ClimateBC: Your Access to Interpolated Climate Data for BC

Dave Spittlehouse

ClimateBC is a computer program that offers high-resolution, spatial climate data for current and future climate change scenarios (Wang *et al.* 2006). The program was developed because applying climate data in resource management often requires matching spatial scales of climate and resource databases. ClimateBC provides data for BC and the Alaska Panhandle, to 113°W in Alberta, and to 2° of latitude into Yukon Territories and the United States adjacent to BC (Figure 1).

Figure 1. ClimateBC coverage (modified from Wang et al. *2006).*

You can obtain data using a stand-alone MS Windows© application that is available to the public. Users of ClimateBC input the latitude, longitude, and elevation of their point of interest. The program outputs monthly maximum and minimum air temperature, precipitation, seasonal summaries, and derived variables such as degree-days and frost-free period for 1961–1990 climate normals (Table 1). A primary reason for developing ClimateBC is to help analyze the effect of climate change on resource management and develop adaptive actions (Spittlehouse 2005). Consequently, the user can obtain the above-mentioned variables from ClimateBC for six climate change scenarios at three periods during the 21st century.

ClimateBC's interactive mode allows the user to input a single location or multiple locations (in batch mode), and select variables, the summary period and the current climate or a climate change scenario (Figure 2). Batch mode requires a comma-delineated text file with station identification, latitude, longitude, and elevation (if known). Batch mode can produce output for a grid that can be used to generate maps of variables (Figure 3). If the user does not input a site elevation, ClimateBC determines one by interpolating between the mean elevation of adjacent tiles in the base data described in the next section.

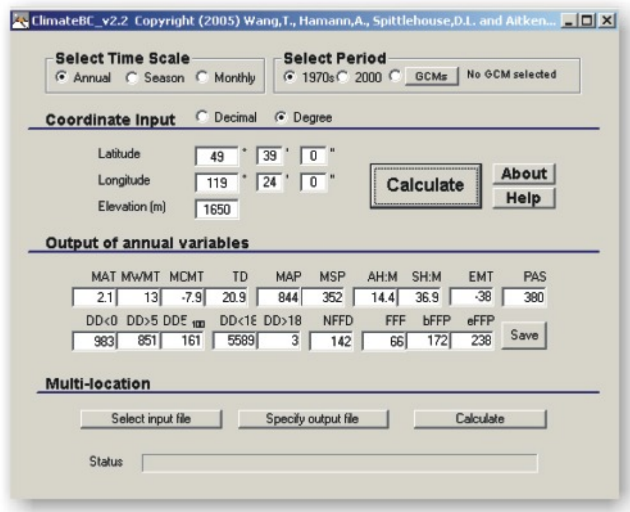

Figure 2. ClimateBC control screen. See Table 2 for the explanation of acronyms for annual variables.

This article briefly describes the program's methodology and accuracy of output variables, presents three examples of applications of ClimateBC, and discusses the limitations of the program.

Methodology of ClimateBC

Climate normals are the arithmetic mean of measurements from weather station records over three consecutive decades (World Meteorological Organization 1989). Due to the limited distribution of weather stations, climate normals for many locations must be interpolated by aspect- and elevation-related correlations, multiple linear regression, flat plate splines, and weighting functions to simulate climatological processes (Price *et al.* 2000; Daly *et al.* 2002). ClimateBC is based on the Parameter-elevation Regressions on Independent Slopes Model (PRISM) (Daly *et al.* 2002). Gridded monthly average, maximum and minimum air temperature and total precipitation generated by PRISM are available for the United States and parts of Canada at a resolution of 2.5 arcmin (a tile of about 4 × 4 km) for the reference period 1961–1990 (http://www.ocs.oregonstate.edu/prism/). PRISM climate data are based on each tile's average elevation; consequently, there may be discrepancies of up to 1200 m in mountainous areas between the

PRISM tile elevation and the elevation of specific locations within the tile. Elevation differences of this size can result in large differences between predicted and observed values, particular for temperature variables.

