



# Statistical Homogenization of Temperature Data from the Williston Basin and Campbell River Regions of British Columbia

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Faron S. Anslow  
Yaqiong Wang

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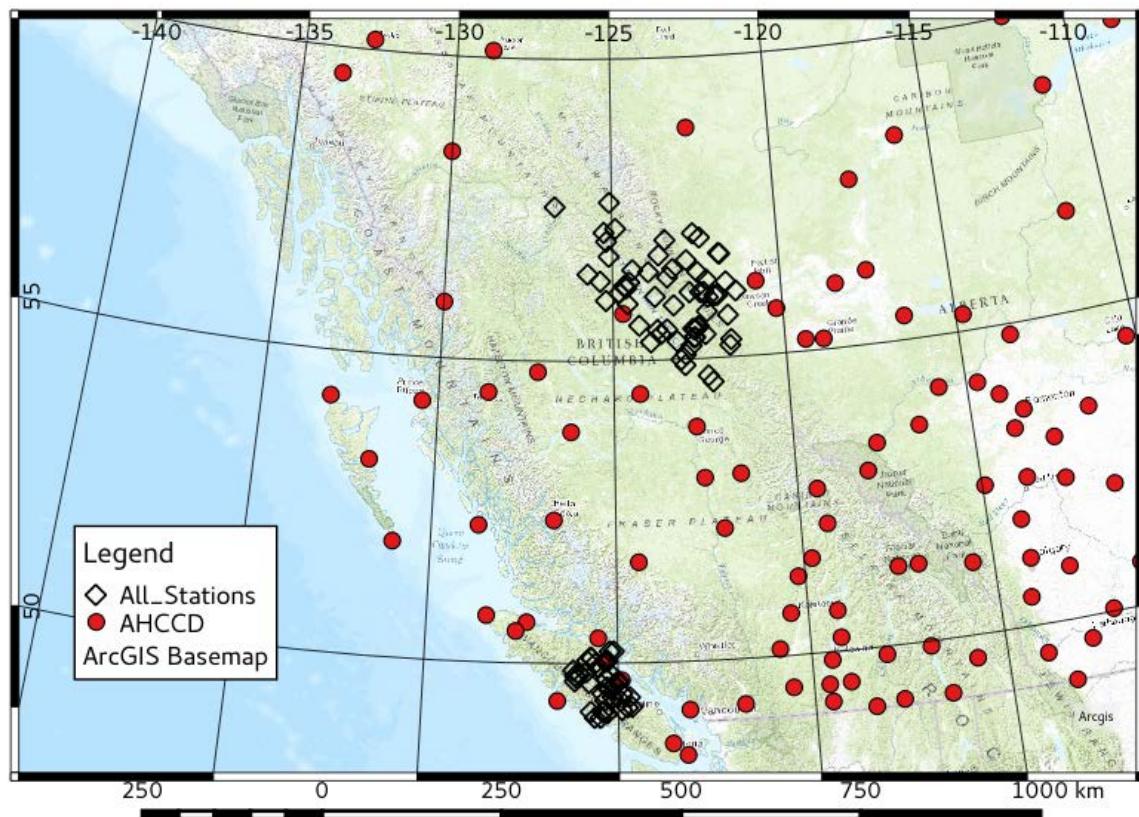


# **Executive Summary**

This document details the exploratory efforts to create a high quality, homogenized set of monthly mean of daily minimum and maximum temperatures for the Williston Basin and Campbell River regions of British Columbia. Data from BC Hydro, the Ministry of Transportation and Infrastructure, and the Ministry of Forests Lands and Natural Resource Operation Wildfire Management Branch are used. The data records are of various lengths, from as many as 50 years to as few as a single year. A set of quality control procedures is applied to the data and then the data are subject to a two step statistical homogenization process. The quality control work revealed that the data are of high quality overall. Inconsistencies were set as missing. Homogenization efforts revealed that fewer than 50% of stations contained any discontinuities with the data in the Williston region being of greater homogeneity than that in the Campbell River region. The outlook for homogenizing daily temperature and monthly precipitation totals is also discussed. Appendices detail station metadata as well as changepoint occurrence for each station. This report will be accompanied by an archive of the results of this project including the homogenized datasets.

# 1. Introduction

In the observation of weather variables it is very common for non-environmental factors to influence the observed data. These factors can include changes in instruments, changes in observing procedures, station relocation or gradual evolution of a station's surroundings among others. These issues can lead to inhomogeneities in climate data either as shifts in the mean, the introduction of trends, or alteration of the daily temperature range even as the mean temperature remains stationary. The inhomogeneities can subsequently cause inaccurate analysis of the climatic characteristics of a given location.

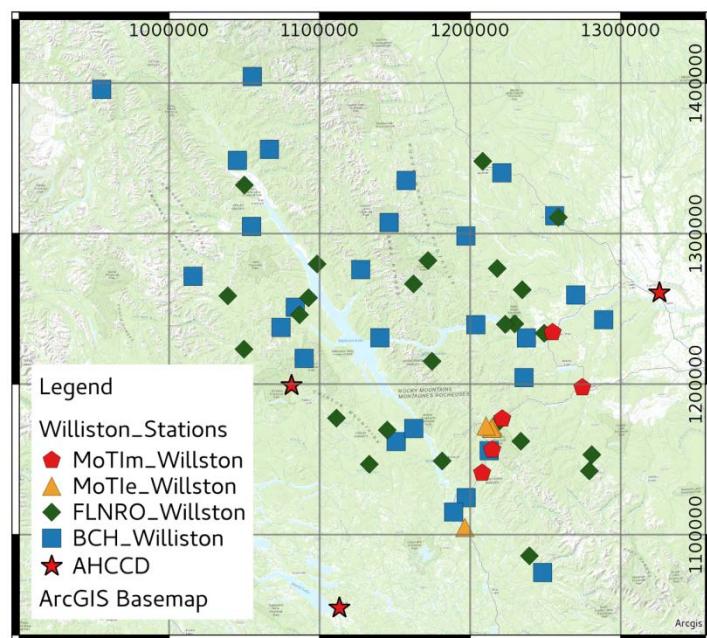


**Figure 1:** Map of British Columbia showing the locations of the stations under investigation in this work (black diamonds) and the Adjusted Homogenized Canadian Climate Data stations available for use as reference stations for homogenization work.

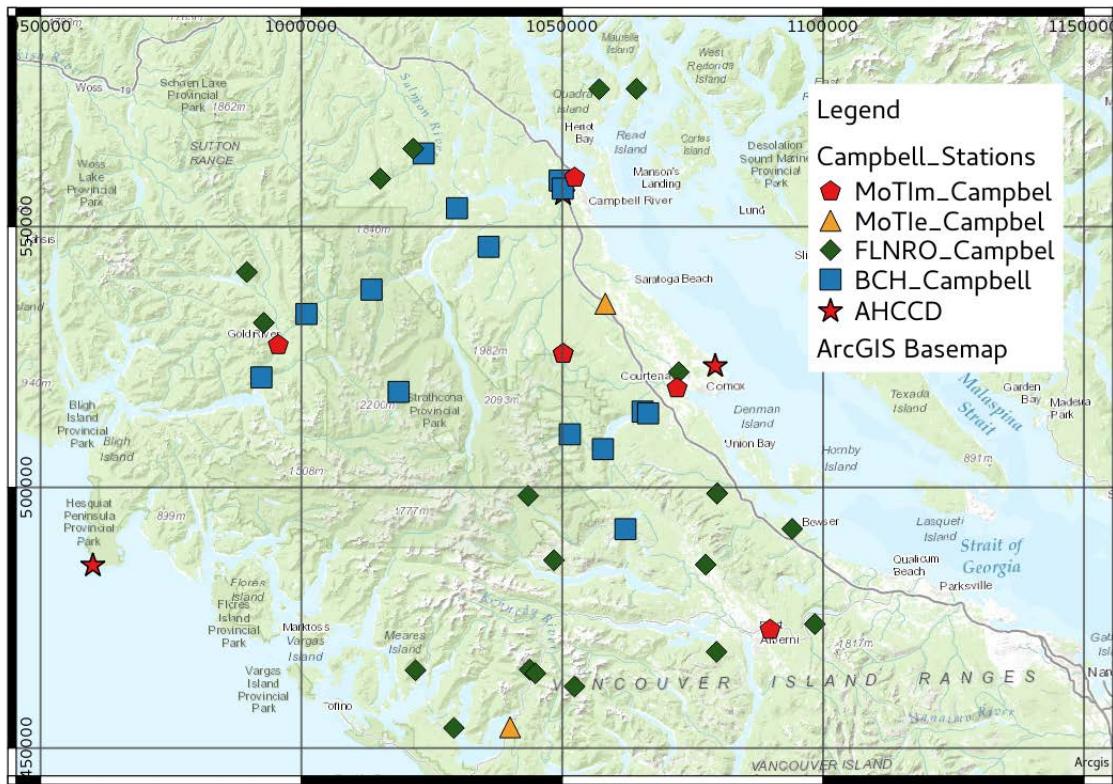
In Canada, Environment and Climate Change Canada (ECCC) has created the Adjusted Homogenized Canadian Climate Datasets (AHCCD) to improve data quality for climate analysis across Canada. The AHCCD data are high-quality and generally very long term with some records spanning more than 100 years. However, AHCCD data are somewhat limited in their availability in BC as shown in Fig. 1. ECCC focuses its monitoring on locations near population centres or along transportation corridors which leaves large areas of BC unobserved especially in the north and at high elevations. Because of the

Ministry of Environment's Climate Related Monitoring Program and the assembly of historical and ongoing weather observations that comprises the Provincial Climate Data Set, a large number of observing locations from numerous observing networks have records that span as much as the past 50 years. Thus, thousands of non-ECCC stations are available in British Columbia for homogenization. The need for creating more high quality temperature timeseries is great and driven by both research and practical use. In one study region in this project, the northeast of BC, the landscape includes mountainous regions which serve as water supply for uses such as hydropower and agriculture among others. These water resources will very likely change with changing climate which places emphasis on understanding recent climatic changes. That kind of analysis is most reliable with high quality homogenized data.

