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Climate Impacts Science for Adaptation

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Abstract: The difficulty of translating scientific results on climate change into useful information defines the abyss that is addressed by a relatively new Pacific Climate Impacts Consortium of academics-government-industry at the University of Victoria. The scope of the consortium is applications of research on climate variability and change to decision-making. In particular, adaptation requires planning and decision making at local and regional scales. Historical hydroclimatology provides context and scenarios based on projections from Global Climate Models indicate a range of future outcomes. Information at ever higher spatial and temporal scales are attained from Regional Climate Models and from empirical downscaling. Investigating the link between adaptation and mitigation with the UVic Earth System Climate Model shows that adaptation will be required in British Columbia even with best case mitigation, but that reducing greenhouse gas emissions will have a considerable effect on the magnitude of climate change in British Columbia. These sources of future climate change projections are being used in projects where active collaboration between the Pacific Climate Impacts Consortium, researchers, and stakeholders results in moving beyond projections of climate itself into projections of impacts that inform adaptation.

Keywords: climate impacts, adaptation, Pacific Climate Impacts Consortium, British Columbia

1. Introduction

This paper is a summary of a presentation given on 11 March 2009 at the National Science Meeting on Planned Adaptation to Climate Change hosted by Environment Canada in Victoria, British Columbia. The text describes most of the topics presented, but only selected results are shown in figures. See "Climate Overview 2007: Hydroclimatology and Future Climate Impacts in British Columbia," available online at **www.PacificClimate.org\publications** (Rodenhuis *et al.,* 2007 for more detail). Following a description of the history and mandate of the Pacific Climate Impacts Consortium, three sections are presented: historical hydroclimatology, future climate change, and future climate change impacts.

2. Bridging the Gap with the Pacific Climate Impacts Consortium

In May 2005, a group of scientists and stakeholders concluded that there was a need to focus resources to build regional capacity to adapt to a changing climate. As a result, the Pacific Climate Impacts Consortium was formed by the BC Ministry of Environment and BC Hydro at the University of Victoria.

> *A vision emerged from the workshop to "stimulate the collaboration of government, academia, and industry to reduce vulnerability to extreme weather events, climate variability, and the threat of global change. The consortium for climate impacts will bridge the gap between climate research and climate applications, and will make practical information available to government, industry, and the public."*

The Pacific Climate Impacts Consortium partners with climate researchers, impacts researchers, and stakeholders in order to assist users to apply research results to management, planning, and decision-making. The Pacific Climate Impacts Consortium carries out its mission by organizing projects into four themes, with most activity currently in the first two: Regional Climate Impacts, Hydrological Impacts, Ocean Influences, and Climate Analysis. The Pacific Climate Impacts Consortium staff with resident expertise in these themes work with stakeholders in order to progress from climate change to bio-physical impacts to inform socio-economic impacts and adaptation (Pacific Climate Impacts Consortium, 2009).

3. Hydroclimatology

Due to its complex topography, British Columbia has considerable diversity in terms of past temperature, precipitation, and streamflow (Figure 1). The effects of short term climate variability such as El Niño and La Niña are considerable, as is the Pacific Decadal Oscillation (PDO) (Figure 2).

A comparison of trends computed from the global CRU TS2.1 dataset (Mitchell and Jones, 2005) over three different time periods (Figure 3) illustrates several features of historical temperature trends in British Columbia: night-time lows have been increasing more rapidly than daytime highs, the difference between these rates has been narrowing, temperatures have been increasing more rapidly towards the end of the century (largely due to the influences of both global warming and of the positive phase of the PDO). In contrast, precipitation trends are within the magnitude of historical variability, as demonstrated by the switch from positive 100- and 50-year trends to strong negative recent (30-year) trends in winter. Differences in trends depending on time period also underscore the importance of using future climate projections from models rather than simply extending past trends.

