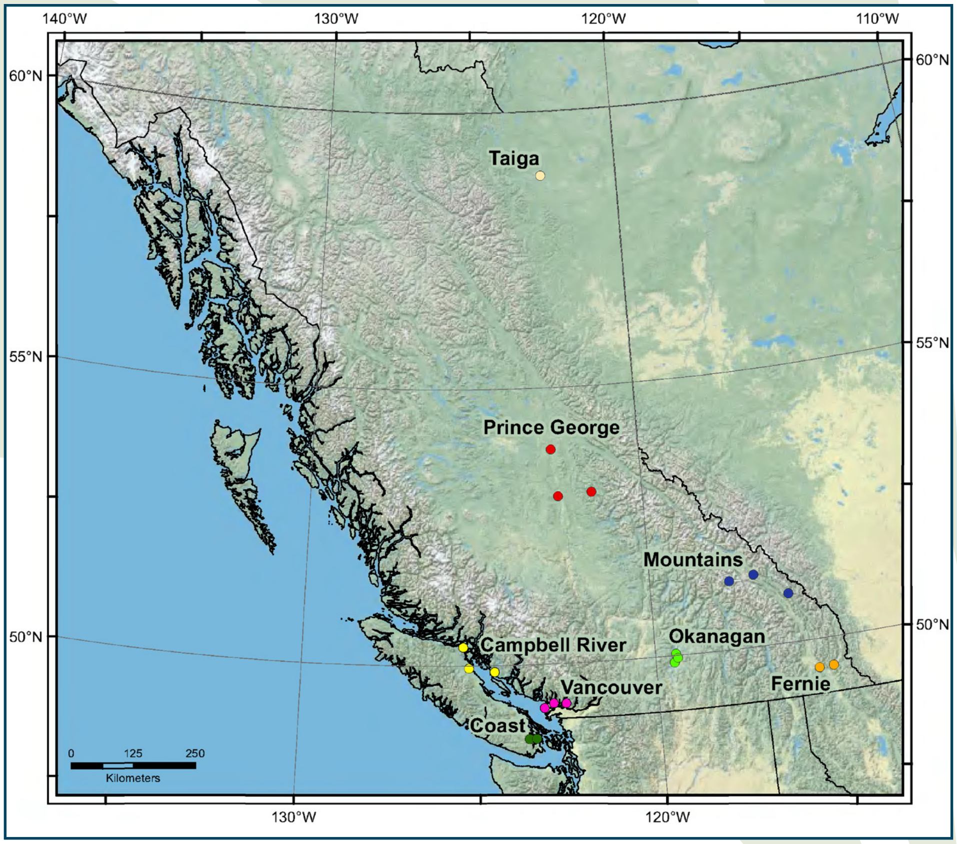

Figure 1: Map of the study area, with stations indicated as dots.

DIP1 EVALUATES DOWNSCALING METHODS AGAINST PAST CLIMATE DATA AND DIP2 EVALUATES THE METHODS' FUTURE CLIMATE PROJECTIONS

The strong performance of BCSD and XDS provides confidence in previous PCIC studies, which used these two techniques extensively. These tests of the various downscaling techniques also provide PCIC—and the broader scientific community—with a better assessment of the abilities of each of these methods and these lessons are reflected in PCIC's new Regional Climate Impacts research plan.

There have been two components to the project performed thus far. In the first part, an experiment referred to as "DIP1," five different statistical downscaling methods were used to simulate extreme weather events for different regions in BC, and the results were compared to data from weather stations in those regions. In the second part, referred to as "DIP2," eight downscaling methods were applied to data from six global climate models, using three different anthropogenic greenhouse gas emissions scenarios, in order to generate future projections of extreme weather events in several regions (Figure 1) of BC.

Many types of climate extremes can be described with purpose-built climate indices, such as the number of summer days (days with a temperature greater than 25° Celsius) or the number of days on which there is more than 10 millimeters of rain. For this project, a standard suite of 27 indices formulated by the Expert Team on Climate Change Detection and Indices (ETCCDI) was used (more information on these indices can be found at: http://cccma.seos.uvic.ca/ETCCDI/list_27_indices.shtml).