The objective of this project is to explore the potential for homogenization of temperature and precipitation observations in British Columbia. Our specific aim is to detect and adjust non-climatic shifts of monthly temperature records for 79 stations from three networks: BC Hydro, Ministry of Transportation and Infrastructure (MoTI) and Ministry of Forests Lands and Natural Resource Operations Wildfire Management Branch (FLNRO\_WMB). Efforts are focussed in two regions: the Williston Basin and Campbell River region. This report documents the preparation of the station data for homogenization, the homogenization techniques applied to the data, and the results of the homogenization work. Finally, we discuss the potential and challenges for homogenizing temperature at the daily time scale as well as applying homogenization techniques to precipitation data.



**Figure 2:** Map of the Williston Basin region indicating the stations analyzed in this project as well as the AHCCD stations nearby that were used as reference data for homogenization. Note that not all AHCCD stations relied upon in this region are presented on this map.



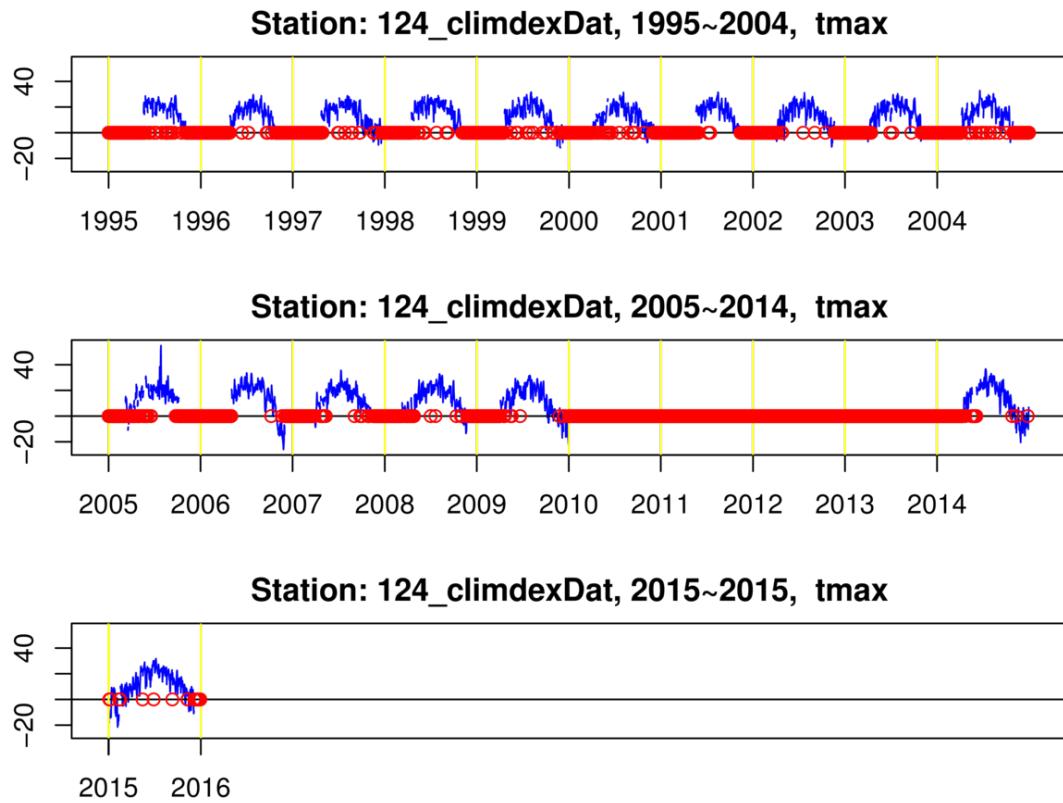
**Figure 3:** Map of the Campbell River region of Vancouver Island indicating the stations analyzed in this project as well as the AHCCD stations nearby that were used as reference data for homogenization. Note that not all AHCCD stations relied upon in this region are presented on this map.



## 2. Data and Techniques

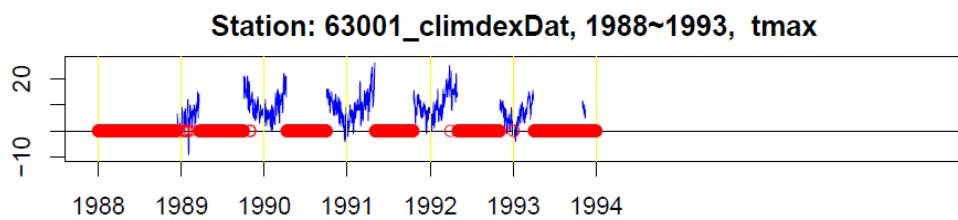
### 2.1 Data Description

Maximum and minimum temperature data from three networks were downloaded directly from PCIC data portal. Each network has its own temporal resolution and other characteristics reflecting the mission of the agency operating the network. For BC Hydro, there are 39 stations being tested, 25 stations in the Williston Basin and 14 stations in the Campbell River region. Maps of these regions are given in **Fig. 2** and **Fig. 3** for the Williston and the Campbell regions respectively. All BC Hydro data are stored in the data portal at daily temporal resolution with maximum and minimum temperatures. Twenty three stations are from the FLNRO WMB network, 12 of which are in the Williston region while the remaining 11 are in the Campbell. The FLNRO WMB data are stored hourly so were converted into daily minimum and maximum temperature. The Wildfire Management Branch's stations are primarily operated to support fire hazard analysis, fire prediction, and for fire suppression activities. Thus, these stations are maintained for summer observations and many do not have all-weather instrumentation for wintertime measurements. **Figure 4** gives a sample for a station in the Williston basin indicating that temperature is not observed during the winter and also showing an extended temporal gap in record from 2010 into 2014.



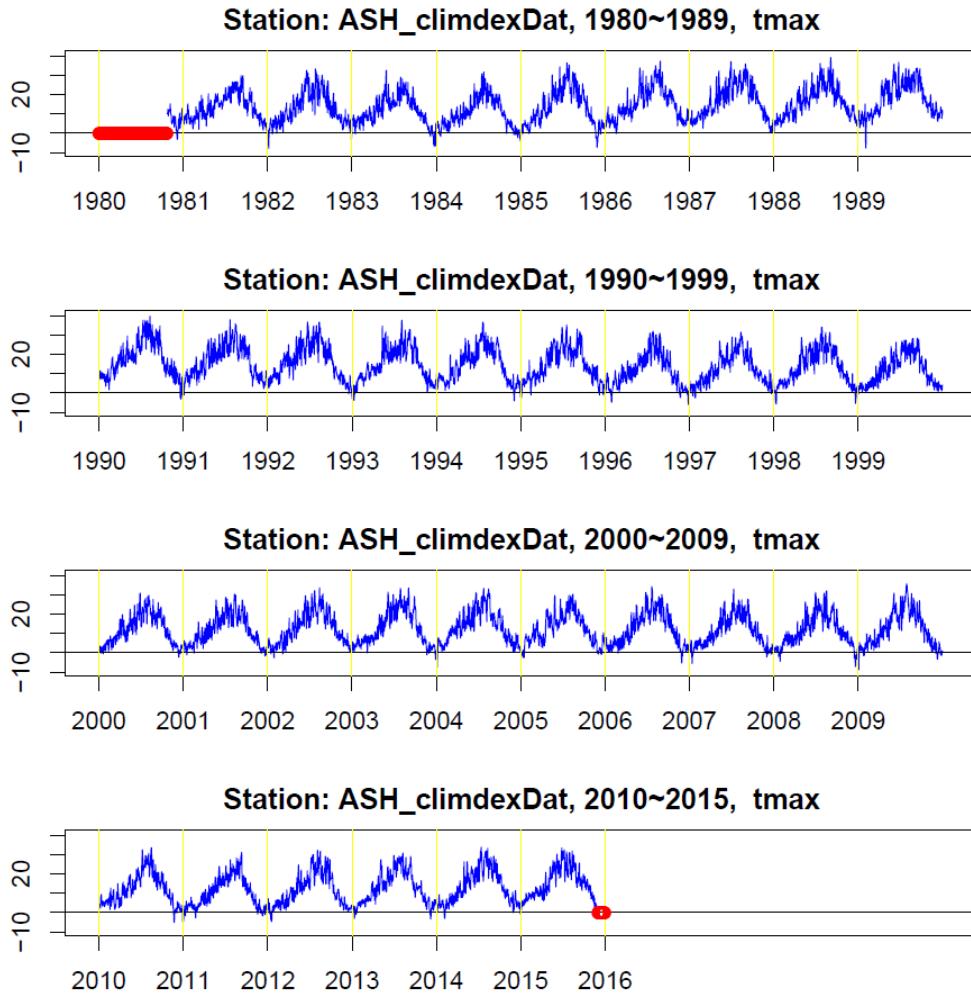
**Figure 4:** Sample daily maximum temperature record in the Williston Basin for station Graham (ID# 124) from the FLNRO WMB network showing the lack of wintertime observations at this station until recent years.

