Climate Variability in the Instrumental Record for the Witsuwit'en Language Area

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Introduction

This section examines the instrumental record of climate observations from the Smithers, British Columbia area, the commercial hub of the Witsuwit'en Language area, for evidence of climate variability. Instrumental records specifically refer to a series of direct measurements of atmospheric variables such as temperature, precipitation or snow depth. In particular, the variability of temperatures during the winter and snow melt during the spring are examined for long term trends.

Weather, Climate, Climate Variability and Climate Change

The terms "weather" and "climate" are sometimes regarded as synonyms outside of specialist literature or technical jargon, so here we make clear exactly how the terms are used here.

Strictly, "weather" is the state of the atmosphere at a given specific place and time, and may include physical variables such as temperature, pressure, wind speed or direction and precipitation rate. In practice, the term is also used to describe atmospheric conditions over periods ranging up to perhaps a month. "Climate" is, essentially, the statistics of weather over long time periods (generally a decade or more). Descriptive climate information often presents information such as normals[1] or extremes, but can also describe the frequency of unusual weather events. Outside of the tropics, of order three decades of weather data are required to produce a statistically robust set of climate variable statistics. The terminology used to describe atmospheric conditions time scales intermediate between weather (in days) and climate (in decades), is inconsistent, although depending upon context "seasonal" or "annual" are used.

[1] "Normals" are derived from statistical measures such as the mean or median of a given data set, but may also include adjustments for changes in observing location or practices or changes in instrumentations.

The terms “climate variability” and “climate change” are not also used in a consistent way, either in specialist literature or in general discourse. Climate variability is used here to refer to statistically significant change in a climate variable that occurs on the time scales on the order of one to two decades; that is, about, or slightly less than the time scale necessary to describe climate. Climate change refers to changes over the order of century or more.[2] Variability between the weather and climate scales is frequently termed “inter-annual” or “inter-seasonal variability”, and many geophysical processes can modulate atmospheric conditions over this scale. These include quasi-regular variations in the sea surface temperatures of the equatorial Pacific Ocean (the El Niño Southern Oscillation (ENSO), the term for the underlying oceanic variation that gives rise to the well known El Niño and La Niña patterns of equatorial Pacific Ocean sea surface temperatures) and rare large volcanic eruptions (especially when occurring at low latitudes).

Physical Drivers of Climate Variability

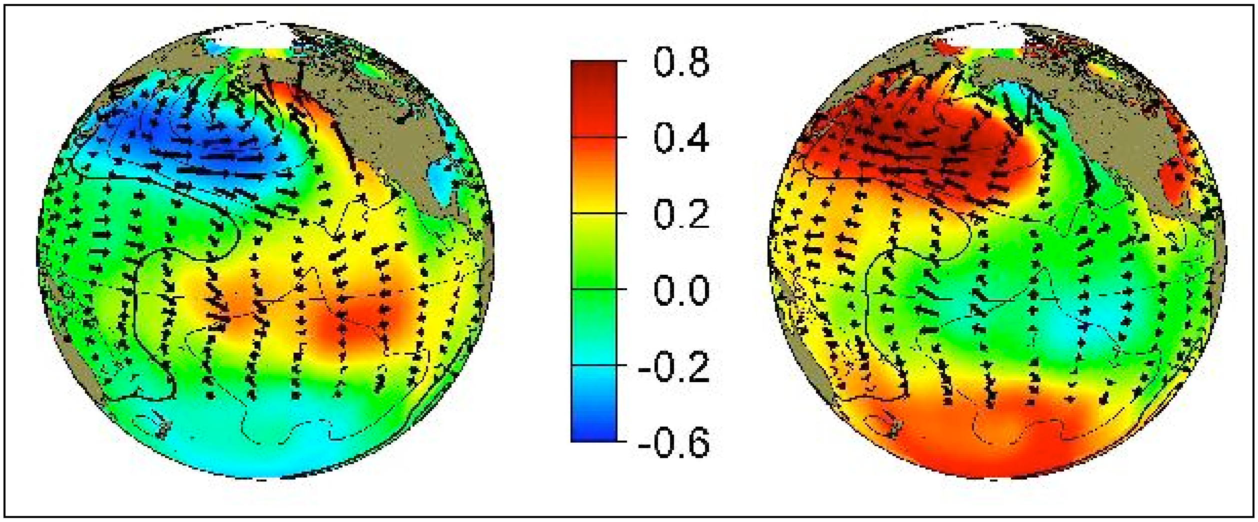
In the extra-tropics, the climate and climate variability of a particular area will be a reflection of the dominant hemispheric-scale circulation patterns. Dominant circulation patterns will in turn be influenced by many factors, with variations in oceanic circulations and sea-surface temperatures prominent. In northwestern North America, long term, large-scale fluctuations in sea surface temperatures in Pacific Ocean, now known as the Pacific Decadal Oscillation (PDO), are correlated with significant ecological and climatological variability in western North America. (Mantua, N.J. el. al. 1997).