4. Future climate change

Several sources of future projections were presented. First, Global Climate Models provide the most comprehensive range of uncertainty. A set of 30 GCM projections prepared for the IPCC Fourth Assessment Report projects changes from the 1961-1990 baseline by the 2050s of +1.2°C to +2.5°C (annual temperature), +3% to +11% (annual precipitation), and -9% to +2% (summer precipitation) for the British Columbia region. Second, a comparison of the Canadian Regional Climate Model (version 4.1.1) to the GCM projection that drives it showed that additional regional detail resulting from dynamical modelling of land surface-atmosphere feedbacks provided important additional regional detail (Figure 4). Finally, draping future climate projections over high resolution historical PRISM climatology (Daly, 2006) allows for illustration of how the projected climate changes look when imposed on the fine scale climatology that results from British Columbia's complex topography (Figure 5).

The three sources of climate projections described above are all based on the IPCC SRES emissions scenarios (Nakicenovic *et al.*, 2000). The three emissions scenarios considered (B1, A1B, and A2) have CO_2-equivalent greenhouse gas (GHG) concentrations that differ widely (600, 850, and 1250 ppm) by the end of the century. None of the scenarios include intentional efforts to reduce GHG emissions, such as those proposed and committed to by many jurisdictions. In order to determine whether adaptation will be required in British Columbia even if aggressive GHG reductions are attained, results from the UVic Earth System Climate Model (ESCM) were averaged over British Columbia and compared to the SRES scenarios (Figure 6). ESCM emissions are reduced linearly until 2050 to the indicated percentage below 2006 levels, then held constant afterwards (Weaver *et al.,* 2007).

The changes for British Columbia by the end of the century (2081-2100) for the B1, A1B, and A2 emissions scenarios according to the median of all IPCC AR4 projections are 3.8°C, 3.2°C, and 2.2°C, respectively. In general, model uncertainty results in roughly 1°C of uncertainty about these median lines over British Columbia (not shown) that is fairly constant throughout the 21st century. Also, these results are averaged over the Province but differences between the scenarios are less in some

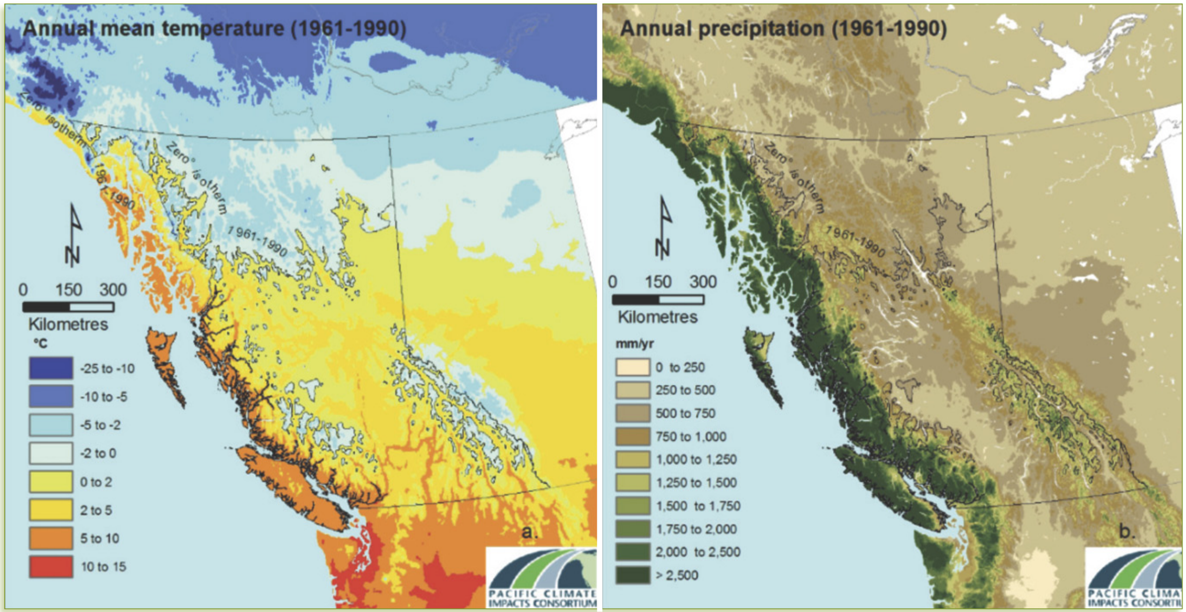

Figure 1 | Historical climatology (1961-1990) for annual average temperature and annual precipitation. Data source: PRISM (Oregon State University).