PAST CLIMATE EXTREMES

Testing the methods against observations

Typical time series for two ETCCDI indices as simulated for the historical period are shown below, in Figure 2. These two indices are PRCPTOT, which is the total annual precipitation accumulated on rain days (where a rain day is defined as a day with more than one millimeter of precipitation) and R95p, which is the annual total precipitation for heavy rainfall events, those rain days when the rain is so intense that it is within the top five per-

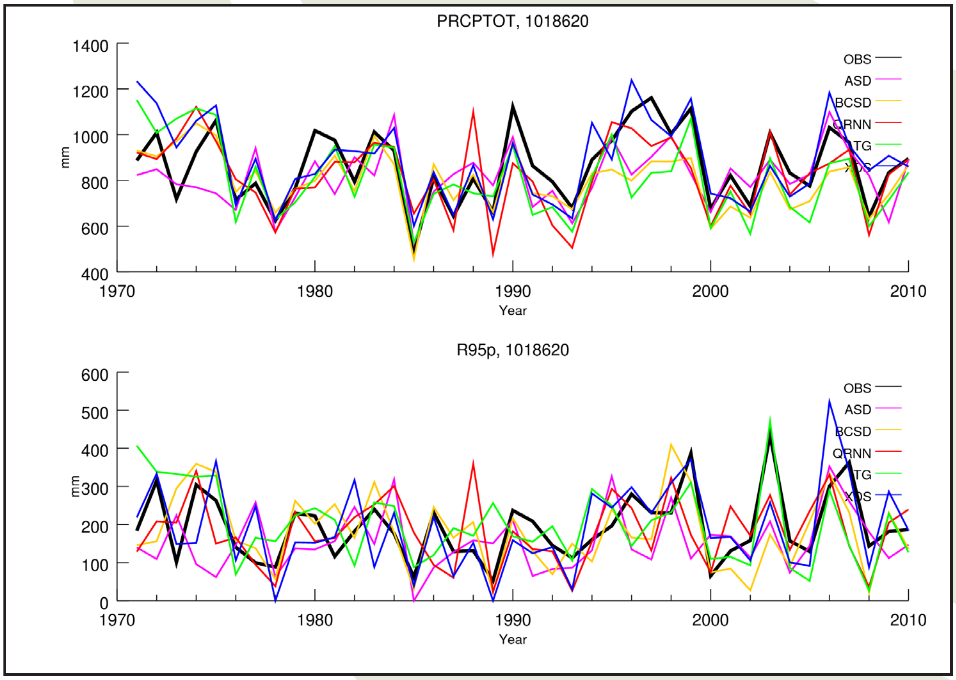

Figure 2: Typical annual ETCCDI series for Victoria. The two variables are total annual precipitation (PRCPTOT, upper panel) and total precipitation for heavy rainfall events (R95p, lower panel). The black lines show the observational data from weather stations and the coloured lines show the results of the downscaling methods.

