PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC UPDATE

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# Why was this spring and early summer so cold in BC?

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For many people in British Columbia the spring and summer of 2011 seemed unusually cold at a time when warm temperature records were being broken in other parts of Canada. How do these months compare with a normal year (defined here as the 30-year average over the baseline period 1971-2000)? Why was this past spring and summer in BC so cool? What does the climate record tell us about similarly cool seasons, or is this part of a new phenomenon? To answer these questions PCIC used data available from Environment Canada and the BC government's Climate Related Monitoring Program.

## How cold and wet was it?

To answer this question, an analysis was performed on 92 locations (fewer when data was unavailable) across the province to compare observed conditions to climate normals for the months from December 2010 through July 2011. The results are presented in Table 1 in the form of averages across all analyzed locations. Results from a selection of cities spread across the province are given in Tables 2 and 3 for maximum and minimum temperature respectively and Table 4 for precipitation. Averaged among all cities analyzed, conditions were colder than normal from February through July and wetter than normal, or near-normal over the same period. For example, in July 2011 the average daily minimum and maximum temperatures were lower (by 0.2 °C and 1.8 °C), while precipitation was 17% higher than normal (Table 1). Figure 1 (next page) shows the average spring temperature anomalies reported by Environment Canada for northern and southern BC for the period 1948-2011. Over southern BC, spring 2011 was definitely cool, though only about one third as cold as the coldest springtime averages for this period (0.9 °C colder than normal versus the seasonal record of 3.1 °C colder). Further north, conditions have been close to average when looking at this large-scale perspective. It's important to note that the region including northern BC also includes the Yukon Territory. Spring (March, April and May) average daily maximum and minimum temperatures (Table 2 and Table 3) in northern cities such as Atlin, Dease Lake, and Fort Nelson were 1-2°C colder than normal. The difference between the colder than average station data and the larger-scale average from Environment Canada arises because northern Yukon, which is included in the average, experienced a warmer than normal spring season. These warm northern Yukon temperatures offset the cooler temperatures observed in the northern BC average. For southern cities, maximum temperatures were much more anomalously cold than in the north while minimum temperatures were less extreme. Minimum temperatures have been near normal for much of the province while maximum temperatures have been as much as 2.5 °C colder than normal. This could be explained by greater cloud cover, which tends to keep night time temperatures warm.

| Month | Difference from 1971-2000 Average | | |
|---|---|---|---|
| | $T_{max}$ (°C) | $T_{min}$ (°C) | Precip (%) |
| Dec 2010 | 0.4 | 0.8 | -9 |
| Jan 2011 | 0.7 | 1.0 | 24 |
| Feb 2011 | -2.3 | -2.2 | 8 |
| Mar 2011 | -1.0 | -0.4 | 27 |
| Apr 2011 | -2.4 | -1.4 | -3 |
| May 2011 | -1.2 | -0.3 | 32 |
| Jun 2011 | -0.7 | 0.4 | -24 |
| Jul 2011 | -1.8 | -0.2 | 17 |

***Table 1:*** *Monthly averages of daily minimum and maximum temperature and precipitation anomalies relative to the baseline period 1971-2000 for roughly 90 cities across British Columbia.*

$T_{max}$ (°C)

| City | DJF | MAM | JJ |
|---|---|---|---|
| Atlin | -1.0 | -0.7 | 0.6 |
| Cranbrook | -0.2 | -2.0 | -1.2 |
| Dease Lake | -0.9 | -1.5 | -0.9 |
| Fort Nelson | -0.3 | -1.3 | -0.4 |
| Fort St John | -1.9 | -2.5 | -1.4 |
| Kamloops | -0.2 | -1.5 | -1.4 |
| Penticton | 0.3 | -1.7 | -1.3 |
| Port Hardy | -0.5 | -1.1 | -1.1 |
| Smithers | -0.8 | -1.4 | -1.8 |
| Terrace | -0.4 | -0.8 | -2.2 |
| Tofino | -0.7 | -1.2 | -0.7 |
| Vancouver | 0.2 | -1.4 | -0.6 |
| Victoria | 0.0 | -1.3 | -0.4 |
| Williams Lake | -0.8 | -1.8 | -2.3 |