The PDO is the name given to the apparently multi-decadal, quasi-cyclical variation in sea-surface temperatures in the north Pacific Ocean. The PDO is usually described as having two phases, a warm phase, when the northeastern Pacific sea-surface temperatures are warmer than normal, and a cold phase, when sea-surface temperatures in this same area are colder than normal. Sea-surface temperature departures from normal in the northcentral Pacific Ocean are of opposite sign, colder than normal during

[2] The term “climate change”, in current practice, is often used to imply change induced or amplified by anthropogenic forcing.

the warm phase and warmer than normal during the cold phase.[3] These patterns are illustrated in Figure 1 (from the University of Washington: http://jisao.washington.edu/pdo/)

Figure 1



Warm Phase Cold Phase

This pattern of sea-surface temperature distribution trends to favor increased storminess in the area with above normal temperatures, with concurrent impacts on favored atmospheric steering flow patterns downstream into northwestern North America. The flow pattern favors southerly flow aloft across northwest North America during the warm phase and northerly flow aloft during the cold phase.

The most recent PDO cycle commenced with a cold phase beginning in the mid 1940s and ending abruptly in the summer of 1976, followed by a warm phase that may have recently ended. However, it is apparent from the multi-century reconstructions of the PDO by both Biondi et. al. (2001) and MacDonald and Case (2005) that, if these reconstructions are even approximately correct, the relatively coherent 30 year phase length evident in the second half of the 20th century is not a regular feature of the PDO. Rather, there are multi-decadal periods (or even centuries in the reconstruction by and MacDonald and Case) that exhibit only small variations in the PDO.

[3] As clearly seen in Figure 1, from a basin-wide perspective the phases of the PDO are mis-named, with much of the North Pacific cooler (warmer) than normal in the warm (cold) phase.

Regional Climate and Climate Variability

Smithers, BC is located along the Bulkley River, a major tributary of the Skeena River, near 55N, 127W. Although Smithers is only about 200 km from the Pacific Ocean, multiple mountain ranges west of the Bulkley valley, collectively the Coastal Mountains, present an important physical barrier to the moderating influences of the Pacific Ocean. As a result, temperatures in the Smithers area have a much greater annual variation and considerably less precipitation than nearby coastal locations. Precipitation is abundant year-round, though with a significant minima February through April. Although winter thaws are not uncommon, a durable snow cover is typically present from November into March or early April. Based on the widely used Köppen climate classification scheme,[4] the area has a Continental Subarctic climate (Köppen category Dfc).[5]

Previous studies have examined multi-decadal climate variability in western Canada, though these often have a hydrological focus, e.g. Whitfield et. al. 2010. Egginton 2005 analyses long term trends of a number of climate variables based on the instrumental record over the northern two thirds of British Columbia through 2003. She finds statistically significant winter warming during most of the 20th century on the Fraser Plateau, which includes the Smithers area. She also finds a significant correlation between PDO phases and mean annual temperatures at many locations in northern British Columbia, with warmer (colder) mean annual temperatures during positive (negative) phase of the PDO.

Data Sources and Assessment

Data for this study was downloaded from the government of Canada's online climate data portal (http://climate.weatheroffice.gc.ca/climateData/canada_e.html). The data have not been adjusted for changes in instrumentation, time of observation or other observing practices, changes in adjacent

[4] See e.g. Rohli and Vega 2007.

