Climate Change in BC

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Historic climate

Fifteen thousand years ago, most of BC was covered in ice. The ice melted between thirteen and ten thousand years ago after which the climate became warm, initially drier and then moister. About 4,500 years ago, BC entered a cooler period. Over the last 1,000 years, the northern hemisphere followed a slow cooling trend until about 1900 when rapid warming began, corresponding with increased industrialization and land clearing (Figure 1). Within those general trends are warmer and cooler periods as shown by the red oscillations in the figure below. See Hebda (1995) and Spittlehouse (2008) for further detail.

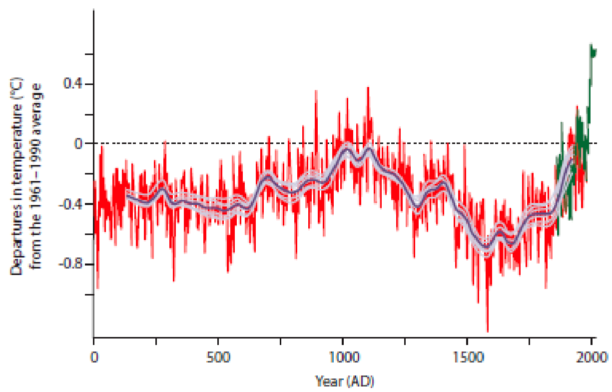

Figure 1. "Variation in the annual Northern Hemisphere temperature over the last 2000 years expressed as the difference between the annual values and the 1961–1990 average. The green line shows data from the instrumental record and the red line is a multiproxy reconstruction from tree rings, ice cores, and corals. The blue line is the low-frequency component with uncertainty. (Adapted from Moberg et al. 2005.)" Reproduced from Spittlehouse 2008 with permission.

Climate varies over a range of temporal scales. Variation in Earth's tilt and orbit around the sun influence variation over centuries and millennia (http://en.wikipedia.org/wiki/Milankovitch_cycles). Several climatic oscillations that operate on the scale of years to decades affect BC, including the El Niño Southern Oscillation, Pacific Decadal Oscillation, Pacific North American Pattern and Arctic Oscillation (Moore et al. 2010). Variation due to oscillations can exceed mean changes in climate variables over a century (Rodenhuis et al. 2009). For example, in southwestern BC, precipitation in La Niña/cool PDO years is 39% greater than in El Nino/warm PDO years (Kiffney et al. 2002).

BC has become warmer over the last century. Northern and southern BC have warmed more than coastal BC and parts of central BC (Rodenhuis 2009). Annual minimum temperatures have warmed more than maximum temperatures—BC is becoming "less cold" rather than "warmer" (Rodenhuis 2009, Pike et al. 2008). All seasons have warmed, but winter has warmed the most. As a result of warming, seasons are changing. The frost-free period has lengthened by 21 days over the last half of the last century.

BC has become wetter (22% increased precipitation) over the last century, with the greatest increases in precipitation occurring in summer and spring (50%), especially in the northern interior, however over the last half century winter precipitation has declined in some locations (Pike et al. 2008 and references therein). Heavy rainfall events have increased. Extreme wet and dry conditions in summer have also increased. Snowpacks in southern BC and over much of western North America have decreased over the last half century (Pike et al. 2010). Glaciers are receding across most of BC, with the exception of some glaciers in cold, high elevation areas experiencing increased precipitation (e.g., northwest BC; Rodenhuis et al. 2009, Pike et al. 2008). Lake ice lasts a shorter time. Spring snowmelt and runoff is starting sooner and is followed by increasingly long, dry summers in south-central BC (Leith and Whitfield 1998) and south coastal BC (Pike et al. 2010).

Projected climate change

The Intergovernmental Panel on Climate Change (IPCC) estimates that average global surface temperature will increase by 1.8 to 4.0°C (best estimate) over this century relative to the period 1980-1999 (range of 1.1˚ to 6.4˚C), a substantial increase over the rate of warming (0.6°C), recorded for the last century (IPCC 2007). The upper end of the projected warming rate is unprecedented in the last 50 million years and is about 50 times faster than warming following ice ages in the last million years (http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-6-2.html). Even if atmospheric carbon were stabilized at year 2000 levels, warming is projected to increase by 0.6°C this century (IPCC 2007). Warming is expected to be greater over land and at high northern latitudes.