Seventeen stations are from MoTI with 9 in the Williston and 8 in the Campbell region. There are two sub-networks in the Ministry of Transportation dataset. The first is a manually observed, principally wintertime network of stations associated with winter road maintenance including avalanche control. This network is dubbed the MoTIm network throughout this report. Observations were made twice-daily with intervening minimum and maximum temperatures recorded at each observation time. To convert these to daily minimum and maximum temperatures, the minimum from either observation in a given day was used for that day's minimum temperature. For maximum temperature, the greatest value between the maximum from the day's afternoon observation and the maximum from the subsequent morning's observation was chosen. The second sub-network in the Ministry of Transportation and Infrastructure's dataset are auto-stations (henceforth the MoTle). These data are recorded hourly, so maximum and minimum temperatures for each day are used for further analysis. The MoTI's data are of greatest importance during the snow season for the purpose of monitoring road snow and ice conditions. Thus, the MoTI data are best maintained for winter. The MoTIm network does not include any observations for summer. This is exemplified in **Fig. 5**.



**Figure 5:** Sample daily maximum temperature record from the Campbell River region recorded at Port Albernie (ID# 63001) from the MoTle network showing the predominance of wintertime observations as well as the relatively short period of record.

In terms of average temporal coverage among the networks, BC Hydro's data has both the most continuous and the longest periods of record among the stations analyzed here. An example of a maximum temperature record from BC Hydro for station ASH is given in **Fig. 6** and shows complete data for more than 30 years from the early 1980s. The second longest records are from the FLNRO WMB network which sometimes have a period of record similar to BC Hydro's stations, but frequently these stations are missing data seasonally as exemplified in Fig. 2. MoTI typically has shorter records, but there are some stations with longer periods of record. Basic metadata for individual stations is given in Appendix A table A.1 for the Campbell River region and table A.2 for the Williston.



**Figure 6:** Sample daily maximum temperature record from the Campbell River region recorded at Elsie Lake Forebay (ID# ASH) from the BC Hydro network showing the continuity of the data as well as the overall long period of record for the station relative to other stations in this analysis.

As will be described in section 2.2.2, homogenized or other high quality reference data are essential to homogenizing station data. For this purpose we utilize the AHCCD dataset which is available here: <http://www.ec.gc.ca/dccha-ahccd/> (accessed March 16<sup>th</sup>, 2016). The homogenized Canadian monthly surface air temperature data include 338 Canadian locations, 54 of which are situated in British Columbia. Data from co-located observing sites, which were usually no more than 20km apart, were sometimes combined to create longer time series. In some instances, the observations of three or four stations were joined to form longer homogenized series (Vincent et al. 2012). The choice of AHCCD reference station was based solely on the distance between the target station for homogenization and the reference. We chose the three nearest AHCCD stations to serve as potential reference stations. Our assumption is that the AHCCD are “perfect” data meaning they do not contain inhomogeneities implying that any changepoints revealed in the difference between a target station and an AHCCD station arose due to a changepoint in the target station. With that in mind, our final selection of reference station (where one was needed) was that which yielded the minimal number of changepoints in the target station. This yielded the fewest changepoints which gives the smallest burden of proof that a set

changepoints is real rather than having arisen by statistical artefact. **Table 1** summarises the distance between AHCCD stations and the station locations for the data being homogenized. Among stations analyzed in the Campbell River region, reference stations were never more than 120 kilometres from the station being homogenized with a median distance of 61.3 kms. In the Williston, reference stations were typically further away due to the less dense AHCCD network in northeast BC. The median distance to a reference station was 146 km, but the maximal distance was quite large at 304.2 kms. The basic metadata for the AHCCD stations used in this project in both regions is given in Appendix A **table A.3**.

**Table 1:** Summary of AHCCD station availability and proximity to the stations undergoing homogenization.

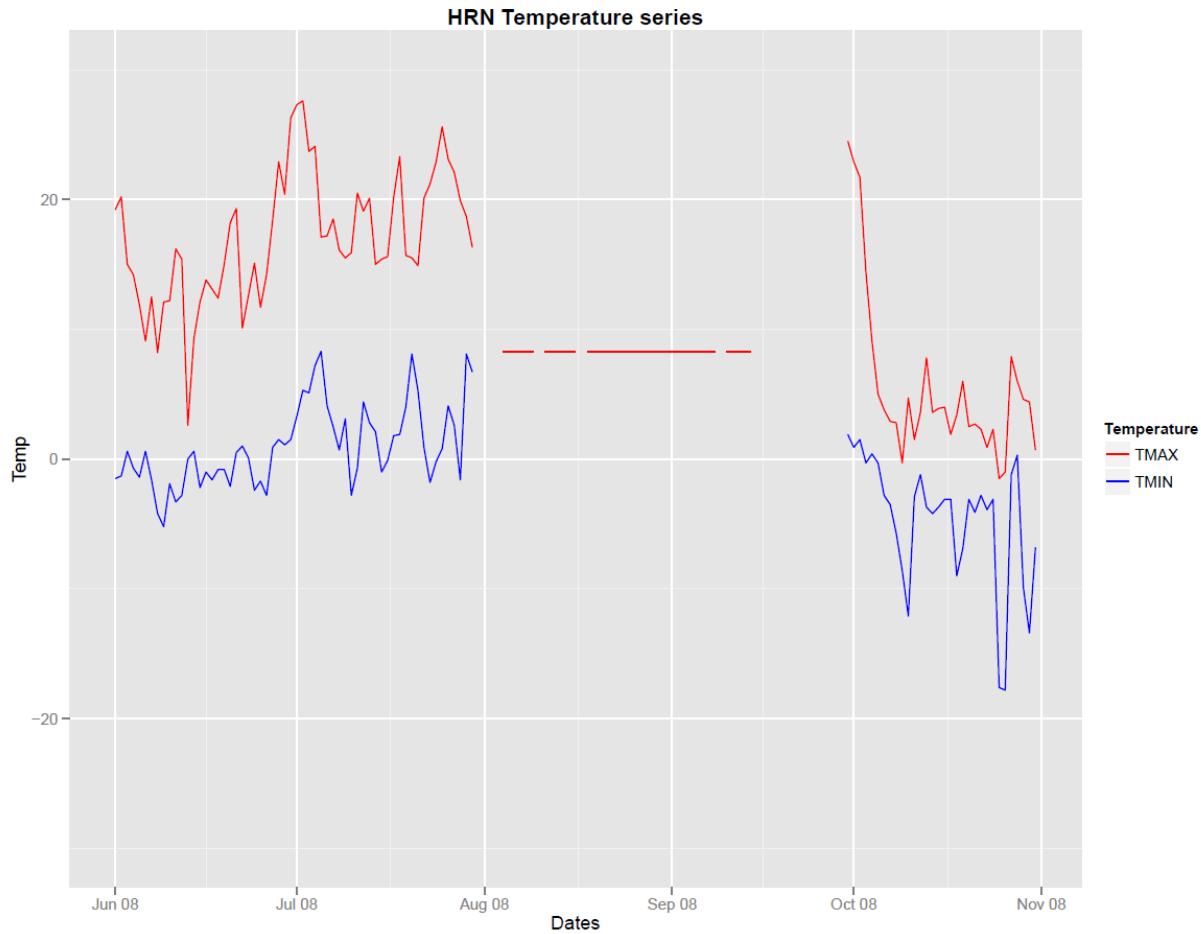
Region	# Reference Stations	Min. Station Distance	Max. Station Distance	Median Station Distance
Campbell River	6	1.03 km	117.5 km	61.3 km
Williston Basin	11	19.9 km	304.2 km	146.0 km

## 2.2 Homogenization Procedures for monthly temperature datasets

### 2.2.1 Quality control

Data homogenization, especially using purely statistical techniques, demands well-quality controlled data. Data with either outliers or so-called “sticky sensor” values (where a broken temperature sensor records the same value for long periods of time; **Fig. 7** gives an example) will hinder statistical homogenization algorithms from properly detecting changepoints because they are capable of altering the data mean if the errors are persistent. For example, one or more outliers toward higher than realistic values could cause detection of a change-point in the data even though there was no long-term systematic changes to the station or surroundings that may be supported by metadata which are the types of inhomogeneities that we would like to detect. Both quality control related issues are detectable with simple procedures that can then make the data more suitable for detecting statistical changepoints.