[5] This classification is based on the 1971-2000 normals for Smithers Airport. Based on this data, Smithers is on the cusp of the Continental Subarctic and the Warm Summer Continental climate categories; if the average temperature in September were 0.1º C higher, Smithers would fall into the Köppen Warm Summer Continental climate (Dfb) category.

landforms, etc. However, the data has been subjected to some quality control over the years by Environment Canada and its predecessors.[6]

Daily climate data is available for the greater Smithers area since June 6, 1922. Initially, daily climate observations were made near Telkwa, about 10 kilometers upriver from Smithers.[7] Over time, a number of climate stations in the Telkwa and Smithers area were operated in the region under the auspices of the Canadian government.[8] The only multi-decadal observational time series are from the original Telkwa station, which made observations for almost 44 years, until March 1968, and at the Smithers Airport, which commenced weather and climate observations in June, 1942, with observations continuing to the present. For this study, data from 1922 through 1942 is from the Telkwa climate site; 1943 through 2009 data is from the Smithers Airport, which is about 5 kilometers north of Smithers community center. Following standard practice, monthly (seasonal) mean temperatures are calculated as the mean of the monthly (seasonal) mean daily maximum temperature and monthly (seasonal) mean daily minimum temperature.

Climatological observations overlap at Telkwa and Smithers Airport for nearly 25 years. This long period of simultaneous observations allows for robust comparisons. The correlation of monthly mean temperatures for all months is extremely high, > 0.998, and nearly as high just for winter (December through February) at > 0.992. However, mean temperatures at Telkwa were consistently cooler than at the Smithers Airport; for individual winter months, the mean temperatures at Telkwa were lower than at Smithers more than 80 percent of the time, and the mean monthly temperatures at Telkwa were, on average, 0.5º C lower than Smithers Airport, across all months and just during winter. For the analytical purposes herein, the reported 1922-1942 mean monthly temperatures have been adjusted by this factor.

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[6] Per the statement by Environment Canada at: http://climate.weatheroffice.gc.ca/climateData/dataQuality_e.html

[7] The meta-data for this site, if accurate, places the observation location several kilometers east-southeast of Telkwa and 100 meters or more higher elevation than either Telkwa proper or the Smithers Airport.

[8] None of these sites have more than 11 years of data.

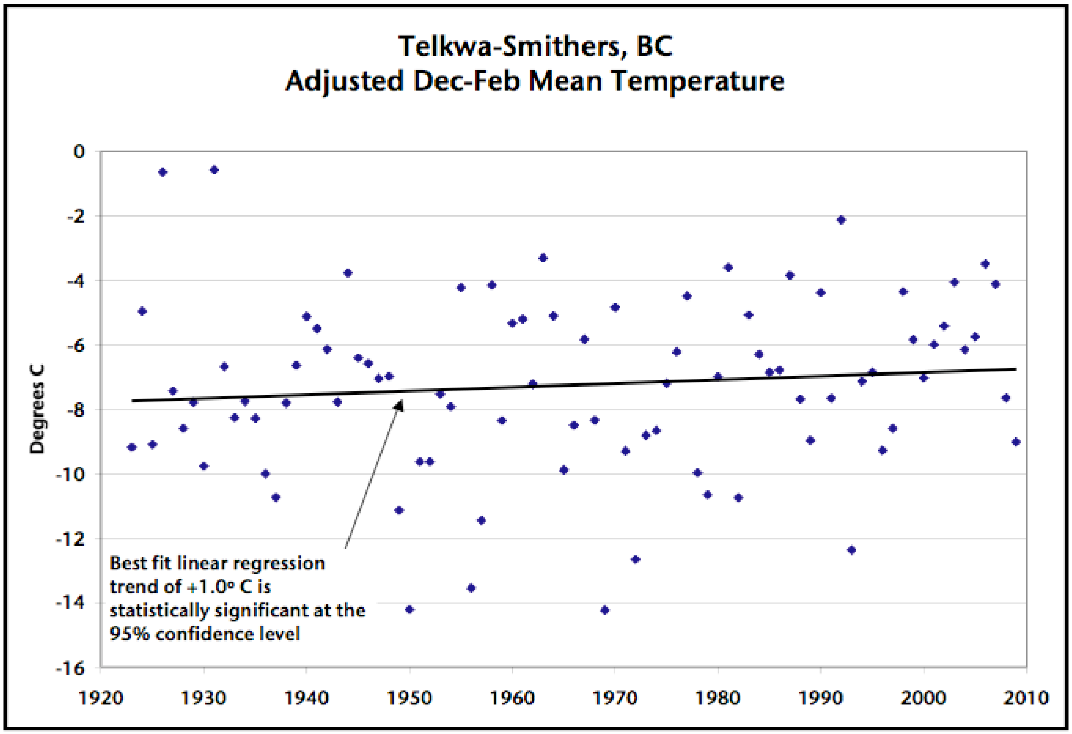
The daily climate data for Telkwa and Smithers is nearly complete except for late 1992 and most of 1993, when there is a sufficiently large amount of missing data to preclude direct calculation of monthly means. As a proxy, the monthly mean temperatures for Smithers for this period have been estimated by applying the standardized departure from normal during these months at Terrace, BC, about 90 kilometers west-southwest of Smithers, to the 1971-200 normal temperatures at Smithers.