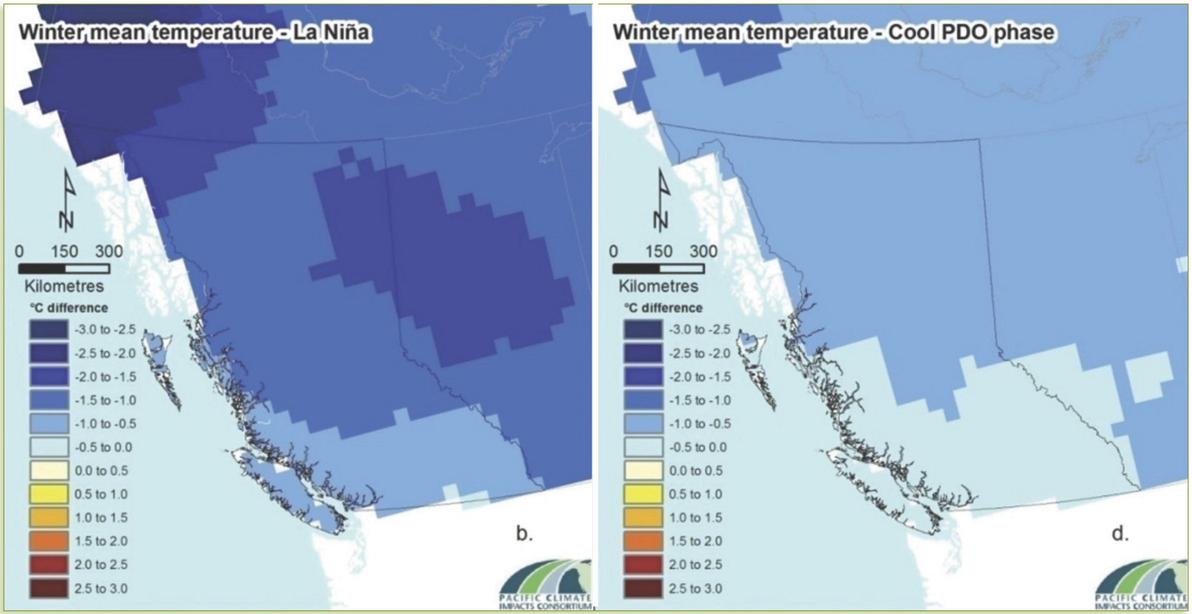

Figure 2 | Winter mean temperature difference between the average of all La Niña years during the 20th century and the average of all years (left). Winter mean temperature difference between average of all the Cool phase PDO years during the 20th century and average of all years (right). Data source: CANGRID (Environment Canada).