Projections (Plan2Adapt website; Box 1) suggest that by mid century, BC will be 1.8 °C warmer than it was in the 1960 to 1990 period. Projected temperatures vary by region and season (Figure 2 and 3). The north and the south (with the exception of the Central Interior) are expected to warm the most (1.7 to 2.0 °C, mean annual temperature over the period) and the coast the least (1.4 to 1.6 °C). Throughout BC, winters are expected to warm more than summers (2.0 vs. 1.6°C). Northern BC follows the provincial trend, however summers may lead warming in southern and coastal BC, except in the Central Interior where little difference between winter and summer warming is expected (**Figure 3**). High variability among projections precludes strong conclusions about regional differences. By the end of this century (2070-2099), mean annual temperature in BC could be 1.7 to 4.5 °C warmer than the 1961-90 period[1]. For perspective, Prince George’s annual temperature is currently 3.7°C cooler than Kelowna’s (Province of BC, 2010).

Figure 2. Ecoprovinces

[1] From Plan2Adapt: Range of 10th to 90th percentile; http://www.plan2adapt.ca/tools/planners?pr=0&ts=9&toy=16 accessed July 16, 2013.

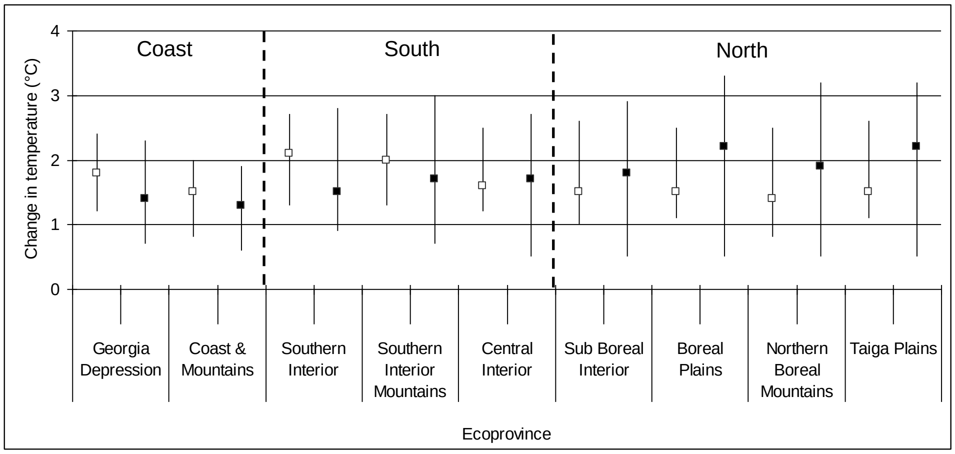

Figure 3. Projected increase in temperature from the baseline (1961-1990) to 2050s (2040-2069) by Ecoprovince (http://www.env.gov.bc.ca/ecology/ecoregions/index.html). Open boxes show mean summer temperature (June, July, August); shaded boxes show mean winter temperature (December, January, February); vertical lines show range of 80% of projections. High variability among projections and their coarse spatial resolution preclude strong conclusions about differences among regions and seasons.

Over BC, annual precipitation is expected to increase by 6 % by mid century with the greatest increase in winter (Plan2Adapt website). Parts of northern coastal BC face a 6 to 26% increase in annual precipitation by the end of this century (Haughian et al. 2012). Winter precipitation is expected to increase in all regions (**Figure 4**); note that precipitation projections, particularly regional and seasonal patterns, are more uncertain than temperature projections. Summer precipitation is expected to increase in northern BC, decrease somewhat in southern BC and decrease more substantially in coastal BC. Increased winter precipitation will lead to increased snowfall in northern BC, but warmer temperatures will reduce winter snowfall (i.e., more rain) somewhat in southern BC and substantially in coastal BC (Figure 5). Spring snowfall will likely be substantially reduced across all regions of BC. Changes in the amount, timing and type of precipitation will substantially influence snowpack characteristics and hydrological regimes. BC is expected to follow projected global trends: snow cover will contract and glaciers and permafrost will thaw (IPCC 2007; Meehl et al. 2007). Further, the depth and duration of the winter snowpacks in BC will likely decrease (Pike et al. 2008).