Analyses of Cold Season Climate Variability

Since many comments by elders interviewed emphasized weather changes associated with the cold season, the analyses focused on that period. This is consistent with Egginton's finding that for the Fraser Plateau, there is a statistically significant increase in mean temperatures in winter and spring but not in summer or autumn.

A plot of mean winter temperatures is presented in Figure 2. For the full period of record, the adjusted winter mean temperature is –7.4º C with a standard deviation of 2.7º C. The warmest winters of record occurred in 1930-31, followed closely by the winter of 1925-26. The coldest winters were 1949-50 and 1968-69. The linear regression illustrates a slight (1.0º C) increase in the mean temperature over the 87 years of record; this is statistically significant at the 95% confidence level but not the 99% level. Again, this is consistent with results in Egginton 2005 for the region.

Figure 2



As noted above, in western North America the PDO is known to be correlated with large-scale variation in the favored flow regimes in the mid-troposphere. Therefore, mean winter temperatures were correlated against the PDO index for the same three months. For the entire period of record, December through February mean temperatures and the mean PDO index value for the same three months are fairly strongly correlated at 0.50. In order to facilitate comparison, normalized winter temperature departures from the full period of record mean temperature and the seasonal PDO index (which is, by definition, a normalized anomaly) are plotted in Figure 3.[9]

[9] Seasonal PDO values are calculated from the monthly PDO values from the University of Washington at http://jisao.washington.edu/pdo/PDO.latest