ClimateBC applies a combination of bi-linear interpolation and elevation adjustment techniques to the monthly temperature and precipitation data produced by PRISM (Hamann and Wang 2004; Wang *et al.* 2006). Annual and seasonal variables (Table 1) are calculated from the interpolated monthly climate normals.

Derived climate variables (Table 1) are estimated with linear or non-linear regression techniques developed from observations of the variables and monthly temperature and precipitation at 493 weather stations in British Columbia, Yukon, and parts of Alberta (Wang *et al.* 2006).

Two global circulation models — Canadian Centre for Climate Modelling and Analysis (CGCM2) and the Hadley Centre for Climate Prediction and Research (HADCM3) — generate predictions of changes to the monthly temperature and precipitation variables for three emissions scenarios. These models predict the absolute change in monthly temperature and percentage change in monthly precipitation normals for the 2020s, 2050s, and 2080s (Climate Change Scenarios Network 2006). The coverage is interpolated to a 1° latitude by 1° longitude grid. The change values are applied to the ClimateBC 1961–1990 reference climate data set to give the predicted absolute values for the respective scenario. The derived climate variables are then recalculated

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Table 1. Climate data produced by ClimateBC

Monthly	Seasonal	Annual
January to December mean temperature (°C)	Winter mean temperature (°C) (Dec-Feb)	Mean annual temperature (°C) (MAT)
January to December mean maximum temperature (°C)	Spring mean temperature (°C) (Mar-May)	Mean temperature of the warmest month (°C) (MWMT)
January to December mean maximum temperature (°C)	Summer mean temperature (°C) (June-Aug)	Mean temperature of the coldest month (°C) (MCMT)
January to December mean minimum temperature (°C)	Autumn mean temperature (°C) (Sept-Nov)	Difference between MWMT and MCMT (°C) (DT)
	Winter mean maximum temperature (°C) (Dec-Feb)	Mean annual precipitation (mm) (MAP)
	Summer mean maximum temperature (°C) (June-Aug)	Mean May to September precipitation (mm) (MSP)
	Autumn mean maximum temperature (°C) (Sept-Nov)	Annual heat: moisture index (AH:M) (MAT+10)/(MAP/1000)
	Winter mean minimum temperature (°C) (Dec-Feb)	Summer (May to Sept) heat: moisture index (SH:M) (MWMT)/(MSP/1000)
	Spring mean minimum temperature (°C) (Mar-May)	Extreme min. temperature over 30 years (°C) (EMT)
	Summer mean minimum temperature (°C) (June-Aug)	Precipitation as snow (mm water equivalent) (PAS)
	Autumn mean minimum temperature (°C) (Sept-Nov)	Degree-days below 0°C, (chilling degree-days) (DD < 0)
	Winter precipitation (mm) (Dec-Feb)	Degree-days above 5°C, (growing degree-days) (DD > 5)
	Spring precipitation (mm) (Mar-May)	Day of the year on which DD > 5 reaches 100, date of budburst (DD5$_{100}$)
	Summer precipitation (mm) (June-Aug)	Degree-days below 18°C, (heating degree-days) (DD < 18)
	Autumn precipitation (mm) (Sept-Nov)	Degree-days above 18°C, (cooling degree-days) (DD > 18)
		Number of frost-free days (NFFD)
		Frost-free period (days) (FFP)
		Day of the year on which FFP begins (sFFP)
		Day of the year on which FFP ends (eFFP)

Note: Seasonal definitions are meteorologically based. Calculate other periods from the monthly data.

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Table 2. Current (1961–1990 normals) and a possible future climate of two biogeoclimatic ecosystem units

	Very Dry Maritime Coastal Western Hemlock (CWHxm2)			Wet Cool Sub-Boreal Spruce (SBSwk1)		
	1961–1990	2050s	± SD	1961–1990	2050s	± SD
Mean annual temperature (°C)	8.3	10.3	0.7	2.5	4.9	0.5
Mean July monthly maximum temperature (°C)	21.3	23.4	1	20.7	23.0	1
Mean January monthly minimum temperature (°C)	–1.0	0.8	1	–14.8	–10.0	1
Frost-free period (days)	173	223	22	78	116	10
May to September precipitation (mm)	370	350	120	350	380	40
October to April precipitation (mm)	1870	2020	590	488	510	90
Water equivalent of the annual snowfall (mm)	190	100	90	340	280	70
Summer heat/moisture index	48	58	15	41	47	5