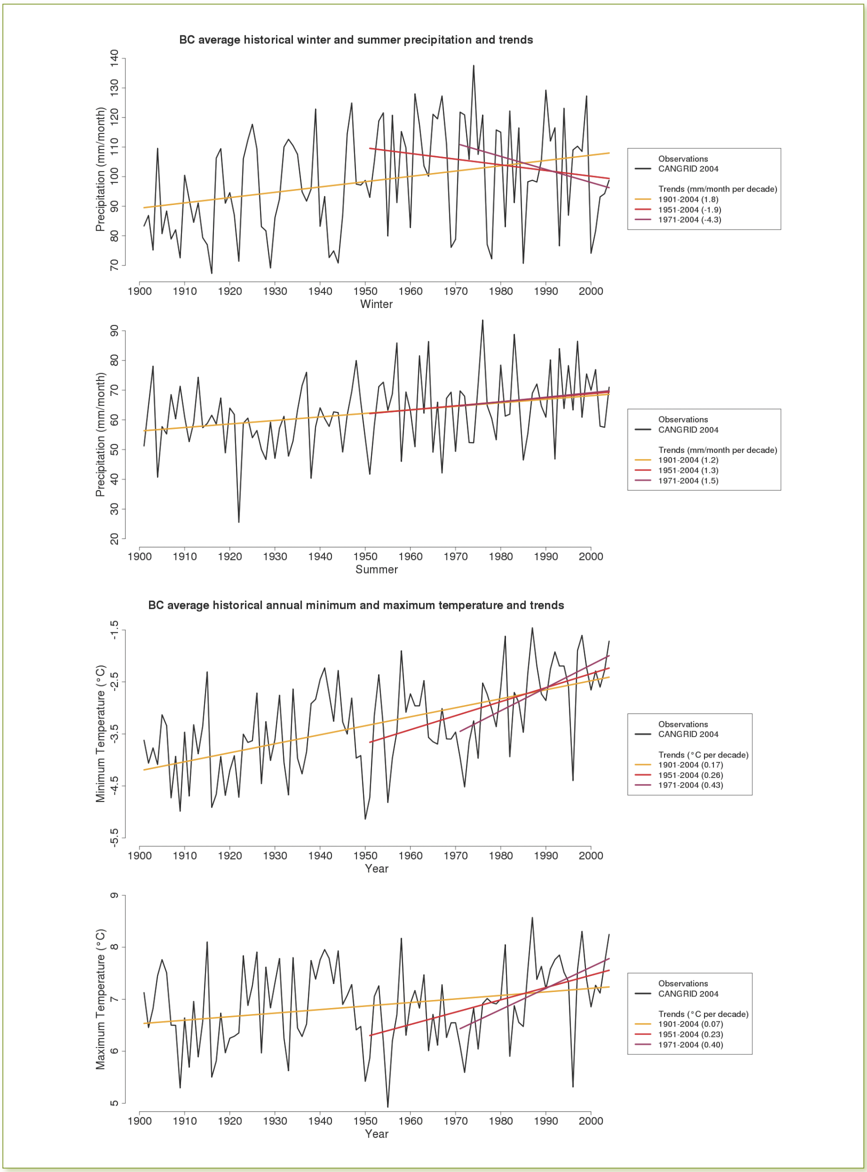

Figure 3 | Median of all trends across British Columbia for minimum temperature (night-time low), maximum temperature (day-time high), winter precipitation and summer precipitation based on CRU TS2.1 gridded time series of historical climate.

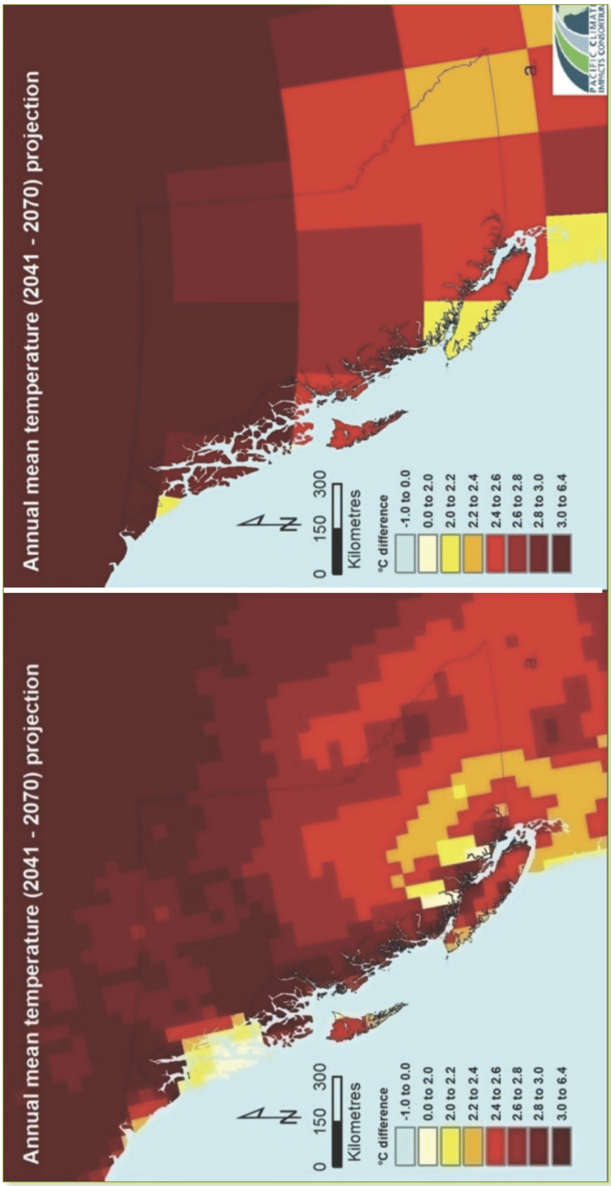

Figure 4 | Comparison of RCM Canadian Regional Climate Model version 4.1.1 (runs acs and act) to its driving GCM (CGCM3 following emissions scenario A2, run 4). Data sources: Ouranos Consortium and Coupled Model Intercomparison Project 4 (Lawrence Livermore National Laboratory).