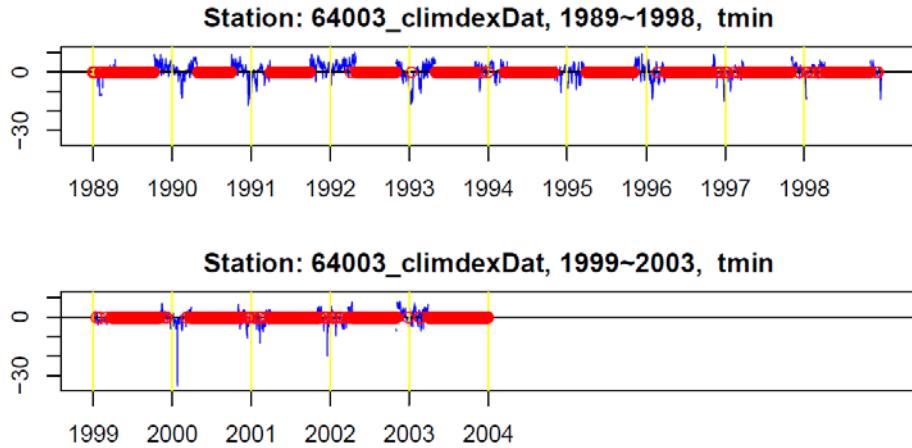
For this work, we applied single station quality control (single station meaning comparisons with nearby stations were not used to detect outlier data) and tested for statistical outliers in Tmin, Tmax and daily temperature range. We also performed so-called “sanity checks” and flag data in which the expectation that  $T_{\text{max}} > T_{\text{min}}$  is not met. This includes flagging data where  $T_{\text{min}} = T_{\text{max}}$ .



**Figure 7:** An example of station data with a “sticky sensor” from the Williston Basin at Horn Creek (ID# HRN) operated by BC Hydro. The data show a more than month-long period where  $T_{\min} = T_{\max} = 8.3^{\circ}\text{C}$ .

To perform this work, we utilized the RClimate package developed for the ETCCDI (Expert Team on Climate Change Detection and Indices). This software is designed to calculate extremes indices but also contains a set of data quality control functions to perform the work needed for this project. We modified the quality control component to improve the detection of outliers using more robust statistics based on methods detailed in Hoaglin *et al.* (1983). The detection of outliers relies on the estimation of the variance of data on a given day of the year for all years in the record. Before our modifications, the RClimate package estimated this using the standard deviation from all of the years available for the day of year of interest. This suffers from two problems. First, even if a given record has numerous years of data, the number of observations corresponding to the day of year of interest will be less than or equal to the number of years of record (less than when there are gaps in the data). Even with complete records, this will be a small sample with no more than  $\sim 50$  observations in the data analyzed here and frequently much fewer. The standard deviation is a better estimate of the true variability of the data when the sample size is large. A more standard practice is to compute this value using a window surrounding the day of interest. Thus introducing a windowed approach increases the sample size of climatologically similar data and thus allows a better estimation of the true variance in the data. The

second issue is that the standard deviation is strongly influenced by the presence of the outliers themselves so in cases where large outliers exist in the data, the computed standard deviation will be large and an outlier is less likely to be flagged. To correct the problem of small sample size, we introduced a 15-day window centred about the day of interest for estimating the variance for the given day of the year. To circumvent the problems of using standard deviation on potentially error-prone data, we introduced an improved method for estimating variance that is highly resistant to outliers (Lanzante, 1996; Hoaglin *et al.* 1983).



**Figure 8:** Sample daily minimum temperature record from the Campbell River region at Gold River (ID# 64003) from the MoTle network indicating the occurrence of an extreme low outlier early in year 2000. This may have arisen from a station maintenance visit in which data was logged during a sensor change.

**Table 2:** Sample data from the MoTl Gold River station (ID# 64003) showing the occurrence of a tmin outlier and two daily temperature range (DTR) outliers.

Date	Tmax Low	Tmax Up	Tmax Low	Tmin Low	Tmin Up	Tmin Up	DTR Low	DTR Up	DTR Up
2000/01/26	-12.54	1.5	19.23	-23.73	<b>-35</b>	22.59	-14.77	<b>36.5</b>	23.15
2001/12/19	-11.83	-1.5	17.12	-22.54	-20	20.97	-9.24	<b>18.5</b>	15.86

The checks for Tmin exceeding Tmax or Tmin equalling Tmax are straightforward as described. Outlier checks involve first computing the daily climatology and estimated standard deviation based on the entire Tmin or Tmax record. From this, anomalies are calculated for each daily observation. A value will be flagged if the anomaly is more than a set number of standard deviation units from the mean for the day. This same procedure is performed for the daily temperature range. Such flagging requires a parameter reflecting the number of standard deviations from the mean that are allowed before data is considered invalid. For this we use six standard deviations. An example of the results of this flagging are shown in **Fig. 8** and in **Table 2**. **Figure 8** shows a timeseries of daily minimum temperature for a station in the Campbell River region with a prominent negative outlier in January of 2000. **Table 2** shows the QC

results for this observation and indicates that the allowable range is for minimum temperatures equal to or above -23.73 °C. The value -35 °C clearly violates this range. The issue propagates to the daily temperature range (“DTR” in the table) which shows a value far exceeding the allowable range.

The requirement that daily minimum temperature be lower than the maximum temperature is strict and days that violate this rule are set to missing for both minimum and maximum temperature. For the range checks, flagged stations were reviewed manually. Upon visual assessment, some instances of these rules being violated were allowed to remain in the data because it was judged that the outliers were meteorologically plausible. The results from the quality control work are given in section 3.1.

## 2.2.2 Homogenization

Numerous techniques have been developed for homogenization. For example, one of the most widely used, and seminal, techniques is the standard normal homogeneity test (SNHT) developed by Alexandersson (1986). SNHT is a likelihood ratio technique which assumes that the tested data is normally distributed and with no trend. It locates the time period where a single changepoint is most likely to exist. Another example technique is the Automated Homogenization Algorithm which is based on the pairwise comparison of monthly temperature series (Menne & Williams, 2007). The algorithm is designed to detect changepoints in the pairwise difference series between the record of interest and neighboring stations. A few studies have performed comparisons among techniques for their ability to detect inhomogeneities in temperature data (Ducre-Robitaille et al., 2003; Reeves et al., 2007; Venema et al., 2012).

In the present study, metadata guiding the detection of changepoints is limited or non-existent. In the case of the detection of undocumented mean shifts, a reliable statistical test is needed. For this, we chose to use RHTestV4 for the detection and adjustment of multiple non-climatic shifts. RHTestV4 is an R-based open-source software package, along with a user manual, developed by researchers participating in the ETCCDI. The RHTestV4 software contains multiple tools for changepoint detection and homogenization. For this work, we utilize two algorithms: the Penalized Maximal T test (PMT) and the Penalized Maximal F test (PMF) for changepoint detection. Both of these use Quantile-Matching (QM) to make adjustments. (Wang et al. 2007, Wang 2008a, Wang 2008b).

The techniques implemented in RHTestV4 are suitable for the monthly temperature datasets under analysis in this study. The statistical underpinnings of these tests require data that have a Gaussian distribution, which monthly temperature anomalies typically have although we note that this was not tested here. The method operates on a month-by-month basis such that data for all years of a given month are homogenized separately from the other months. The final analysis looks for common year changepoints among the months’ timeseries. The procedure may also be carried out on annual data. These procedures are iterative in that once an initial pass is done, the remaining segments that don’t have changepoints are tested until a maximum number of changepoints is revealed. These are then pruned by their statistical significance until a final set of changepoints is obtained. Application of the changepoint detection algorithms yields so-called Type-0 and Type-1 changepoints which are distinguished by the statistical confidence in a given changepoint. Type-0 changepoints are those with

low confidence and, lacking supporting metadata, should be disregarded. Type-1 changepoints are those with high confidence and are less likely to be statistically spurious. Throughout the homogenization, a confidence level of 95% was used. The potential for generating homogenized daily temperature and monthly homogenized precipitation datasets using the other tools in the RHTestV4 package will be discussed in Section 4.

### 2.2.2.1 The Penalized Maximal F Test

The penalized maximal F (PMF) test developed by Wang (2008b) and implemented in RHTestV4 is a statistical test that may be used for detecting undocumented mean shifts in time series that may have a linear trend and where reference data are not available. The approach accounts for lag-1 autocorrelation which is important for data in British Columbia where the Pacific Ocean provides mechanisms for autoregressive characteristics in observed data, especially between months in winter. Our focus here is detecting the mean shifts although non-climatic shifts might include mean or variance or both. By comparing the statistical characteristics (including the mean and variance) of data before and after each point in the time series, locations where the difference is greatest are marked. Once the first change is identified, subsequent passes do the same on the individual segments.

The PMF test was developed to address the observation that the common-trend two phase regression model based unpenalized maximal F test has a higher false alarm rate than the expectation determined by the chosen confidence interval for points near the ends of the series and lower values for points between either of the ends and the middle of the series. The result of this error is that the method could more frequently declare changepoints near the ends of a homogeneous series that are not real or could underreport changepoints at the intermediate portions of the timeseries. The penalized portion of the PMF test is an empirical adjustment developed to correct this tendency (Wang 2008a & 2008b).