Note: Climate data are from a ClimateBC interpolation with 400-m grid spacing. The predictions for the 2050s are from the Canadian Global Climate Model CGCM2ax2 scenario. Unit means and one standard deviation (± SD) of each variable are presented. Total area of units: CWHxm2 = 580,250 ha; SBSwk1 = 785,950ha.

for the new conditions. Data adjusted to the 1998–2002 period are also available. Rather than possible conditions at specific times in the future, the global climate model outputs can be viewed as sets of consistent annual climate regimes to be used for sensitivity analyses to a changing climate.

Accuracy of ClimateBC

The accuracy of the ClimateBC predictions was determined using weather station records (Wang *et al.* 2006). The monthly temperature and precipitation data were evaluated on 191 weather stations in BC that are independent of the data used to generate PRISM. The accuracy of the derived variables was determined using data for 197 stations in BC, Yukon, and parts of Alberta that operated for at least 20 years from 1961 to 1990.

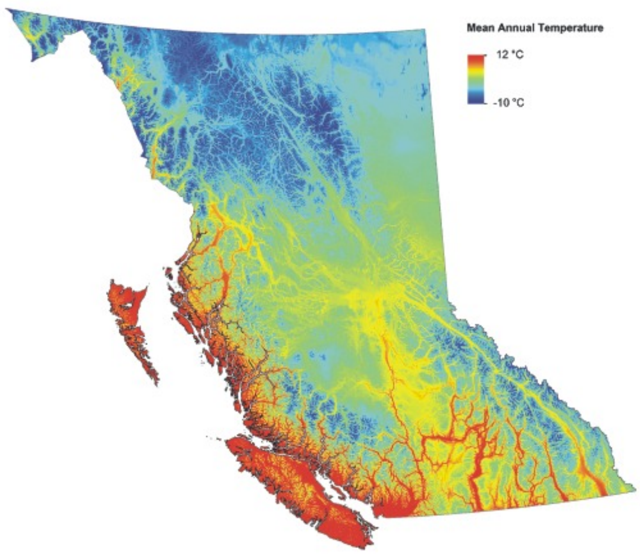
The validation exercise found that standard error of predictions for monthly temperatures and precipitation varied with each month (0.8–1.1°C for maximum temperature; 0.8–1.6°C for minimum temperature; 0.7–1.3°C for average temperature; 8–24 mm for precipitation). For all months and variables the R^2 was >0.9 and slopes of the regressions were approximately 1. For the derived variables the standard errors were of 10–15% of a variable's value. The R^2 was >0.84 for all variables and >0.9 for degree-day variables and slopes of the regressions were close to 1 (Wang *et al.* 2006). We found a few weather stations that were not well predicted for certain variables. This result, possibly due to errors in the PRISM data or to the interpolation procedure, indicates limits in the methodology.

Applications of ClimateBC

ClimateBC has many potential applications in watershed management. For example, this article illustrates the use of ClimateBC in determining climate regimes of ecological units and predicting vegetation shifts; estimating precipitation regimes of ungauged areas; and evaluating the effect of climate change on snow accumulation and melt.

Determining Climate Regimes of Ecological Units and Predicting Vegetation Shifts

Grid-based data from ClimateBC can be overlaid on resource maps such as ecosystem units (Meidinger and Pojar 1991) to obtain descriptions of the climate of these units. For example, Table 2 is based on a 400-m grid of selected variables for the very dry maritime Coastal Western Hemlock unit (CWHxm2) on the eastern slope of Vancouver Island mountains and the wet cool Sub-Boreal Spruce unit (SBSwk1) in the Central Interior of BC on the west side of the Quesnel Highlands and on the MacGregor Plateau. Conditions vary within a unit for any one variable, with precipitation showing the greatest range. Most of this variability is to be expected, but some may be due to discrepancies in mapping using vegetation to define areas of similar climate and to errors in the interpolations. Applying a climate change scenario (CGCM2ax2) shows how the climate of the area might change (Table 2). The change scenario shifts all values of a variable in a unit by about the same amount so the standard deviation on the means stays the same. Both units are warmer by about 2°C and wetter in the winter. The CWHmx2 has less rain in the summer while there is a slight increase in summer rainfall for the SBSwk1. The CWHxm2 climate changes towards that of the coastal plain on the east coast of the island. The implications for tree growth are that Douglas-fir should continue to grow well but western redcedar could disappear from currently marginal sites. The SBSwk1 climate is moving towards that of some units of the