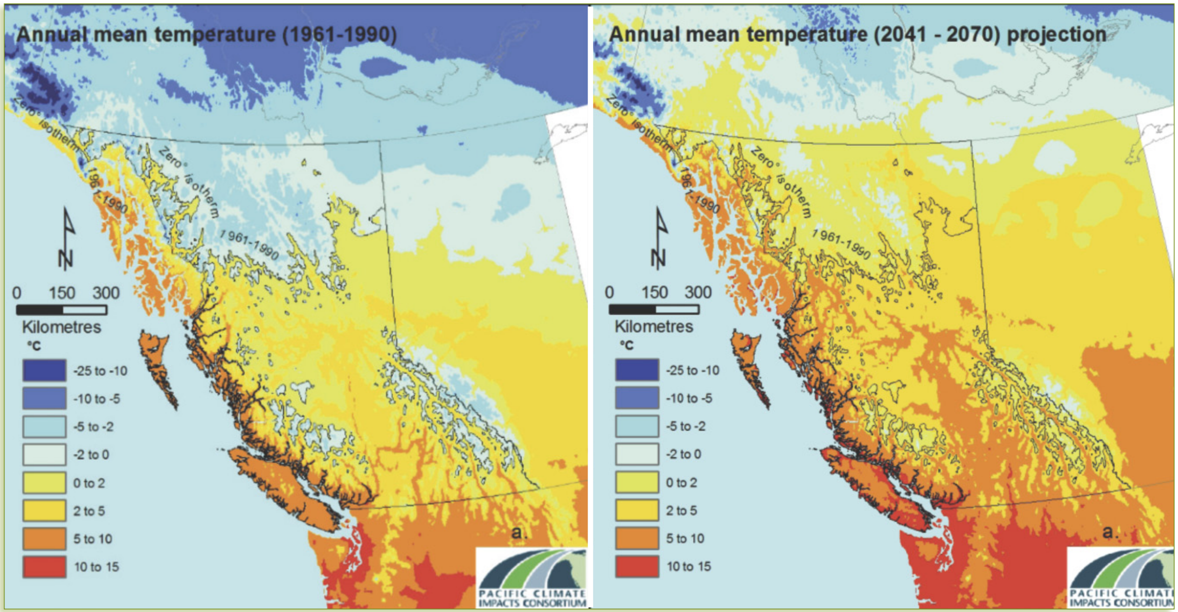

Figure 5 | Historical climatology (1961-1990) for annual average temperature and future projected temperature by draping the GCM projection from CGCM3 following emissions scenario A2 (run 4) over the high resolution (4 km) climatology. Data sources: PRISM (Oregon State University), Coupled Model Intercomparison Project 4 (Lawrence Livermore National Laboratory).

regions (e.g., coast) and larger in others (e.g., north). The amount of climate change associated with the 0% and 25% reductions, 2.3°C and 2.1°C, respectively, are comparable to the B1 scenario. This suggests that the UVic ESCM response is comparable to the median of IPCC models as the 0% to 25% reductions result in similar greenhouse gas concentrations by the end of the century to the B1 emissions scenario. More aggressive reductions result in less warming: 1.8°C and 1.5°C for 50% and 75%, respectively. Overall, there is a considerable difference in magnitude of climate change (and thus in expected impacts on ecosystems and infrastructure) between the highest (A2) emissions (3.8°C) and the very aggressive 75% reduction target (1.5°C). These results imply then that adaptation will be required even with an extremely high level of success in GHG reduction efforts (mitigation) and also that success at mitigation will result in considerably less change to adapt to.

5. Future impacts

The ultimate goal of the analysis of historical climatology and projections of future climate is to facilitate adaptation. Resident expertise of the Pacific Climate Impacts Consortium staff in physical sciences including hydrology, climate scenarios, and downscaling has been applied through collaborative projects with stakeholders. Three examples in particular are: (1) hydrological modelling (BC Hydro, BC Ministry of Environment), (2) forest impacts (BC Ministry of Forests and Range), and (3) community assessments (several stakeholders).