Figure 3

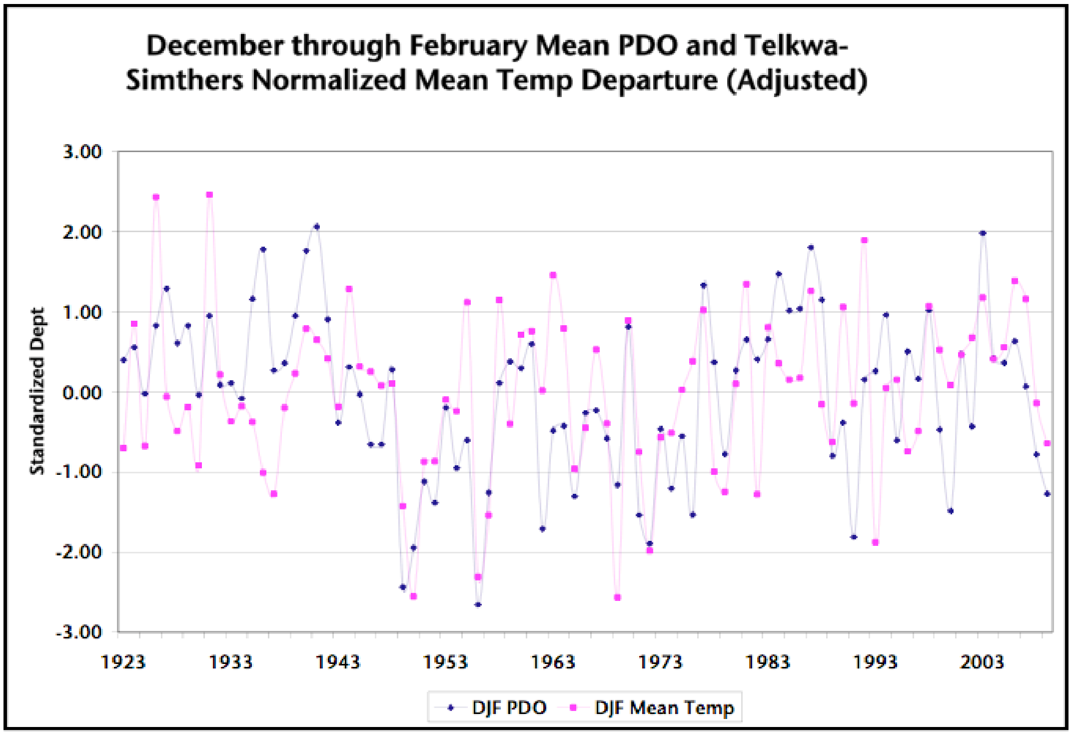
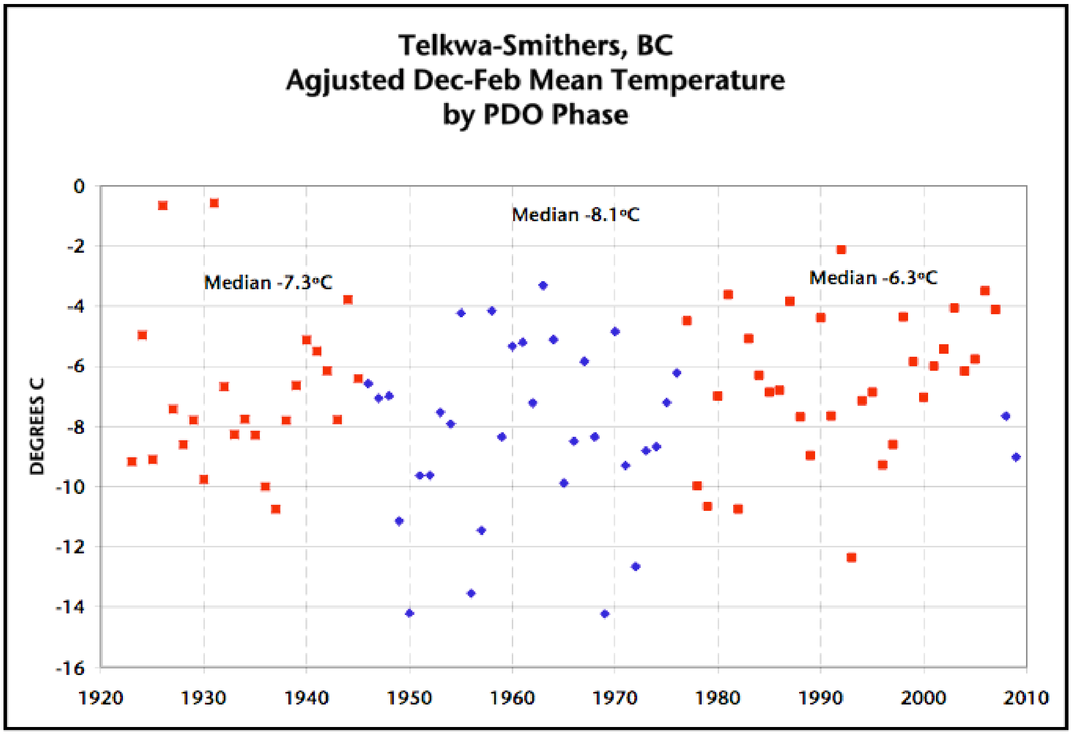


Figure 4 shows the same temperature data as in Figure 2, but with temperatures grouped by PDO phases. The mean temperature during the negative phase of the PDO (here 1946-47 through 1975-76) of –8.2º C is statistically significantly lower (at the 95% but not 99% confidence level) than the 1976-77 through 2006-07 warm phase mean of –6.5º C. Of likely significance for elder perception of climatic variation, note that the four coldest winters occurred through the negative phase of the PDO, during the 1950s through the early 1970s, when many of the Witsuwit'en elders interviewed for this project were young adults. Also note that these winters were colder than any in the instrumental record before the mid-1940s PDO phase shift. Additionally, the only occurrences of winter minimum temperatures of –40C or colder also occurred during this period (during January 1947, 1950 and 1972). However, and importantly, there is no statistically significant difference in the winter mean temperature for the two warm phases of the PDO for which there is data (1922-23 through 1945-56 and 1976-77 through 2006-07).