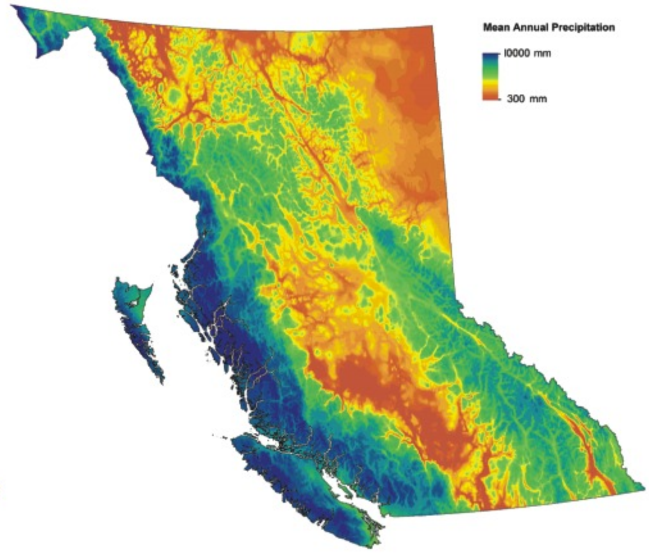


Figure 3. The 1961–1990 normals of mean annual temperature and mean annual precipitation for BC, generated with ClimateBC.

Interior Cedar–Hemlock zone. Warming of this unit may favour the growth of interior Douglas-fir and lodgepole pine over spruce.

Precipitation in Ungauged Areas

ClimateBC can estimate precipitation regimes of ungauged areas. For example, there are no long-term weather stations and only a few snow survey sites above 500 m on Vancouver Island. Figure 3 shows that mean annual precipitation can be well over 5000 mm at high elevation. Overlaying watershed boundaries on high resolution precipitation data can give an estimate of the volume of precipitation falling in such basins.

Influence of Climate Change on Snow Accumulation and Melt

ClimateBC can also be used to investigate the influence of climate change on snow accumulation and melt. High-elevation snowpacks are an important water source in the southern Okanagan. Future climate warming and changes in precipitation will affect the amount and timing of streamflow. In this example, ClimateBC's climate change scenarios help to evaluate potential changes in snow accumulation and melt at the Upper Penticton Creek Watershed. In this area, snowpacks persist from late October to late May or early June, depending on the year and elevation (Winkler *et al.* 2004). Snow water equivalent (SWE) for the winter of 2000–2001 was simulated for a forested site at 1650 m using daily weather data and a snow accumulation and snow melt model (Spittlehouse and Winkler 2004). ClimateBC was used to determine the monthly changes in temperature and precipitation for the 2050s for the CGCM2ax2 scenario. These changes were calculated from monthly values for the site for the 2050s and for the 1961–1990 normals produced by ClimateBC. For the southern Okanagan, October to May mean temperatures are predicted to increase by 1.5–2.5°C, early winter precipitation to increase by 10%, and mid-winter to early spring precipitation to decrease by 0–5%. These changes were applied to the weather data (solar radiation,