The hydrological modelling for BC Hydro and BC Ministry of Environment applies the Variable Infiltration Capacity (VIC) model, originally developed for use in Global Climate Models (Liang *et al.,* 1994; Liang *et al.,* 1996). The model has been widely applied in basins throughout North America, including the Columbia River Basin (Hamlet and Lettenmaier, 1999). The Pacific Climate Impacts Consortium (in collaboration with the BC River Forecast Centre and BC Hydro) has set up VIC to run in major British Columbia watersheds, including the Peace, the Canadian portion of the Columbia and the Fraser River basins. Future climate change scenarios have been developed for these watersheds, and in the Fraser additional analysis has been done to determine the effects of change in forest cover as a result of the Mountain Pine Beetle outbreak. Subsequently, the Peace and Campbell River basins will be investigated (Figure 7). In addition to the VIC model, the Pacific Climate Impacts Consortium will explore the effectiveness of applying the Canadian Regional Climate Model to determine changes to future streamflow. Results will be compared between the hydrologic modelling and the Regional Climate Model.

Impacts on forestry have been investigated in collaboration with the BC Ministry of Forests and Range, Pacific Forestry Centre, University of Victoria, and University of British Columbia researchers. In particular future tree species suitability and pest outbreak risk were investigated using bioclimatic envelope modelling (Flower and Murdock, in prep.). This approach shows only where the currently suitable climate moves to and does not consider the effects of interactions with soil, water availability, forest genetics, and other considerations. Suitable climates are projected to move much more rapidly than trees can migrate. These projections are useful for adaptation in order to inform the decision as to which species to plant in which location (assisted migration). This is an example of a decision in which adaptation and mitigation are linked, as the planting of trees to act as carbon sinks in order to reduce GHG emissions relies upon the survival to maturity of the species planted. Survival will depend in part upon the changing climate over the next century, as well as changes to pest outbreak risks that will accompany climate change.

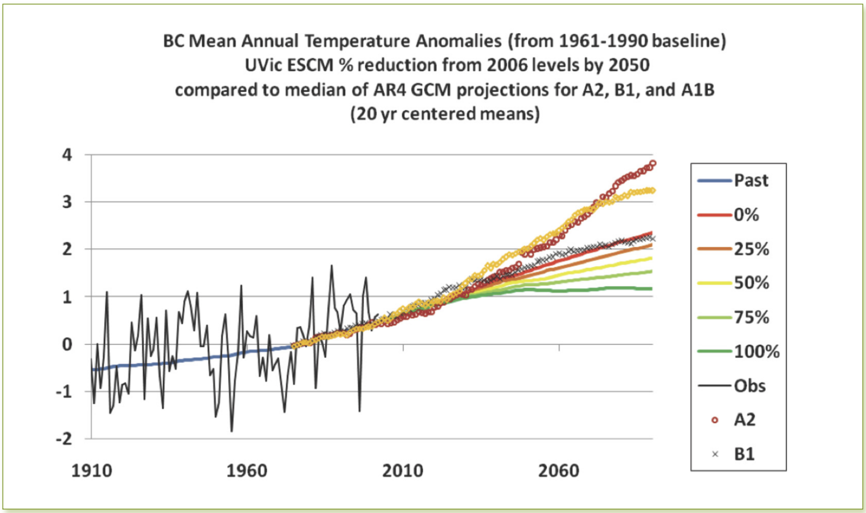

Figure 6 | British Columbia Mean Annual Temperature Anomalies from 1961-1990 baseline from the UVic ESCM by 2050 for five emissions scenarios (% reduction from 2006 levels) compared to median of AR4 GCM projections for A2, B1, and A1B displayed as 20-yr centered means to remove annual and decadal variability. The 100% reduction (green line) indicates carbon-neutrality (i.e. net zero global emissions) by 2050 – this may be considered a best case scenario for mitigation. ESCM projections provided by Ed Wiebe and Mike Eby of the UVic Climate Modelling Lab.