Preliminary analyses suggest growing season moisture deficits will increase in several locations, particularly in southern and coastal BC (Spittlehouse 2008). Deficits occur where monthly precipitation is less than monthly evaporative demand (reflecting solar radiation, air temperature and humidity, and wind).

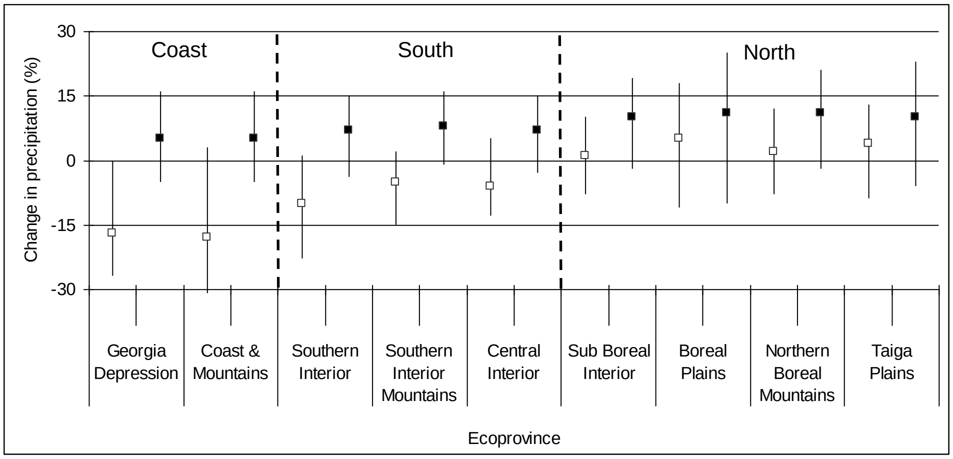

Figure 4. Projected percentage change in precipitation from the baseline (1961 to 1990) to 2050s (2040 to 2069) for Ecoprovinces of BC. Open boxes show summer precipitation (June, July, August); black boxes show winter precipitation (December, January, February); vertical lines show range of 80% of projections. High variability among projections and their coarse spatial resolution preclude strong conclusions about differences among regions and seasons.

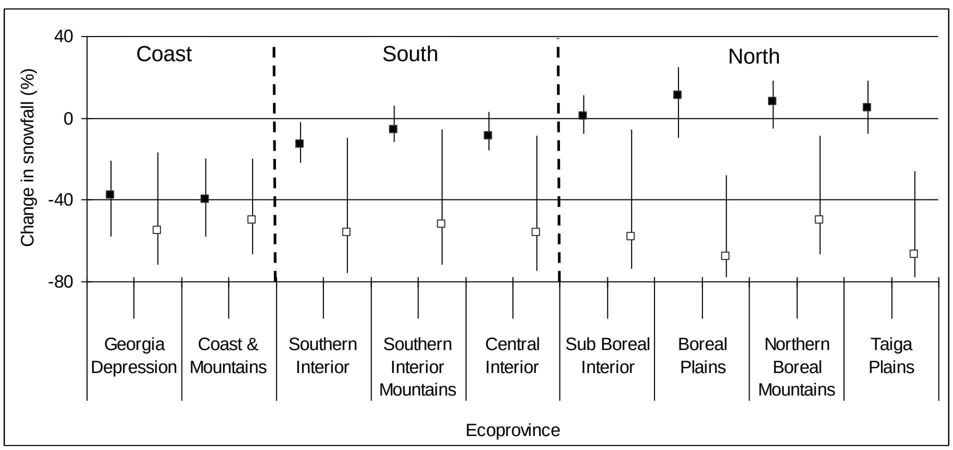

Figure 5. Projected percentage change in snowfall from the baseline (1961 to 1990) to 2050s (2040 to 2069) for Ecoprovinces of BC. Open boxes show spring snowfall (March, April, May); shaded boxes show winter snowfall (December, January, February); vertical lines show range of 80% of projections.