### 2.2.2.2 The Penalized Maximal T Test

As implemented in the RHTestV4 package, the penalized maximal T test ( Wang et al. 2007; PMT) is used for detecting undocumented shifts in time series with a Gaussian distribution, but unlike the PMF test, the PMT test cannot accurately detect changepoints in trended data. However, when applying the PMT algorithm with the use of reference series the effects of trends are largely eliminated because the reference series, if nearby and highly correlated, should have a trend similar to that of the data being analyzed. The PMT test is applied to the time series of differences between base series and reference series at the monthly level in our work. Similar to the PMF test, this statistical test looks for the position of breaks in a segment and marks those that are most probable. Also similar to the PMF test, the PMT test incorporates an empirical correction for the greater likelihood of detecting changepoints at the beginning and ends of timeseries which contrasts with non-penalized statistical tests (such as SNHT). The PMT prevents the situation that more changepoints are declared near the ends of a timeseries than would be expected at a given confidence interval. Lag-1 autocorrelation is accounted for in the PMT as well. in addition to the test on the base minus reference series, a multi-phase regression (MPR) model with a common trend is fitted to the anomalies of the base series to get the most probable estimates of the shifts using the base series alone. The PMT implemented in

RHTestV4 outputs adjusted data using the base series alone as well as the adjustments calculated using the reference data. This allows corroboration between changepoints detected with reference data and those detected with the stand-alone dataset.

### 2.2.2.3 Application of the Homogenization Tests

The quality controlled daily data were converted into monthly average of daily maximum (TMAX) and minimum (TMIN) temperature. We first run TMAX and TMIN from all stations (79 stations) through the PMF test without reference series. The application of each changepoint test generates a list of potential changepoints (if any are detected) and their associated level of statistical significance. Changepoints that are detected with low confidence are termed type-0 and must be rejected unless supporting metadata are available to indicate that a change was likely. At higher levels of confidence, type-1 changepoints are declared, which are more likely to be valid and thus are less dependent on supporting metadata for confirmation. In all cases metadata is extremely valuable for homogenization work, and is useful for changepoints detected at any statistical level or even guiding the changepoint detection itself. The PMF test is applied iteratively wherein low-significance changepoints are eliminated and then the test is repeated. This cycle eventually yields a set of changepoints that are all statistically significant at the chosen level. We note that PMF detects changes in data with a trend but frequently the handling of the trend in the adjusted data yielded very strongly trended output which we have low confidence in. Because of this, we use the PMF test only as a screening tool to warrant further investigation for changepoints using reference data.

After this first round of detection using the PMF test, if a changepoint is discovered, the station is subject to further testing using the PMT test with a reference temperature series from the AHCCD. We chose the nearest three stations from the AHCCD to serve as potential reference stations for the base time series being tested. The procedure for applying the PMT test with reference data is similar to that with the PMF test in that changepoints that are identified with low statistical confidence are rejected and the PMT test is repeated until this iteration yields a set of changepoints that are all statistically significant. Time series that have no Type-1 changepoints can be declared to be homogenous at this point at the chosen level of statistical significance.

The output from the homogenization tests and adjustments where they were needed were compiled on a station-by-station basis with the region/network organization preserved. This organization is detailed in Appendix C. The process of applying the PMF and PMT tests yields plots of the base data and any changepoints fitted to that data. An example of the output plots from application of the PMT test with a reference dataset is given in [Fig. 9](#). In that particular case, two changepoints were detected in both the base minus reference timeseries as well as the base timeseries alone. This indicates that the detected changepoints arose from the data in question alone and are not spurious changepoints introduced by the reference series. In some instances, the PMT test could not be applied even when a changepoint was indicated by the PMF test. This happens because the PMT test has more stringent requirements for completeness and length of record while the PMF test is more liberal. These instances are noted in Appendix tables B.1 and B.2 and we have taken the data adjusted using the PMF test as the adjusted data.



# 3. Results

## 3.1 Quality Control Results

A simple network-level summary of the quality control efforts is provided in **Table 3**. Although the numbers of stations reporting any errors is high, this count does not indicate that the data are of poor quality in light of these tests. For any given station, there are typically a very small percentage of observations that are flagged as invalid or outliers. In fact, it's surprising that there are some stations with no invalid data for their record. This may be a result of the quality control that each network's data undergoes before it is ingested into their databases. Furthermore, the zero-rate of invalid data for the MoTIm and MoTle data arose because those stations' maximum and minimum temperatures were computed from hourly data which enforced the proper relationship between maximum and minimum temperature.

**Table 3:** Network-level summary of quality control results for stations in the Williston and Campbell regions indicating the numbers of stations with occurrence of errors in the sanity and outlier checks.

Williston	Number of stations with any Tmin >= Tmax	Number of stations with any outlier failures
BC Hydro	21/25	21/25
MoTIm	0/5	4/5
MoTle	0/4	2/4
FLNRO_WMB	4/12	4/12
Campbell		
BCHydro	11/14	11/14
MoTIm	0/6	3/6
MoTle	0/2	0/2
FLNRO_WMB	3/11	7/11

The most pernicious issue is the occurrence of “sticky sensor” results for one station in the BC Hydro network and multiple stations in the FLNRO WMB network especially in the Williston basin. This issue is known within the network and typically occurred when temperatures fell below -20 °C. Due to datalogger programming issues, temperatures below that threshold were set to -20 °C, so during cold snaps, that temperature would be recorded continuously. Because the network's operational mandate centres on summer weather, this issue was not prioritized for update. We have set these data to NA for

the homogenization efforts. More detailed results of the quality control efforts for each station including which observations failed tests and plots of the variables are contained in the RClimdex output folders that will accompany this report.

## 3.2 Homogenization Results

After applying the changepoint detection tests as described in section 2.2.2 we find that six stations were too short for application of any test for homogeneity. These stations have ID's of 539, 839 and 960 in the Campbell region from the FLNRO WMB network and station 1030 in the Williston Basin region from the FLNRO WMB network and stations 43126 and 43127 in Williston Basin from the MoTle network. An additional four stations had records that were too short for testing with the PMT test. The PMT test requires ten years of observations for all months represented in the data set. It's capable of homogenizing seasonal data as long as the seasonal coverage is consistent from year to year.

**Table 4:** Network-level summary of homogenization results for stations in the Williston and Campbell regions indicating the number of stations with changepoints in maximum temperature separately from those in minimum temperature.

Williston	# of stations with Tmax Changepoints	# of stations with Tmin Changepoints
BC Hydro	5/25	3/25
MoTIm	1/5	0/5
MoTle	0/4	0/4
FLNRO WMB	0/12	2/12
Campbell		
BC Hydro	11/14	10/14
MoTIm	0/6	0/6
MoTle	1/2	0/2
FLNRO WMB	0/11	3/11

A station-level summary of changepoints is given in Appendix B tables **B.1** and **B.2**. For information on the timing and number of individual changepoints for a given station, the output of RHTestV4 is provided with plots (such as that shown in Fig. 9) and tables showing the changepoints for each station. Of the stations with statistically identified changepoints, in the BCHydro network 41% of stations (16 out of 39) revealed potential changepoints in maximum temperature with a much higher rate of inhomogeneity in the Campbell River region than for the Williston. This same pattern is seen for Tmin albeit with a smaller overall number of stations having one or more changepoints at 33% (13 out of 39). The FLNRO WMB network demonstrated very few changepoints. For maximum temperature, no