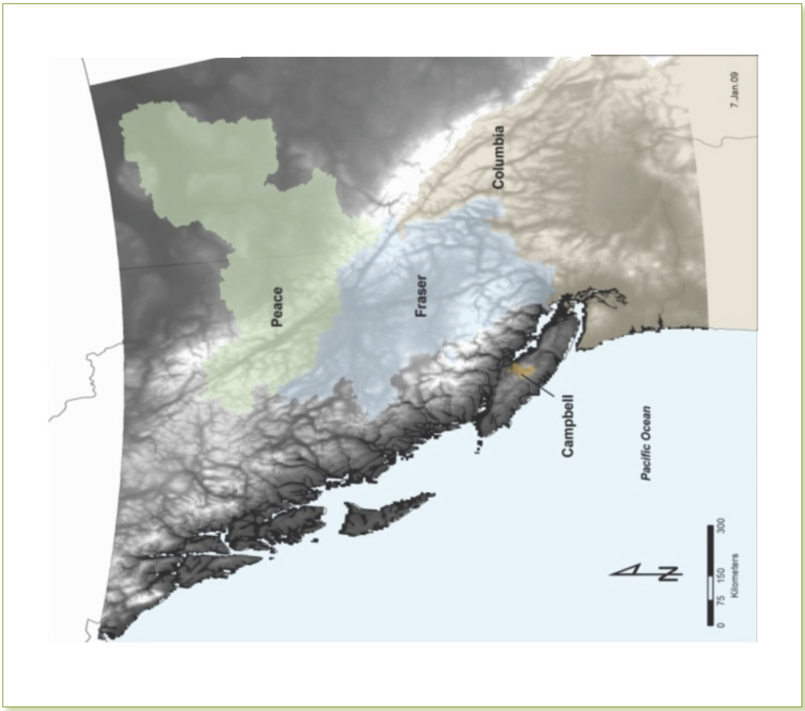

Figure 7 | Watersheds under investigation within the scope of the VIC hydrologic impacts project.

Figure 8 shows the change in the climate envelope for spruce in British Columbia by the end of the century based on a principal components analysis of three species of spruce combined (Engelmann, white, and their hybrid) according to current tree locations in British Columbia, Alberta, Washington state, Yukon, and Northwest Territories. The figure on the left shows a significant contraction of the range of climatic suitability for spruce by the end of the century, with some gains at elevation and in the north based on an average of 10 GCM projections. The results from individual projections vary considerably from each other and this uncertainty can be paralyzing to adaptation decision-making. The agreement between GCM results is also shown in the figure on the right so that a risk management approach can be taken. The darker shades of green and brown show increasing agreement between GCMs on suitability and unsuitability of the climatic envelope for spruce, respectively.

Finally, community assessments have been undertaken in collaboration with several stakeholders (e.g. Werner and Murdock, 2008). In each case the Pacific Climate Impacts Consortium staff provides analysis of past and future climate conditions along with interpretation, in order to facilitate adaptation by stakeholders. Each project requires a stakeholder partner, results in a climate impacts assessment report, and in each case different regional priorities are investigated. In addition to presenting analysis centred over smaller regions of British Columbia and the Yukon, a common feature to each project has been an attempt to go beyond annual average temperature and precipitation into parameters that will be more meaningful for adaptation. One example of this is shown in Figure 9: changes to frost free period in the Cariboo-Chilcotin region from one GCM.