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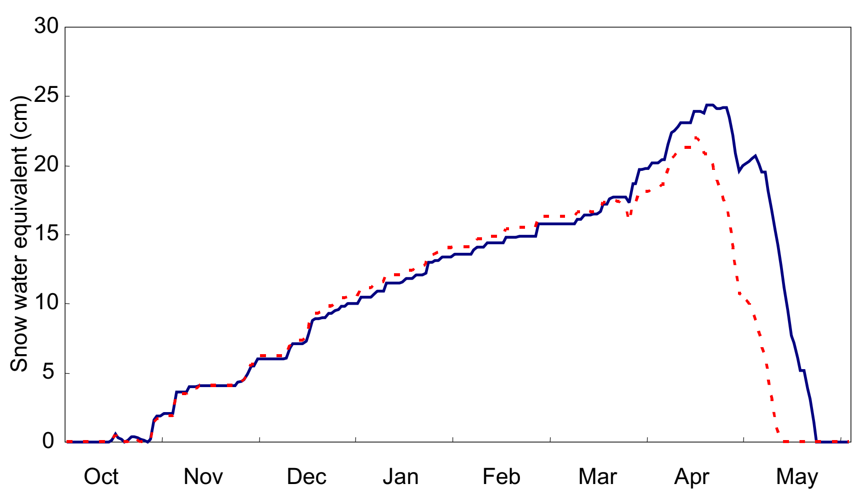

Figure 4. Snow water equivalent (cm) of the snowpack for a forested site at Upper Penticton Creek Watershed for the winter of 2000–2001 (solid blue line) and for a climate change scenario of about 2°C warming in winter (red dotted line).

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humidity, and wind speed were not changed) and the SWE simulated for the new conditions (Figure 4).

The warmer conditions in early winter did not affect the development of the snowpack and the precipitation increase resulted in a slightly higher SWE by the end of the year. The main effect of the increased temperature was an earlier start to the snow melt. Spittlehouse and Winkler (2004) show that a few consecutive days in late winter with air temperatures above 0°C are enough to start melt. Under the current climate, the temperature in March was not sufficient to start snow melt; however, in the changed climate warming was sufficient to initiate melt and reduce snowpack SWE. Cooler air temperature in early April stopped melt and SWE increased in response to precipitation. The main melt season began a week earlier in the climate change scenario and finished 11 days earlier. Peak snow melt rates (17 mm/day) were similar. Total melt was 261 mm for 2000/2001 and 247 mm for the climate change scenario, reflecting a projected small decrease in late winter precipitation. A similar pattern was obtained with the simulations for a clearcut but with a greater amount of melt in March. These data are consistent with other analyses of climate change impacts on Pacific Northwest snowpacks (Mote *et al.* 2003). Incidentally, the March to May 2005 melt season at Upper Penticton Creek was similar to that simulated for the warming scenario.

The results produced by ClimateBC in this scenario are important to consider. For example, an earlier end to the melt season could influence summer water resources through lower streamflow and greater soil moisture deficits. Global climate models suggest a 2–5°C warming in the summer and a 5–40% decrease in summer precipitation, which would exacerbate the effects of earlier snow melt under a warming winter climate. Remember that a complete climate change sensitivity analysis requires evaluating the influence of a range of climate change scenarios and weather conditions.

Limitations

ClimateBC has limitations. For example, poor predictions in the original PRISM data for areas not covered well by weather stations would lead to relatively poor predictions from ClimateBC. Additionally, PRISM data are generated from weather station data recorded at 1.5-m height in open areas. Consequently, ClimateBC predictions also represent climate for this condition and thus these data must be applied carefully in resource analysis. The microclimate of small-scale topographic features (e.g., frosts pockets, and rivers and lakes) will also not be correctly represented. Temperatures in forest canopies are often a few degrees cooler during the day and warmer at night than in open areas (Spittlehouse *et al.* 2004). Temperature in a snowpack can be substantially warmer than the air above the pack. As with using individual weather station data, users need to know how the local environment of interest may vary from the reference values that ClimateBC generates.

Future Developments

The current version of ClimateBC produces 30-year average values. Our goal over the next year is to add information on inter-annual variability about the mean and extreme values, add the normals for 1971–2000, and provide a wider range of climate change scenarios. Why some variables from a few weather stations are not well predicted will also be investigated. A Web-based version will soon be available.

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For further information, contact:

Download ClimateBC (17 MB zip file) from http://genetics.forestry.ubc.ca/cfgc/climate-models.html

The monthly temperature and precipitation data base at 400-m grid and a spreadsheet describing the climate of BC's ecosystem units is available from Research Branch, BC Ministry of Forests and Range.