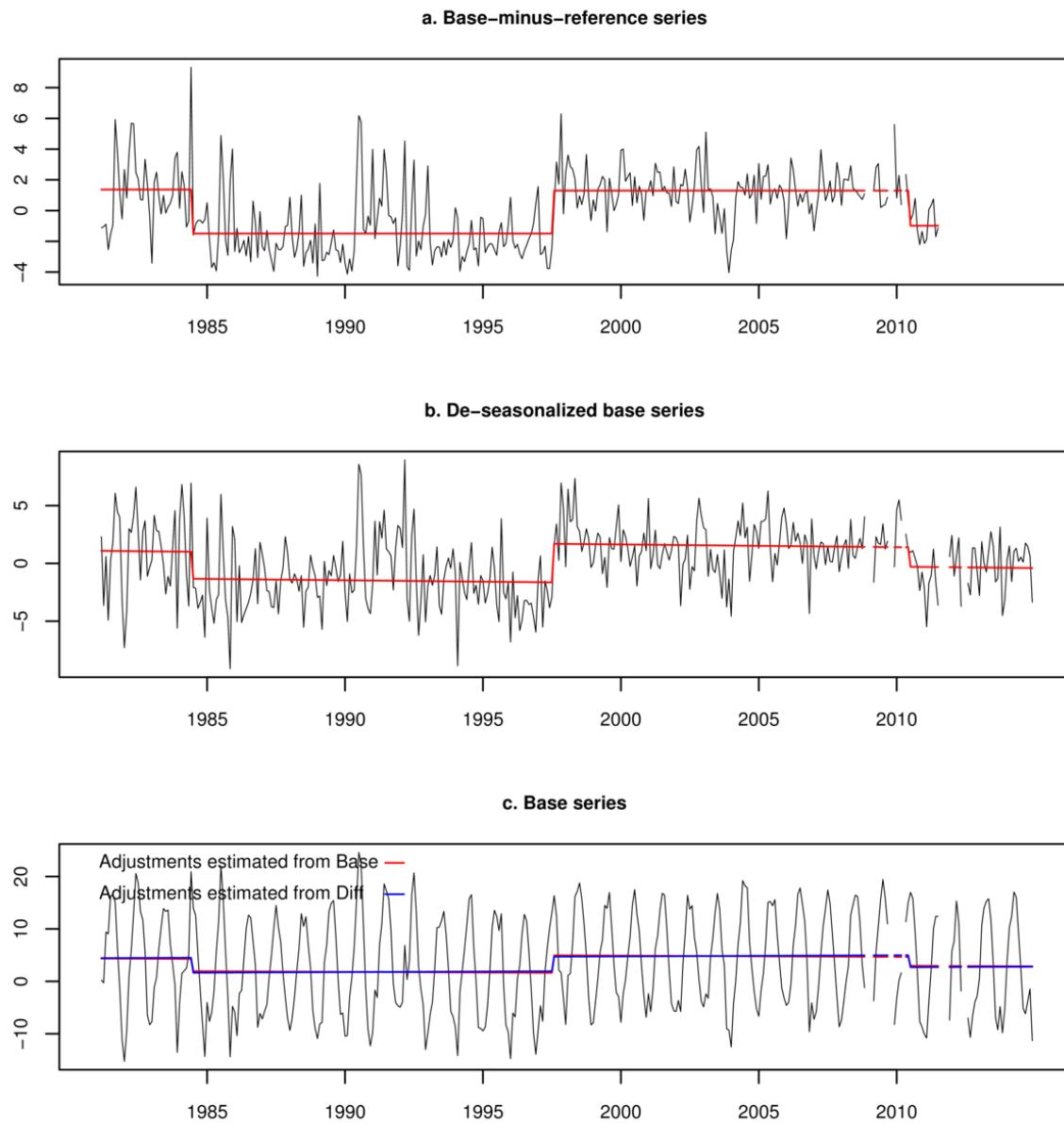
changepoints were detected for the network while for minimum temperature 22% of stations had one or more changepoints (5 out of 23). Finally, for the MoTI network as a whole, 12% of stations exhibited changepoints in maximum temperature while none did for minimum temperature. It's tempting to ascribe the lower rates of changepoint detection for the FLNRO and MoTI networks on better quality data, but it's more likely that the shorter records that these networks contain have not been as frequently subject to station alterations that could cause inhomogeneities.

On a regional level, data in the Williston basin appears to have fewer detected incidences of inhomogeneous station data than that in the Campbell River region. For maximum temperature 13% of stations in the Williston have one or more detected changepoints while 36% of stations in the Campbell River do. For minimum temperature 11% of stations in the Williston while 40% of the stations in the Campbell have changepoints. We do not speculate on why the rates of inhomogeneity is lower in the Williston than it is for the Campbell.

Finally and very importantly we note that a major and unresolved bug has very recently been discovered in the RHTestV4 code that affects adjustments to data using a reference dataset in which the reference dataset has a shorter period of record than the target data set. The result is a seeming scrambling of the data after the end date of the reference data. Because of this, note the following warning:

**FOR STATIONS ADJUSTED USING THE PMT TEST, NO DATA AFTER THE  
END OF THE REFERENCE AHCCD STATION'S PERIOD OF RECORD SHOULD BE  
USED**

Typically this is the year 2011, but this issue was discovered near the end of this contract and has not yet been fully investigated. See Appendix B tables B.1 and B.2 for stations that were adjusted with PMT. The end date for AHCCD was typically around 2011, but sometimes earlier.



**Figure 9:** Sample results for changepoint detection in maximum temperature at station Kwadacha North (ID# KWA) showing the. Results are shown after application of the PMT test with reference data from the AHCCD station Germansen (ID# 1183090). **(a)** The timeseries of the difference between the base data and the reference data along with the fitted changepoints in red and means indicating three changepoints. **(b)** The timeseries of anomalies from the base data showing the detected changepoints in red. **(c)** The timeseries of the base data with the adjustments proposed from the changepoints detected with reference data in blue and those detected with the base data alone shown in red. For this station, the reference data confirms changepoints that were detected with the basedata alone.



## 4. Discussion, Conclusion and Outlook

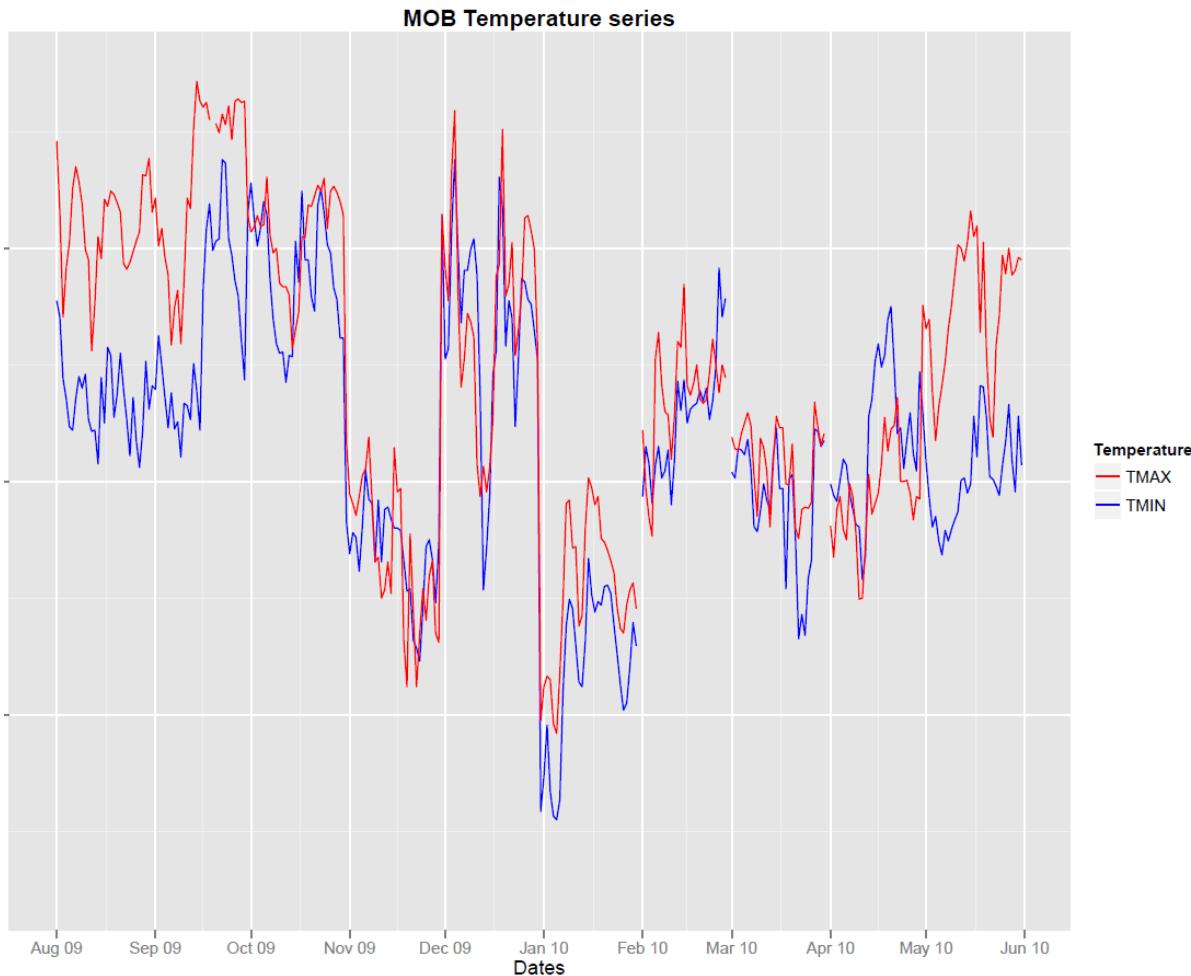
We have applied statistical changepoint detection techniques to stations in the Campbell River and Williston regions of British Columbia. This approach was three phased. First the data were quality controlled at the daily level and averaged to monthly values, second the Penalized Maximal F-test was applied to detect changepoints with minimal requirements for supporting data. Finally, where changepoints were identified with the PMF test, the Penalized Maximal T-test was applied with the support of reference data from one of the nearest three AHCCD stations. As implemented in RHTest, the PMT test requires ten years of data for all months in the record which was a requirement that could not be met for four stations that were analyzed with the PMF test. This analysis revealed that roughly half of the stations analyzed had statistically significant changepoints using these techniques. Of these, most changepoints were revealed with data from a reference station. However, confusingly in terms of ascribing a given changepoint to a change in the measurement environment of the station, the timing of changepoints was frequently different among the PMF and PMT tests. Furthermore, testing with multiple reference timeseries often yielded changepoints with different timing as well, but these differences in timing within a single test were generally smaller than between the two test types.