***Table 2:*** *2011 seasonal anomalies in daily maximum temperature (°C) for selected cities in BC relative to the baseline period 1971-2000. DJF corresponds to the December-January-February average, MAM corresponds to the March-April-May average, and JJ corresponds to the June-July average.*

$T_{min}$ (°C)

| City | DJF | MAM | JJ |
|---|---|---|---|
| Atlin | -0.9 | -2.1 | -0.7 |
| Cranbrook | -1.0 | -0.7 | -0.7 |
| Dease Lake | -1.2 | -1.2 | 1.6 |
| Fort Nelson | 0.3 | -1.1 | -0.2 |
| Fort St John | -0.9 | -1.8 | 0.5 |
| Kamloops | 0.2 | -0.2 | -0.3 |
| Penticton | 0.6 | 0.1 | -0.6 |
| Port Hardy | 0.2 | -0.3 | 0.6 |
| Smithers | 0.1 | -0.4 | 0.7 |
| Terrace | -0.2 | -0.6 | -0.1 |
| Tofino | 0.8 | -0.1 | 0.9 |
| Vancouver | 0.4 | -0.4 | 0.3 |
| Victoria | -0.1 | -0.6 | 0.2 |
| Williams Lake | -0.4 | -1.0 | -0.2 |

***Table 3:*** *2011 seasonal anomalies in daily minimum temperature (°C) for selected cities in BC relative to the baseline period 1971-2000. DJF corresponds to the December-January- February average, MAM corresponds to the March-April-May average, and JJ corresponds to the June-July average.*

For precipitation, the story is more complicated because trends and patterns of anomalies tend to be less coherent than for temperature. Table 1 shows an alternating series of wetter than normal and near normal or even dry months. Looking at individual cities, Table 4 shows that this past spring was wetter than normal for all selected cities except Atlin, Terrace and Port Hardy. In winter, northern and interior locations such as Fort Nelson, Fort St. John, Penticton, and Williams Lake were wetter than normal while cities elsewhere experienced near normal precipitation. The summer months were neither systematically wet nor dry, but great variation was seen within the province. In some places more than double the normal amount of precipitation fell (e.g., Fort St. John) and less than half of normal amounts fell in others (e.g., Atlin). Overall, the data indicate a near normal winter followed by a spring with cool and wet days and normal night time temperatures. This has now been capped by a cool summer with normal rainfall.

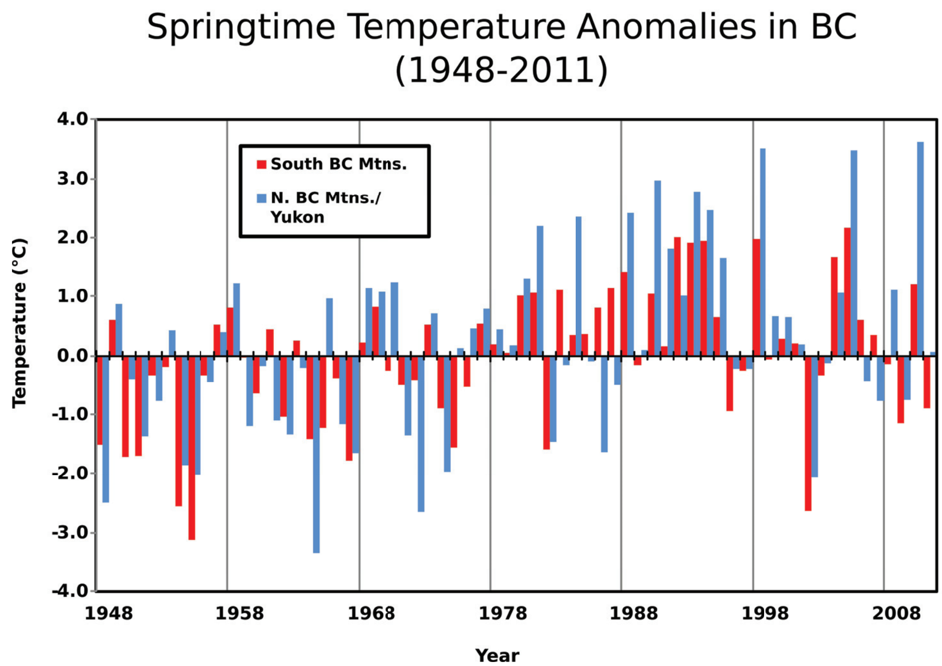


***Figure 1:*** *Spring temperature anomalies for major climate regions of British Columbia for the period 1948-2011 relative to the baseline period 1971-2000. The two bars on the extreme right indicate a cool temperature anomaly in Southern BC Mountains (red), and almost normal for Northern BC Mountains and Yukon (blue) for this Spring 2011. Data from Environment Canada, http://www.ec.gc.ca/adsc-cmda/default.asp?lang=en&n=4CC724DA-1.*