Extreme climatic events are projected to increase. Globally, it is very likely (> 90% chance) that heat waves and heavy precipitation events will continue to occur more frequently (IPCC 2007). The frequency and duration of summer drought events are expected to increase over much of southern BC (Haughian et al. 2012). Precipitation is expected to fall in fewer, larger events (IPCC 2007), with consequences for ecosystem function (Knapp et al. 2008). Storm-mediated precipitation is projected to increase 40 to 60% on the southern coast and 100 to 150% in the Northern Caribou Mountains (Haughian et al. 2012, based on Salathe 2006).

In general, climate warming is expected to increase the intensity of atmospheric convection processes, leading to an increased frequency of intense windstorms (Pojar 2011, Haughian et al 2012; Lambert and Fyfe 2006). The average speed of intense wind events (i.e., top 10% of wind events) is expected to increase by up to 14% in coastal BC and the Northern Boreal mountains (Haughian et al 2012). Globally, extratropical storms tracks are projected to move poleward, although storm tracks in BC are projected to remain relatively stable (Haughian et al. 2012; Lambert and Fyfe 2006).

Changes in extreme conditions will accompany the changes in the mean (Pike et al. 2008; Kharin et al. 2007). By the mid century, what is currently a 1 in 20 year extreme warm temperature event becomes a 1 in 5 year event and extreme cold events become less frequent. Extreme precipitation events show similar changes with 1 in 20 year events becoming 1 in 10 year events or lower. Dry periods during the summer will likely become more intense, particularly in southern BC (Spittlehouse 2008 and references therein). Extreme conditions also increase if climate variability increases. Climatic variability in the northern hemisphere seems to be increasing (Hansen et al. 2012).

In addition to causing warming, increased concentrations of atmospheric carbon dioxide are absorbed by ocean water and have caused a 30% increase in ocean acidity since 1750 (Orr et al. 2005, Copenhagen Diagnosis 2009 and references therein). Consequences are expected to reverberate throughout the ocean's foodweb, including impacts to salmon (Farbry et al. 2008). When atmospheric concentrations of carbon dioxide reach 450 ppm, by approximately 2030, Arctic and Southern Oceans are expected to start dissolving certain shells. Aquaculture off the coast of Washington may already be affected (Feely 2012). Models suggest that increased carbon dioxide may also substantially increase oxygen-poor "dead zones" by the end of this century (Oschlies et al. 2008). Increased carbon dioxide is also expected to increase tree growth (Johnson et al. 2009).

Box 1. Source of projected climate variables

Unless otherwise stated, projected climate variables were retrieved from the Pacific Climate Impacts Consortium Plan2Adapt website (http://pacificclimate.org/tools-and-data/plan2adapt) on Nov 30, 2012. Projected means and ranges are based on 15 different global climate models running the A2 and B1 emissions scenarios (30 projections). The A2 scenario is relatively pessimistic (i.e., high emissions) and the B1 relatively optimistic. Actual emissions are currently tracking along the A2 scenario (Copenhagen Diagnosis 2009) so mean values presented here could be viewed as somewhat conservative, however the magnitude of the warming is somewhat insensitive to scenarios prior to 2030 (IPCC 2007). The wide variation in projections reflects differences in how climatic processes are modelled and the influence of emissions assumptions. Differences due to models are greater than differences due to emissions scenarios (Figure SPM 5, IPCC 2007).

Literature Cited

Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science. I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

Fabry V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65: 414–432.

Feely, R. 2012. Washington state presses for action on ocean acidity. Vancouver Sun, Nov 29, page B1.

Hansen, J., Mki. Sato, and R. Ruedy. 2012: Perception of climate change. Proceedings of the National Academy of Science. 109: 14726-14727.

Haughian, S.R., P.J. Burton, S. W. Taylor, & C. L. Curry. 2012. Expected effects of climate change on forest disturbance regimes in British Columbia. BC Journal of Ecosystems and Management 13(1):1–24.

Hebda, R. 1995. British Columbia Vegetation and Climate History with Focus on 6 ka BP. Géographie Physique et Quaternaire 49: 55-79.