Figure 4

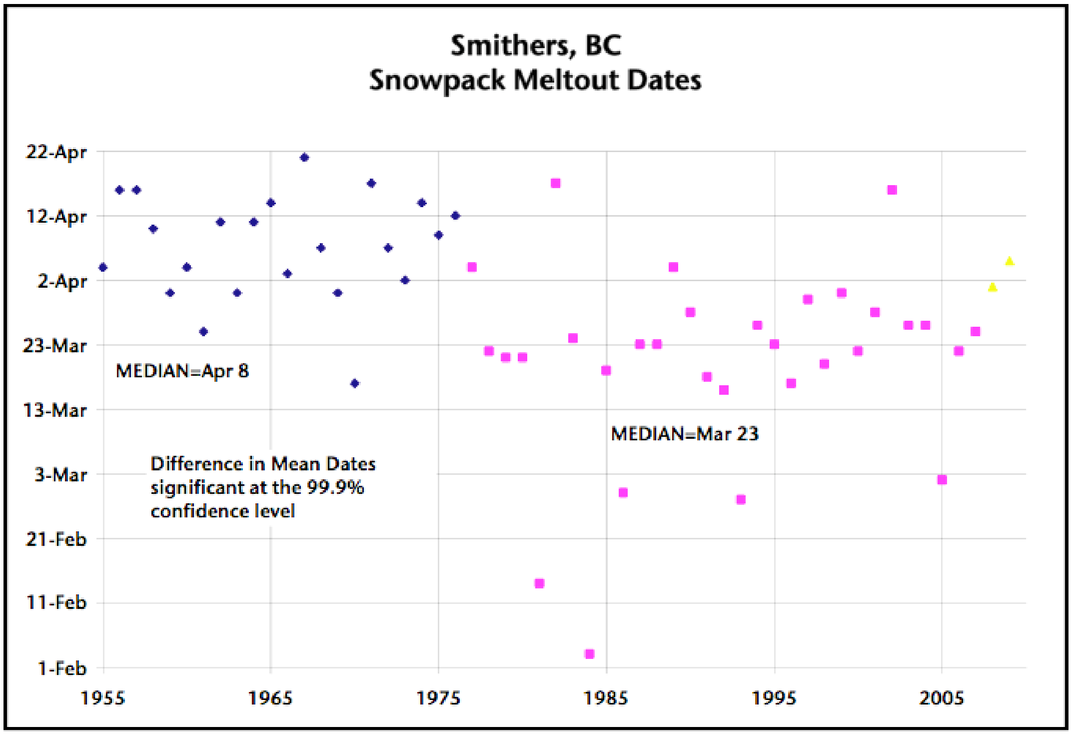


Daily snow depth data is available only since 1955, but in this case the change in the spring disappearance of the winter snowpack appears to be dramatic and unequivocal. Figure 5 plots the date of winter snowpack melt-out.[10] The median date of snowmelt in the 1977-2007 PDO warm phase snowmelt is more than two weeks earlier than the 1955-76 PDO cold phase median. In the 32 years since the 1976 PDO phase shift, the date of spring snowmelt has been as late as the <u>mean</u> 1955-76 melt-out date only twice. Unless there has been a significant local change systematically impacting the snow depth measurement at the Smithers Airport, this change is a dramatic and significant reduction in the length of

[10] Defined here as the latest date in the spring with a reported snow depth of 2cm and previous 5 days had ≥ 2cm of snow on the ground at the time of observation.

the snow cover season, as the date of establishment of the winter snow cover (median date November 19th) shows no trend at all over the period of record.

Figure 5



Conclusion

Winter temperatures in the Smithers area show a modest statistically significant increase over the full period of record, and winters during the 1946-1976 cold phase of the PDO were statistically significantly colder than the following warm phase. In addition, there has been a dramatic change in the melt out of the winter snowpack across the PDO shift in 1976. Since most of today's elders' life experiences came after the early 20th century warm phase of the PDO, the relatively cold winters experienced during the PDO cold phase may contribute to perceptions of weather and climate changes reported by Witsuwit'en elders interviewed for this project.

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