**Precip (%)**

| City | DJF | MAM | JJ |
|---|---|---|---|
| Atlin | 7 | -30 | -60 |
| Cranbrook | -4 | 31 | -9 |
| Dease Lake | NA | NA | NA |
| Fort Nelson | 51 | 14 | -6 |
| Fort St John | 75 | 68 | 110 |
| Kamloops | -13 | 85 | -3 |
| Penticton | 21 | 37 | -20 |
| Port Hardy | 14 | -1 | 22 |
| Smithers | 5 | 84 | 7 |
| Terrace | -4 | -11 | 5 |
| Tofino | 4 | 11 | -40 |
| Vancouver | -4 | 28 | -19 |
| Victoria | 5 | 58 | -26 |
| Williams Lake | 23 | 21 | 64 |

***Table 4:*** *2011 seasonal precipitation anomalies (%) for selected cities in BC. Values close to zero indicate normal precipitation. A value of 100% would correspond to twice normal precipitation. DJF corresponds to the December-January-February average, MAM corresponds to the March-April-May average and JJ corresponds to the June-July average.*

# Why has it been cold?

This spring and summer have been cold in BC because of a combination of natural variability in atmospheric and oceanic conditions, and the tendency for such conditions to persist in time. It's also possible that our perception of a normal spring has been affected by the warm temperatures that were experienced in the early part of this decade.

The fall of 2010 saw one of the most rapid transitions from El Niño to La Niña since the El Niño Southern Oscillation has been observed. The result was that the winter of 2010-2011 in British Columbia was influenced by the cold phase of the oscillation known as La Niña. In the southern portions of British Columbia, this phenomenon typically corresponds with colder than normal temperatures and greater than normal precipitation. In the north, La Niña typically corresponds to cold and dry conditions. The effects of La Niña usually fade during spring and have minimal influence on the summertime climate of BC. This most recent La Niña phase officially ended in June 2011.

One principle of weather forecasting, called persistence, is that tomorrow's weather is likely to be a lot like today's weather. The reason for this persistence is that atmospheric and oceanic circulation have timescales of coherence that extend from days to months and sometimes even longer. A good example is the El Niño/La Niña cycle of sea surface temperatures that occurs in the tropical Pacific. Until very recently, the sea surface temperature pattern in the North Pacific established by La Niña during winter was intact, producing cold temperatures off the coast of western North America and much warmer than normal temperatures in the central North Pacific. This pattern drove anomalies in atmospheric circulation that affected the weather of BC. Such ocean temperature patterns, which can be described by something called the Pacific Decadal Oscillation (PDO), so-named for its tendency to prefer one state or another for decade-long periods of time despite sometimes rapid fluctuations. The PDO index can persist from year to year. Thus, the ocean serves as the 'memory' in the climate system and it is this memory that appears to be partially responsible for our cooler spring and summer. The coldest springs in southern BC shown in Figure 1 (1954, 1955 and 2002) were accompanied by a phase of the PDO similar to last spring. Conversely, the warmest springs (1992, 1998 and 2005) are associated with the opposite PDO phase.

During a typical summer, the Northeast Pacific High establishes itself off the BC coast, providing a barrier to storms from the Pacific Ocean and driving them north to Alaska, the Yukon and northern parts of the province. This high pressure center allows warm, continental air to spread over BC when it is situated in its normal location. The result is warm and dry conditions over the south coast and southern interior, with some influence from storms over the northern part of the province. However, this year that high pressure center stayed further west, allowing Pacific storms to reach Canada further to the south than they normally would. A low pressure area was stationed near the southwest corner of the province causing the transport of cold, moist air from the Pacific Ocean onshore across the southern part of the province. The result was cooler and sometimes rainier than average conditions in many places. Furthermore, the normally docile spring and summertime jet stream (a high altitude air current which provides energy for storms and a means of moving them across the globe) was very active this spring and summer (Figure 2).