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Johnson, M., M. Campagna, P. Gray, H. kope, J. Loo, A. Ogden, G. A. O'Neill, D. Price and T. Williamson. 2009. Vulnerability of Canada's Tree Species to Climate Change and Management Options for Adaptation: An Overview for Policy Makers and Practitioners. Retrieved Jan 15, 2011 from http://www.ccfm.org/pdf/TreeSpecies_web_e.pdf

Kharin, V.V., F.W. Zwiers, X. Zhang, and G.C. Hagerl. 2007. Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations. Journal of Climate 20:1419–1444.

Kiffney, P.M., J.P. Bull, and M.C. Feller. 2002. Climatic and hydrologic variability in a coastal watershed of southwestern British Columbia. Journal of the American Water Resources Association 38(5):1437–1451.

Knapp, A.K., C. Beier, D.D. Briske, et al. 2008. Consequences of more extreme precipitation regimes for terrestrial ecosystems. Bioscience 58(9): 1-11.

Lambert, S.J. & J.C. Fyfe. 2006. Changes in winter cyclone frequencies and strengths simulated in enhanced greenhouse warming experiments: results from the models participating in the IPCC diagnostic exercise. Climate Dynamics 26:713–728.

Leith, R.M. and P. Whitfield. 1998. Evidence of climate change effects on the hydrology of streams in south-central B.C. Canadian Water Resources Journal 23(3):219–230.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Moore, R.D., D.L. Spittlehouse, P. Whitfield, and K. Stahl. 2010. Weather and climate. In Compendium of forest hydrology and geomorphology in British Columbia. Pike, R.G., T.E. Redding, R.D. Moore, R.D.

Winker and K.D. Bladon (editors). 2010. Compendium of forest hydrology and geomorphology in British Columbia. B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Manag. Handb. 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm.

Oschlies, A. K.G. Schulz, U. Riebesell and A. Schmittner. 2008. Simulated 21st century's increase in oceanic suboxia by CO2-enhanced biotic carbon export. Global Biogeochemical Cycles, 22, GB4008, doi:10.1029/2007GB003147

Orr, J. C., V.J. Fabry, O. Aumont et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437, 681-686.

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Eggington, P.J. Tschaplinski, T.Q. Murdock and A.T. Werner. 2008. Climate change and watershed hydrology: part I—recent and projected changes in British Columbia. Streamline 11: 1-7.

Pike, R.G., K.E. Bennett, T.E. Redding, A.T. Werner, D.L. Spittlehouse, R.D. Moore, T.Q. Murdock, J. Beckers, B.D. Smerdon, D.D. Bladon, V.N. Foord, D.A. Campbell and P.J. Tschaplinski. 2010. *In* Compendium of forest hydrology and geomorphology in British Columbia. Pike, R.G., T.E. Redding, R.D. Moore, R.D. Winker and K.D. Bladon (editors). Compendium of forest hydrology and geomorphology in British Columbia. B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Manag. Handb. 66. www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh66.htm.

Pojar J. 2011. A new climate for conservation: nature, carbon and climate change in British Columbia. Commissioned by the Working Group on Biodiversity, Forests and Climate. http://www.forestethics.ca/new-climate-for-conservation-report

Province of BC (B.C. Ministry of Forests, Mines and Lands). 2010. The State of British Columbia's Forests, 3rd ed. Forest Practices and Investment Branch, Victoria, B.C. Available online at www.for.gov.bc.ca/hfp/sof/index.htm#2010_report

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2009 (revised). Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium, Univ. Victoria, Victoria, B.C. http://www.pacificclimate.org/resources/publications/.

Salathé, E.P. 2006. Influences of a shift in North Pacific storm tracks on western North American precipitation under global warming. Geophysical Research Letters 33:L19820, doi:10.1029 /2006GL026882

Spittlehouse, D.L. 2008. Climate Change, impacts, and adaptation scenarios: climate change and forest and range management in British Columbia. B.C. Min. For. Range, Res. Br., Victoria, B.C. Tech. Rep. 045.http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm

Wigley, T.M.L. 2009. The effect of changing climate on the frequency of absolute extreme events. Climate Change 97:67-76.