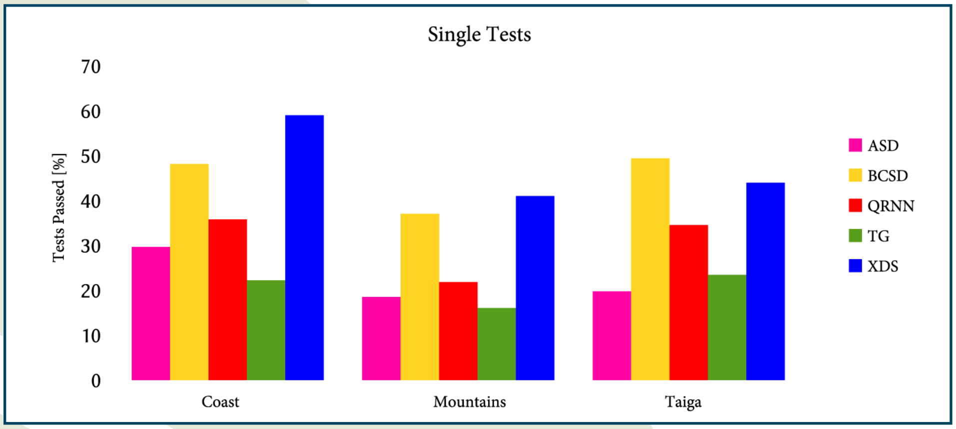

Figure 3: Rate of DIP1 tests passed, by method and region. The coloured bars represent the number of indexes for which each method passed testing, in percent. These are divided into coast, mountain and taiga regions.

cent of rainfall events for the 30-year period of 1961-90.

Figure 2 shows how closely the individual methods follow observations for PRCPTOT and R95p. Of note is the increased scatter of the models around the observations for R95p. The fact that the individual coloured lines representing the models more closely resemble the black line representing observations for PRCPTOT illustrates the point above, that the models better represent annual sums than extreme events.

The methods tested in DIP1 included: automated regression-based statistical downscaling (ASD), bias corrected spatial disaggregation (BCSD), a quantile regression neural network (QRNN), TreeGen (TG) and expanded downscaling (XDS).

Figure 3 shows how each of the methods fared when their climate simulations were compared against the data from weather station observations in different regions. The bars are colour coded by statistical downscaling method, with taller bars indicating better performance of the method in that region. As mentioned above, the two methods most often used by PCIC (XDS and BCSD), showed the best performance, which gives confidence in previous PCIC studies and informs PCIC's RCI research plan.

THE TWO DOWNSCALING METHODS USED MOST EXTENSIVELY BY PCIC WERE THE BEST PERFORMING METHODS TESTED

FUTURE CLIMATE EXTREMES

Analyzing future climate projections

For the DIP2 experiment eight statistical downscaling methods were used to make projections of future climate extremes. One of the main findings of DIP2 is that, if all of the downscaling methods are tested for their ability to simulate climate over a number of regions, using a range of greenhouse gas emissions scenarios and data from several global climate models, the choice of downscaling method contributes the most to uncertainty. However, this is mainly due to the inclusion of two of the downscaling methods, NRCAN's biophysical model (BioSim) and the Long Ashton Research Station Weather Generator (LARS-WG) . If the analysis is repeated using only the best performing methods from DIP1, the choice of climate model becomes the largest contributor to uncertainty.

IF ONLY THOSE DOWNSCALING METHODS WHICH BEST SIMULATE HISTORICAL OBSERVATIONS ARE USED, THE CHOICE OF CLIMATE MODEL IS THE LARGEST CONTRIBUTER TO UNCERTAINTY FOR FUTURE CLIMATE PROJECTIONS

Statistical downscaling methods rely on statistical relationships between large-scale climate phenomena and local climate phenomena. While an in-depth discussion of how each of these methods works is beyond the scope of this report, some of the important features of the two main methods employed by PCIC (BCSD and XDS) will be discussed below.

BCSD first takes global climate model data for the region it will be used on and compares that data to observations from weather stations, correcting the model data if it is too warm, cool, dry or wet relative to the data from the weather stations. The model then takes the corrected data and renders it onto a finer, regional grid and smaller time scale while preserving consistency with the original large-scale data.

XDS begins by considering a number of atmospheric variables from large-scale data around a given point, such as temperature, atmospheric moisture content, etc. and determining a relationship between these and the same atmospheric variables at the point. Because the method by which it determines this relationship tends to make the model simulate weather with less variability and fewer extreme events than observed, XDS employs a variance inflation technique in order to preserve the observed variability.

An important feature of the two methods used by PCIC is the resolution to which they downscale. BCSD provides gridded data down to a resolution of a few kilometres, whereas XDS can only be used to downscale directly to a point. XDS also requires more data to use than BCSD. These methods can then be verified against historic data and, if found to be reliable, applied to simulate future climates in the region, as has been done here.