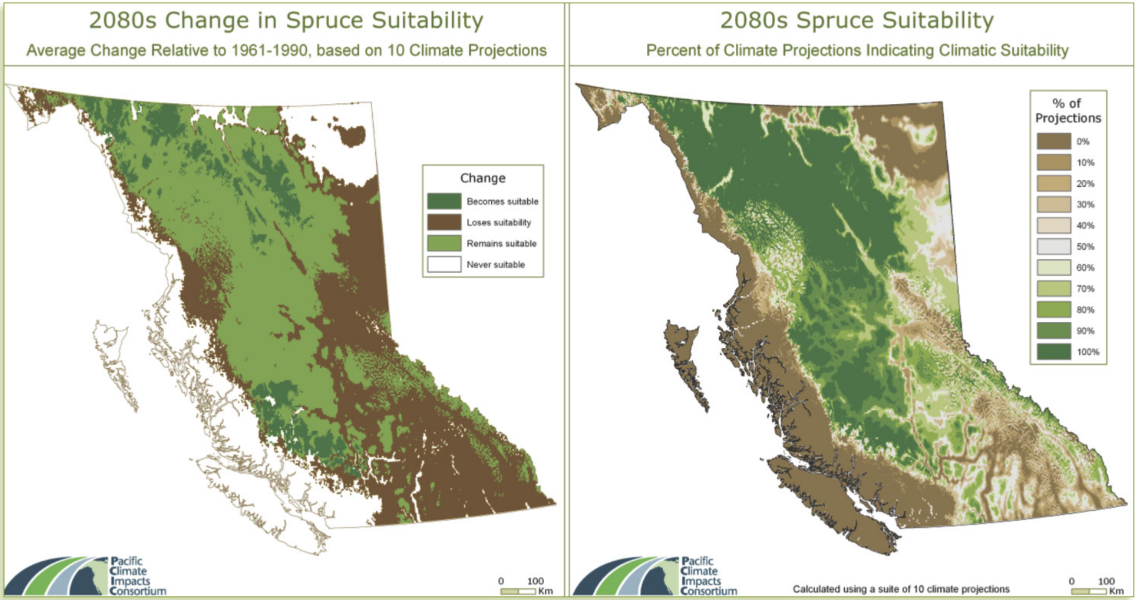

Figure 8 | Change in climatic suitability for Spruce by the 2080s based on an average of 10 Global Climate Models. The figure on the left shows areas that become suitable that were not previously (dark green) and areas that lose suitability that were suitable previously (dark brown). The figure on the right shows the percentage of the 10 projections that showed suitability: darker green indicates more agreement on suitability, darker brown indicates more agreement on unsuitability.

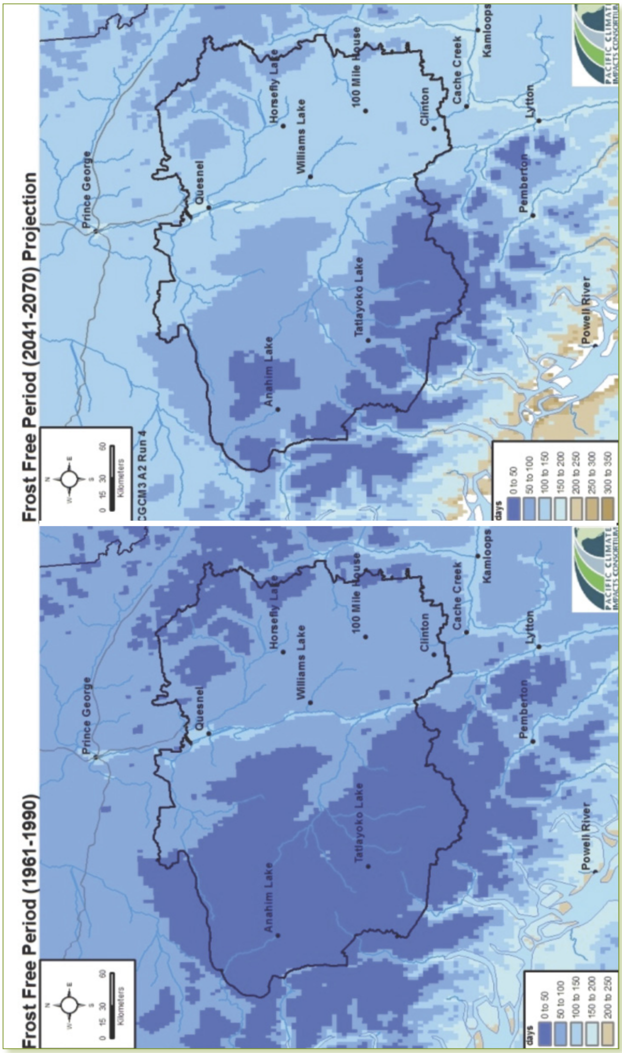

Figure 9 | Historical and future projected frost free period. Data sources: ClimateBC (University of British Columbia), PRISM (Oregon State University), and Coupled Model Intercomparison Project 4 (Lawrence Livermore National Laboratory).

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