To report errors in ClimateBC or to suggest improvements, contact:

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Fish Traps Threaten Pacific Water Shrew Recovery

Kym Welstead and Ross Vennesland

The Pacific Water Shrew Recovery Team has learned of several water shrews being killed in minnow traps during fisheries surveys. The many fisheries-related studies on the South Coast of British Columbia could therefore threaten this species at risk. The objectives of this article are to introduce this species at risk and its related conservation issues to fisheries practitioners; to request information on past and future mortalities or observations; and to recommend methods to mitigate this potential source of mortality to facilitate recovery of the species.

Species Biology

The Pacific water shrew (*Sorex bendirii*), also known as the marsh shrew, is a curious creature that feeds on invertebrates in aquatic and riparian areas of streams, wetlands, estuaries, lakes, beaches, and anthropogenic watercourses (Nagorsen 1996). It occurs from sea level to about 700 m elevation (Craig and Vennesland, in review). Currently, the species is known to occur in the lower Fraser River valley and associated watersheds from Hope to West Vancouver (Figure 1). However, the boundaries of this species' range in BC are not well documented, even with extensive surveys conducted in the early 1990s (Zuleta and Galindo-Leal 1994). The North American range stretches south to northern California. Only 38 observations of this rare species have been documented in Canada in the past 30 years.

Compared with other shrews, the Pacific water shrew is large. Its total body length is about 15 cm, almost half of which is tail (Figure 2; Nagorsen 1996). The waterproof outer coat and insulated undercoat keep shrews warm and help to trap air bubbles that aid in their buoyancy while swimming and diving (Figures 2 and 3). These bubbles give the fur a metallic appearance underwater. The water shrew's feet are fringed with stiff hairs, a characteristic unique to this type of shrew (Figure 3; Nagorsen 1996). Fringed feet give the water shrew its impressive swimming and diving abilities, allowing it to dive as deep as 2 m for up to 48 s and run across the water surface for several seconds, appearing to walk on water (Nagorsen 1996). The fringe hairs may also aid in detecting prey underwater. Both

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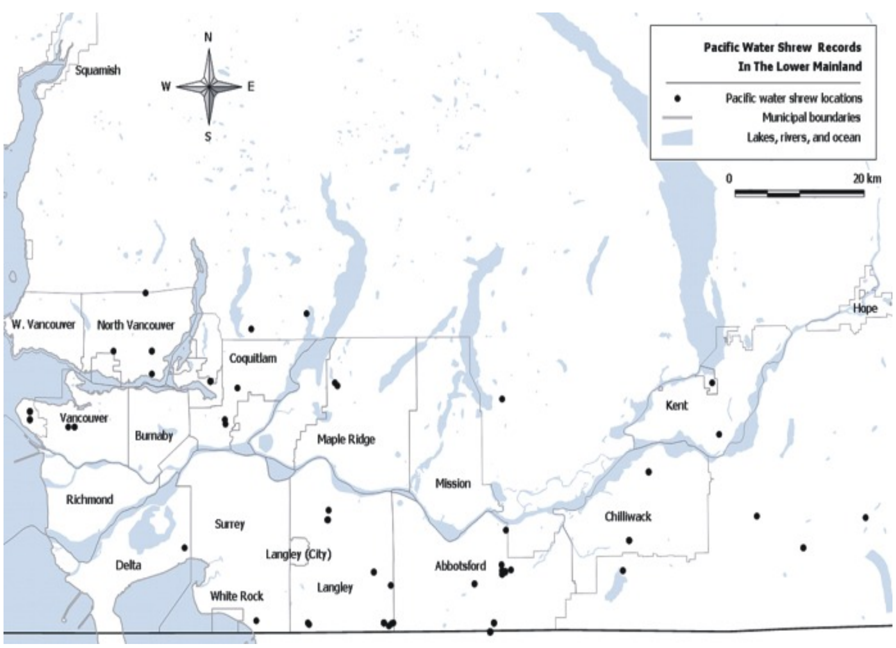

V. Craig map, EcoLogic Research

Figure 1. Location of Pacific water shrew captures and sightings current to 2003. Contact the BC Conservation Data Centre for up-to-date information about water shrew capture locations.