THE NEED FOR DOWNSCALING METHODS FOR CLIMATE EXTREMES

Placing the findings of DIP in context

SUBSTANTIAL CHANGE TO REGIONAL AND GLOBAL CLIMATES IS OVERWHELMINGLY PROBABLE

Current scientific findings show that, regardless of future greenhouse gas emissions, there will be further warming of the global climate. Climate change will bring a host of effects on the regions of British Columbia, ranging from long-term overall changes to the mean temperature, precipitation and surface wind patterns at a given location, to changes in the number and magnitude of extreme weather events. To analyze the potential impacts of climate change on individual communities requires information about the changing climate, on the scale of 50 kilometres or less, and perhaps down to the scale of a single station. However, the general circulation models from which recent projections of global climate change have been made have coarser resolutions, on the scale of a few hundred kilometers.

COMMUNITIES REQUIRE INFORMATION ABOUT HOW THE CHANGING CLIMATE WILL AFFECT THEM, IN ORDER TO PLAN AND ADAPT

In order to provide communities with information that they can use to prepare for the potential impacts that a changing climate will have on their area, some method must be used to work out how the projected changes to climate seen in the larger, global models will affect climate at smaller scales. There are two approaches to this problem, regional climate modelling and statistical downscaling methods, such as the ones which were examined in DIP.

Regional climate models are similar to global general circulation models, in that they work from the equations that describe the physical processes that are to be simulated within the model. They take the coarse output for a given region from global general circulation models and use this to drive the physics of the regional climate model at a finer scale.

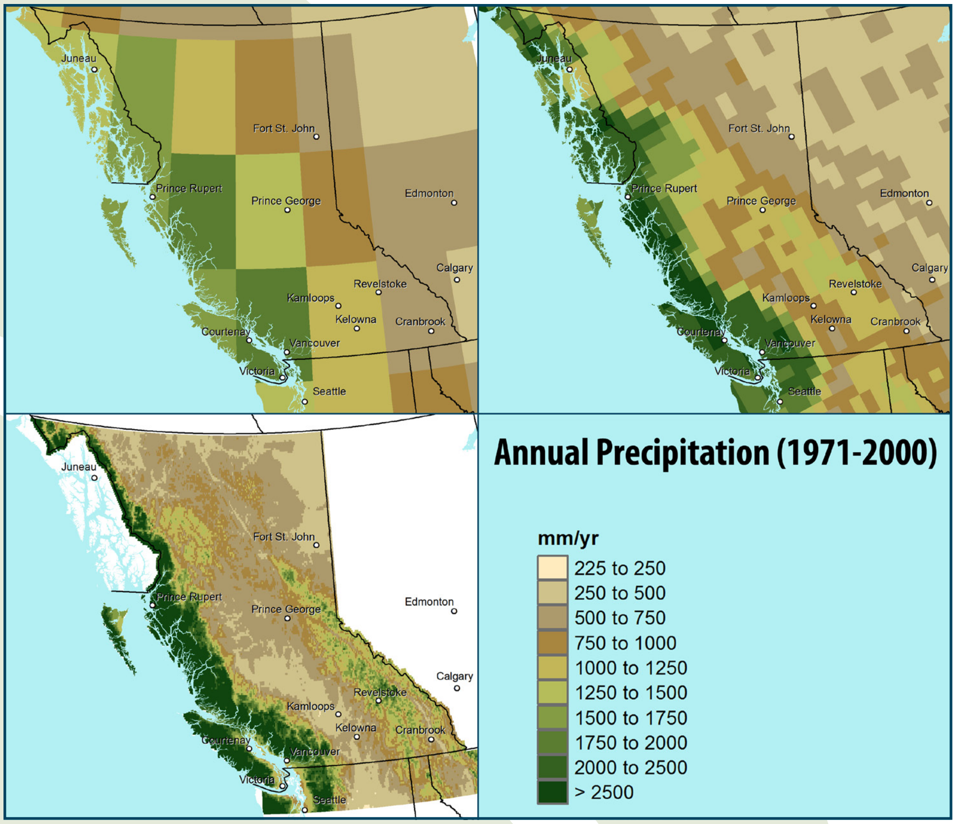

Figure 4: Maps showing simulations of past annual precipitation in millimeters per year, for the province of British Columbia. This figure illustrates the differences in resolution between a global general circulation model (top, left), a regional climate model (top, right) and the BCSD statistical downscaling method (bottom, left).