Overall, this work was successful in that we were able to apply corrections to previously non-homogenized data. However, more detailed analysis is needed to increase confidence that the changepoints determined statistically are truly robust. Most importantly, full access to any station maintenance records or other meta data would enable rejection or suggestion of potential changepoints in order to assist the statistical technique. In cases in which there is no supporting meta data, further work exploring the results of testing using varied thresholds for statistical significance (we used 95% confidence in this study) are needed. It is possible that a more stringent significance level would reveal more robust results among the tests and within the PMT test with multiple reference stations. Our approach to selecting a reference would ideally be based on correlation between the target station and the reference data and this would be a straightforward addition to this work.

Metadata is also useful for quality control efforts. For example, some stations have extended periods in which minimum daily temperature exceeds the maximum daily temperature. This can be seen for the station Moberly (ID# MOB) within the BC Hydro network in the Williston region for which a detail plot is given in [fig. 10](#). This station was tested to have 73 pairs of invalid observations in total, among which 72 pairs are concentrated in the time period August, 2009 June, 2010. Station meta data might help to determine if this issue arose because of sensor failure in this one year, a change in recording the maximum and minimum temperatures from hourly data or some other cause. In this current case invalid pairs of observations are set as missing values.

Ultimately, it would be beneficial to homogenize observational temperatures at the daily timescale and to homogenize monthly precipitation. It was the original intention of this project to investigate these possibilities but we were not able to reach that milestone. Although we were not able to approach this topic, the experience gained in this work allows us to speculate on potential difficulties. It is more difficult to identify changepoints in data at a higher temporal resolution due to the much

larger scale of temporal variability in the data. This variability makes detecting the timing of any change with precision difficult. For example, the PMT and PMF tests work on all years of a given month to locate changepoints for each month and then collect common changepoints among the months. With daily data, the year-to-year variability of temperature for a given day can be very large, even more so for wintertime temperatures in which temperature variability is the largest. That variability could easily mask a potential changepoint with an anomalously cold year or two after a potential upward changepoint. The analysis of daily changepoints is only possible in light of changepoints detected at the monthly scale and is much more dependent on metadata to enable the statistical technique to narrow the potential range of change point times.



**Figure 10:** Sample daily minimum and maximum temperature from the period August, 2009 through June, 2010 within the Williston Basin region for the BC Hydro station at Moberly River. (ID# MOB). The results show a period with multiple instances of minimum temperature equalling or exceeding maximum temperature.

Detecting changepoints in precipitation data is made challenging by the statistical distribution that precipitation data exhibits. That distribution is highly non-Gaussian. Precipitation cannot be

negative and large precipitation events are rare so the distribution will have a long tail and be skewed toward low precipitation amounts. The tests described for temperature rely on the quasi Gaussian behaviour of temperature data to make the statistical inferences that a change has or has not occurred. The use of monthly total precipitation partially mitigates the issue of non-Gaussian data. The issue can be further addressed by transforming the data to a more Gaussian distribution before analyzing for changepoints. But, this step introduces some uncertainty into what is already an uncertain process. Finally, especially in the more Mediterranean climate of southwest BC, the large seasonality of precipitation causes some locations to receive little or no precipitation for months or longer. This would make any adjustments subject to maintaining the sanctity of a zero monthly precipitation total. Extending this concept, it's possible that changepoints would only be detectable in precipitation of a certain magnitude or in certain seasons. With respect to magnitude, it is possible that the accuracy of observations is a function of precipitation rate and that relationship varies by instrument type. For example, stand-pipe gauges with pressure transducers often mask small accumulations when evaporation or large daily temperature fluctuations affect the data. These instruments will provide higher quality observations of larger precipitation events (although one could argue that missing light precipitation is less important than inaccurately measuring heavy precipitation) where evaporation and the influence of temperature are smaller. With rate-varying accuracy, it's conceivable that an instrument change with no supporting metadata would only reveal itself in the data when precipitation totals are of an amount where the largest errors occur.

Although it represented challenges at the time of analyzing the data, a positive outcome of this work was the improvement of the RClimDex and RHTestV4 software. Unfortunately, discovering the errors and modifying the programming code to correct them restricted our ability to complete the exploration of homogenizing daily temperature and investigating application to precipitation. The positive impact is that our improvements to the code have made the quality control procedures in RClimDex statistically more robust and in better alignment with major meteorological centres around the world. Our correction of the issues with RHTestV4 did not improve the outcomes of the homogenization tests, but have prevented inadvertently poor results book-keeping by the software. A final error in the software which causes the mishandling of data processed with the PMT test has not yet been corrected. This issue causes the output of the PMT test to somehow dis-organize the monthly data when a reference dataset is used with a shorter period of record than the target dataset. This will be looked into and corrected. All of these changes will be presented to the authors of the code for incorporation into the main versions of these packages.

Despite the potential challenges to homogenizing daily temperature and monthly precipitation, it is possible and well documented. The software package that was used to homogenize monthly temperature in this study has tools for homogenizing daily temperature and monthly precipitation. Those techniques have not yet been tried and homogenizing daily temperature first requires completion of the monthly temperature homogenization work to guide the daily process. We hope to address these challenges in coming months as this project evolves. Ultimately, a province-wide homogenized temperature and precipitation dataset is achievable and will be of great benefit to climate and impacts scientists throughout western Canada..



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# Appendix A: Basic metadata for stations in this analysis

**Table A.1:** Basic station metadata for the stations in the Campbell River region that underwent homogenization for this project

Network	Native	Station Name	Lon.	Lat.	Elev. (m)
Name	ID				
BCH	ASH	Elsie Lk forebay	-125.144	49.441	340
BCH	CMX	Comox Dam forebay	-125.094	49.643	135
BCH	COX	Comox Lake @ Courtenay	-125.080	49.640	140
BCH	CRU	Cruickshank R. nr the Mouth	-125.201	49.579	150
BCH	ELK	Elk R. ab Campbell Lk	-125.813	49.857	270
BCH	ERC	Eric Ck	-125.288	49.605	280
BCH	GLD	Gold R. nr Ucona R.	-126.106	49.706	10
BCH	HEB	Heber R. nr Gold R.	-125.986	49.815	215
BCH	JHT	John Hart sub-station	-125.309	50.043	15
BCH	QIN	Quinsam R. @ Argonaut Brg	-125.500	49.930	280
BCH	QSM	Quinsam R. nr Campbell R.	-125.300	50.029	15
BCH	SAM	Salmon R. ab the Diversion	-125.672	50.092	215
BCH	SCA	Strathcona Dam	-125.584	49.997	227
BCH	WOL	Wolf R. Upper	-125.742	49.681	1490
FLNRO-WMB	19	MENZIES CAMP	-125.789	50.049	438
FLNRO-WMB	56	BOWSER	-124.703	49.437	184
FLNRO-WMB	956	TS EFFINGHAM	-125.283	49.170	632
FLNRO-WMB	37	BEAVER CREEK	-124.933	49.378	100
FLNRO-WMB	39	ZZ CATS EARS (FD7)	-125.385	49.193	500
FLNRO-WMB	36	ZZ PASS (CAMERON)	-124.648	49.272	974
FLNRO-WMB	23	ZZ COUS	-124.908	49.227	455
FLNRO-WMB	29	ZZ VIEW (FD7)	-125.333	49.388	300
FLNRO-WMB	539	ZZ QUADRA ISLAND	-125.200	50.200	50
FLNRO-WMB	839	ZZ MUCHALAT LAKE	-126.146	49.888	1125
FLNRO-WMB	960	GM COURtenay	-124.997	49.710	37
MoTIm	63094	Kennedy Lake	-125.453	49.101	35
MoTIm	64093	North Courtenay	-125.190	49.830	100
MoTIm	63001	Port Alberni	-124.766	49.263	90
MoTIm	64003	Gold River	-126.061	49.762	85
MoTIm	64008	Mt. Washington	-125.304	49.744	1210
MoTIm	64107	Mt. Washington (Avalanche)	-125.304	49.744	1210
MoTIm	64002	Campbell River	-125.269	50.048	25
MoTIm	64001	Courtenay	-125.002	49.683	30

**Table A.2:** Basic station metadata for the stations in the Williston Basin region that underwent homogenization for this project