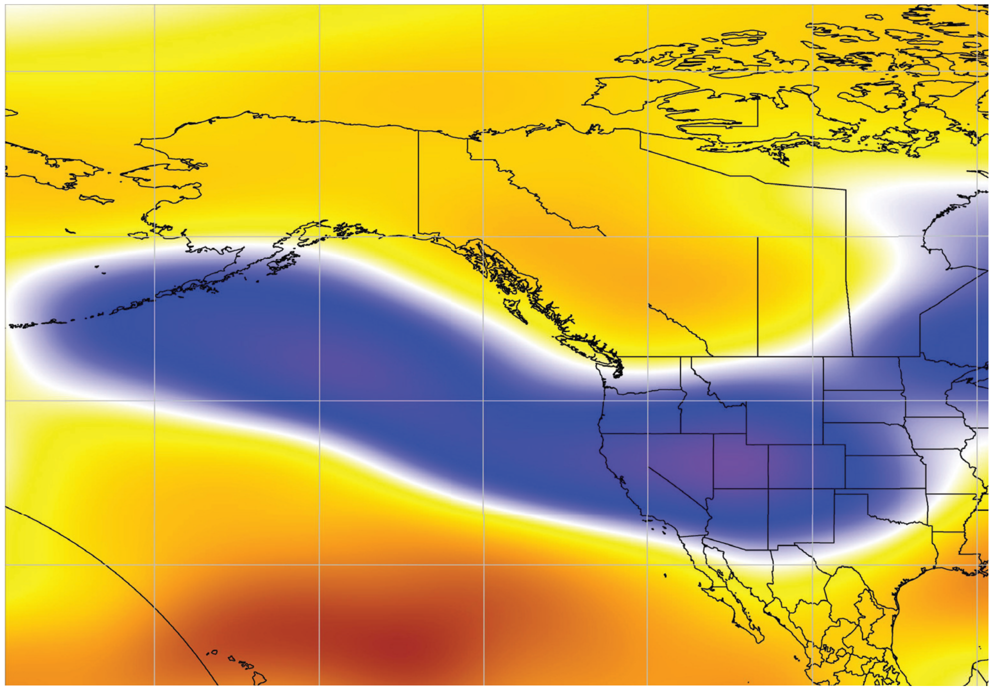

***Figure 2:*** Map showing the westerly wind speed anomaly at the 200 hPa pressure level (roughly the height of the jet stream) during spring and early summer 2011. Stronger than normal westerly jet stream winds are shown in blue hues. Anomalously weak winds are shown in orange shades. There are two important features of this map. The first shows stronger than normal westerly winds aimed just south of BC. The other is the anomalous dip in the jet stream centered over the western US. This indicates the prevalence of storms during the time period.
Data source: http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html

## Isn't it supposed to be getting warmer?

A common question that arises when weather does unexpected things is whether such patterns are a consequence of climate change. This question is difficult to answer because the attribution of the cause of a single cold season over western North America to climate change is very challenging. Recent research has shown that some extreme rainfall events and extremely hot summers have likely been influenced by our changing climate (Min et al. 2011; Zwiers et al. 2011) and that some recent heat-waves and cold snaps are unprecedented or are influenced by climate change (Barriopedro et al. 2011; Ouzeau et al. 2011). Both warm and cold record-breaking events will continue to occur in the warming climate, but with greater than expected frequency (under normal conditions) in the case of warm events, and vice-versa in the case of cold events. This has already been observed in the temperature record of the United States (Meehl et al., 2009) However, the anomalies in temperature and precipitation over British Columbia this past spring and summer fall well within the range of natural variability. This makes attributing these anomalies to climate change tenuous. Figure 3 shows how the spring 2011 season was situated among past springs going back to 1948. Although there were precipitation and temperature anomalies for all regions