Statistical downscaling, as mentioned above, relies upon statistical relationships between large-scale climate phenomena and local climate phenomena.

Each approach has its advantages and disadvantages. Statistical downscaling methods require comparatively little computing power and can downscale to a finer resolution than many regional climate models. This is illustrated by Figure 4, above, in which the size of the coloured regions, representing areas with a given value of precipitation, are much smaller for the statistical downscaling method, than for the global climate model and regional climate model results.

STATISTICAL DOWNSCALING METHODS REQUIRE LESS COMPUTING POWER THAN REGIONAL CLIMATE MODELS AND CAN DOWNSCALE TO THE RESOLUTION OF A SINGLE POINT, BUT MUST BE USED WITH THEIR LIMITATIONS IN MIND

Though statistical methods can downscale to a finer resolution—some of them to a single point—and require less computing power, they do not necessarily produce physically consistent results for different climate variables. For example, when downscaling temperature, precipitation and evaporation separately, it is possible to arrive at values which, if taken together, would not necessarily give physically sensible results for a given day, though the overall statistical picture that they provide for the whole period could be quite useful. Further, given that the statistical methods aren't based on physical laws, it is uncertain to what degree their results will hold in the future. Regional climate models produce results that are internally consistent, work from basic physical laws which are expected to hold into the future and can describe climate feedback mechanisms. However, regional climate models require more computational power and generally have a resolution on the order of tens of kilometers, which is still too coarse for many regions in British Columbia, where topography can vary greatly over a very short distance.

Statistical downscaling methods are then potentially very useful for providing the information necessary to help British Columbia residents prepare

DIP IS A SOLID FIRST STEP, BUT MUCH PROMISING RESEARCH LIES AHEAD, INCLUDING EVALUATIONS OF MORE METHODS, AND IMPROVING THE BCSD METHOD

for the impacts of a changing climate. The results from DIP will be valuable both for research into regional climate impacts and for informing future downscaling method development.

GOING FORWARD

Prospects for the future development of downscaling

DIP serves as a first step, offering a methodology for testing and comparing downscaling approaches for the various regions of British Columbia.

Further improvements to BCSD or similar methods present a promising research avenue. There is a minimal difference in quality between BCSD and the other top performing methods evaluated in DIP. This is true even though BCSD uses much less input data, relying only on surface temperature and precipitation values. BCSD was developed before daily data from global climate models was readily available. However, this situation has changed and now it will be possible for a BCSD-like approach to use daily data as an input, which could potentially increase the accuracy of its simulations.

Though the DIP project presents a number of evaluations of downscaling methods, much work remains to be done. Ideally, all of the methods used in DIP2 will undergo similar testing to the methods used in DIP1, so that the spread of the projections can be better understood and the reliability of the methods better assessed.

As an additional research direction, future projections from statistical downscaling methods could be tested against future projections from very high resolution regional climate models. In order to do this, projections of future climate would first be made using regional climate models. Then, in an experiment similar to DIP1, but using projections of future climates from regional climate models in place of weather station observations, the statistical downscaling techniques could be tested for their consistency.

Finally, each of the methods are comprised of several steps or components and each of these steps can be assessed individually, which will allow PCIC to better compare the methods and understand the role and effect of each of these steps on downscaling results. In general, much work remains to be done on quantifying what additional uncertainty downscaling introduces. This can be examined through the further comparison of different methods and the identification of the sources of uncertainty in their results.

REFERENCES

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