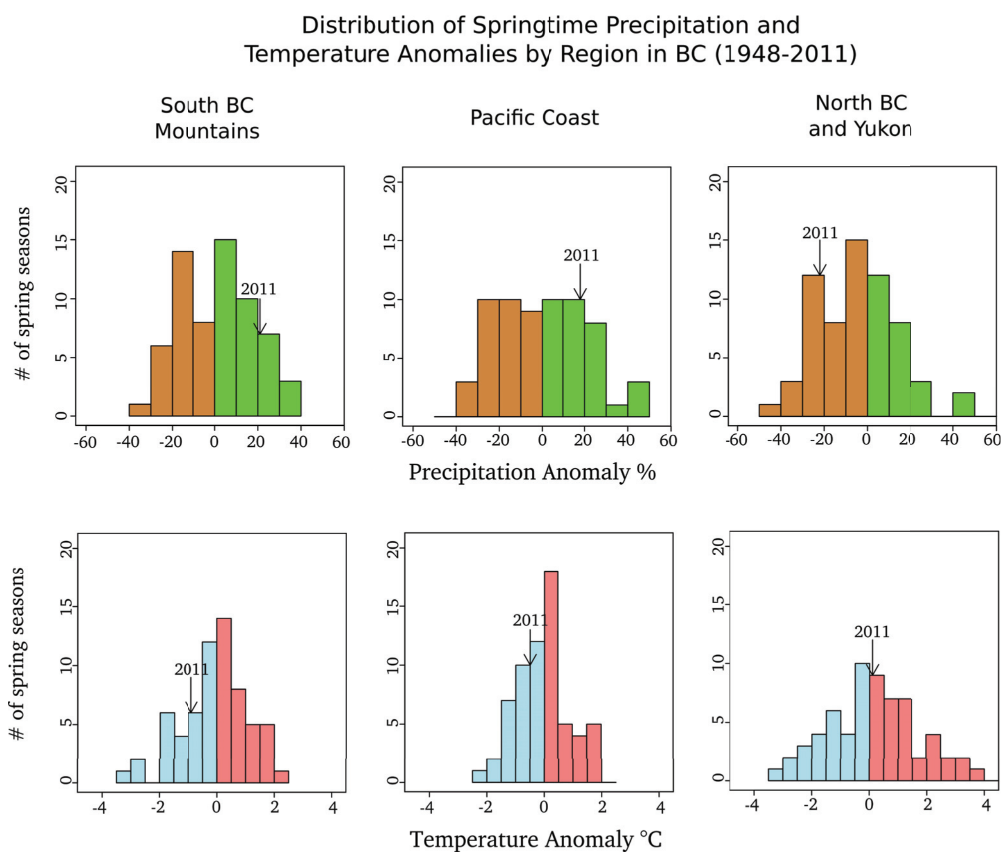


***Figure 3:*** Histograms of historical springtime temperature and seasonal mean precipitation anomalies. Temperature anomalies are shown in panels across the top with precipitation below. The anomalies are averaged over stations in the South BC Mountains (left), Pacific Coast (center), and North BC and Yukon (right). Data are courtesy Environment Canada (see Figure 1 for details).

(except temperature in Northern BC and Yukon), the figure indicates that none of the anomalies fall toward the tail of the distribution of observed anomalies. They all lie within one standard deviation of the mean anomaly, a standard criterion for determining whether a given climate condition is part of normal variability.

One explanation for why this past spring felt so cold is that climate change may have affected our perceptions of warm or cold seasons. These seasons may have appeared colder because of the appearance of warmer springs and summers in recent years. Looking again at Figure 1, we see that in three out of the last four years spring has been similarly cool, but for five years before that springtime was unusually warm, including the warmest spring on record for southern BC in 2005. There is a clear trend toward warmer springtime conditions so perhaps the perception of a normal spring has been skewed. Furthermore, research by Ozeau et al. (2011) suggests that cold seasons in the present day could have been record-setting if not for the influence of anthropogenic climate warming. It is possible that this past spring would have been much cooler if not for climate warming.

## Looking ahead

For the remainder of the BC summer and into the fall the seasonal climate forecast from Environment Canada is for cool temperatures across much of the province. For precipitation, the forecast is split on a north-south axis suggesting drier than normal conditions east of the Coast Mountains and near normal conditions to the west. These forecasts can be accessed at http://www.weatheroffice.gc.ca/saisons/index_e.html. The effects of last winter's La Niña had faded by August. However, there is an increasing chance of a resurgence of La Niña during winter 2011/2012. Current estimates are for an even chance of a second consecutive La Niña this coming winter and its attendant cool conditions over the province.

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