Network	Native	Station Name	Lon.	Lat.	Elev. (m)
Name	ID				
BCH	NAT	Nation R. nr the Mouth	-123.610	55.430	725
BCH	KWA	Kwadacha North - snowpillow	-125.073	57.623	1554
BCH	OSL	Osilinka R. nr End Lk	-124.801	56.127	775
BCH	AKI	Akie nr the 760m contour	-124.896	57.188	760
BCH	FIN	Finlay R. ab Akie R.	-125.249	57.125	711
BCH	LST	Williston @ Lost Cabin Ck	-123.747	56.051	712
BCH	PUL	Pulpit Lk	-126.749	57.548	1311
BCH	HRN	Horn Ck	-123.606	56.735	1450
BCH	AKN	Aiken Lake	-125.742	56.437	970
BCH	PMD	GMS Hudson's Hope	-122.184	56.013	720
BCH	WON	Wonowon	-121.804	56.729	910
BCH	MCQ	McQue Terrace	-123.404	56.982	1200
BCH	ING	Ingenika R. ab Swannell R.	-125.103	56.731	711
BCH	PNK	Pink Mtn.	-122.354	57.002	1204
BCH	MES	Mesilinka R. ab Gopherhole Ck	-124.644	56.245	728
BCH	PRS	Parsnip R. ab Misinchinka R.	-122.900	55.080	700
BCH	PAK	Pack R. @ outlet of Mcleod Lk	-123.037	54.998	675
BCH	MOB	Moberly R. @ Ft. St. John	-121.347	56.093	600
BCH	PYN	Pine Pass	-122.637	55.353	1400
BCH	OMI	Ominica R. ab Osilinka R.	-124.560	55.940	715
BCH	PAR	Parsnip Upper	-122.146	54.613	790
BCH	HFF	Halfway R. @ Farrell Ck	-121.629	56.251	480
BCH	OSP	Ospika R. ab Alley Ck	-123.930	56.460	750
BCH	CHW	Chowade Upper	-122.779	56.637	1480
BCH	WSC	Williston @ Schooler Ck	-122.716	56.106	676
FLNRO-WMB 145	INGENIKA PT		-125.176	56.978	1213
FLNRO-WMB 141	MANSON		-124.232	55.580	1047
FLNRO-WMB 132	HUDSON HOPE		-121.990	56.035	704
FLNRO-WMB 129	PINK MTN		-122.558	57.077	989
FLNRO-WMB 151	NABESHE		-123.366	56.364	1108
FLNRO-WMB 155	MACKENZIE FS		-123.135	55.304	690
FLNRO-WMB 144	TABLE RIVER		-122.273	54.716	760
FLNRO-WMB 148	BLACKPINE		-125.368	56.319	1126
FLNRO-WMB 140	LEMORAY		-122.517	55.525	757
FLNRO-WMB 124	GRAHAM		-122.458	56.435	768
FLNRO-WMB 136	WONOWON		-121.765	56.719	967
FLNRO-WMB 1030	GWILLIM		-121.564	55.295	1100

**Table A.2 cont'd:** Basic station metadata for the stations in the Williston Basin region that underwent homogenization for this project

Network	Native	Station Name	Lon.	Lat.	Elev. (m)
Name	ID				
MoTle	41092	Link Creek	-122.657	55.501	730
MoTle	41093	Whiskers Point	-122.928	54.904	710
MoTle	43127	Solitude Low	-122.589	55.494	1060
MoTle	43126	Solitude High	-122.600	55.486	1555
MoTIm	41002	Pine Pass	-122.605	55.358	915
MoTIm	43101	Mount Lemoray	-122.483	55.539	670
MoTIm	44003	Hudson's Hope	-121.900	56.037	455
MoTIm	43003	Chetwynd	-121.620	55.699	630
MoTIm	41001	Honeymoon Creek	-122.722	55.223	750

**Table A.3:** Basic metadata for AHCCD stations used as reference for homogenization

Region	Native ID	Station Name	Province	Lon.	Lat.	Elev. (m)	Joined
Campbell	1021830	COMOX	BC	-124.9	49.72	26	Y
Campbell	1026639	QUINSAM RIVER	BC	-125.3	50.02	46	Y
Campbell	1032730	ESTEVAN POINT	BC	-126.55	49.38	7	N
Campbell	1021480	BLIND CHANNEL	BC	-125.5	50.42	23	N
Campbell	1017230	SHAWNIGAN LAKE	BC	-123.63	48.65	138	N
Campbell	1108447	VANCOUVER	BC	-123.18	49.2	4	Y
Williston	1183090	GERMANSEN	BC	-124.7	55.78	766	N
Williston	1192940	FORT NELSON	BC	-122.6	58.83	382	N
Williston	1183000	FORT ST JOHN	BC	-120.73	56.23	695	Y
Williston	1077500	SMITHERS	BC	-127.18	54.82	522	Y
Williston	1092970	FORT ST JAMES	BC	-124.25	54.45	686	N
Williston	1182285	DAWSON CREEK	BC	-120.18	55.75	655	Y
Williston	3070600	BEAVERLODGE	AB	-119.4	55.2	745	Y
Williston	1192340	DEASE LAKE	BC	-130	58.42	807	N
Williston	1096450	PRINCE GEORGE	BC	-122.68	53.88	691	Y
Williston	1090660	BARKERVILLE	BC	-121.52	53.07	1265	N
Williston	1067742	STEWART	BC	-129.98	55.93	7	Y

# Appendix B: Summary of PMF and PMT results for each station

**Table B.1:** Summary of homogenization results for stations in the Campbell River region. NA\* indicates that a station has a potential changepoint based on the PMF test, but the record is too short for application of the PMT test.

Network Name	Native ID	T Max				T Min			
		CPs with	CPs with	Reference	CPs with	CPs with	Reference		
		PMF?	PMT?	Station Used	PMF?	PMT?	Station Used		
BCH	ASH	Y	Y	1032730	Y	Y	1032730		
BCH	CMX	N	NA	NA	Y	Y	1021830		
BCH	COX	Y	Y	1021480	N	NA	NA		
BCH	CRU	Y	Y	1021480	Y	Y	1021480		
BCH	ELK	Y	Y	1021830	Y	Y	1021830		
BCH	ERC	Y	Y	1021830	Y	Y	1021830		
BCH	GLD	Y	Y	1032730	Y	Y	1032730		
BCH	HEB	Y	Y	1021480	Y	Y	1021480		
BCH	JHT	Y	N	1021830	Y	N	1021830		
BCH	QIN	Y	Y	1021830	Y	Y	1021830		
BCH	QSM	Y	Y	1021480	N	NA	NA		
BCH	SAM	N	NA	NA	Y	N	1026639		
BCH	SCA	Y	Y	1021480	Y	Y	1021480		
BCH	WOL	Y	Y	1032730	Y	Y	1032730		
FLNRO-WMB	19	Y	N	1021830	Y	N	1021830		
FLNRO-WMB	56	N	NA	NA	Y	Y	1108447		
FLNRO-WMB	956	N	NA	NA	N	NA	NA		
FLNRO-WMB	37	N	NA	NA	Y	Y	1032730		
FLNRO-WMB	39	N	NA	NA	Y	NA*	NA*		
FLNRO-WMB	36	N	NA	NA	N	NA	NA		
FLNRO-WMB	23	N	NA	NA	N	NA	NA		
FLNRO-WMB	29	N	NA	NA	N	NA	NA		
MoTIm	63094	N	NA	NA	N	NA	NA		
MoTIm	64093	Y	Y	1021480	Y	N	1021480		
MoTIm	63001	N	NA	NA	N	NA	NA		
MoTIm	64003	N	NA	NA	N	NA	NA		
MoTIm	64008	N	NA	NA	N	NA	NA		
MoTIm	64107	N	NA	NA	N	NA	NA		
MoTIm	64002	N	NA	NA	N	NA	NA		
MoTIm	64001	N	NA	NA	N	NA	NA		

**Table B.2:** Summary of homogenization results for stations in the Williston Basin region. **NA\*** indicates that a station has a potential changepoint based on the PMF test, but the record is too short for application of the PMT test.

Network Name	Native ID	T Max				T Min			
		CPs		Reference		CPs		Reference	
		with PMF?	with PMT?	Station Used	with PMF?	with PMT?	Station Used		
BCH	NAT	N	NA	NA	N	NA	NA		
BCH	KWA	Y	Y	1183090	Y	Y	1183090		
BCH	OSL	N	NA	NA	N	NA	NA		
BCH	AKI	N	NA	NA	N	NA	NA		
BCH	FIN	N	NA	NA	N	NA	NA		
BCH	LST	N	NA	NA	N	NA	NA		
BCH	PUL	Y	N	1183090	N	NA	NA		
BCH	HRN	N	NA	NA	Y	Y	1183090		
BCH	AKN	N	NA	NA	N	NA	NA		
BCH	PMD	N	NA	NA	N	NA	NA		
BCH	WON	N	NA	NA	N	NA	NA		
BCH	MCQ	Y	Y	1192940	N	NA	NA		
BCH	ING	Y	Y	1092970	Y	Y	1092970		
BCH	PNK	N	NA	NA	N	NA	NA		
BCH	MES	N	NA	NA	N	NA	NA		
BCH	PRS	N	NA	NA	N	NA	NA		
BCH	PAK	N	Y	1183090	N	NA	NA		
BCH	MOB	N	NA	NA	N	NA	NA		
BCH	PYN	N	NA	NA	N	NA	NA		
BCH	OMI	N	NA	NA	N	NA	NA		
BCH	PAR	N	NA	NA	N	NA	NA		
BCH	HFF	Y	Y	1183000	N	NA	NA		
BCH	OSP	N	NA	NA	N	NA	NA		
BCH	CHW	Y	N	1183090	N	NA	NA		
BCH	WSC	Y	N	1183090	N	NA	NA		
FLNRO-WMB	145	N	NA	NA	Y	<b>NA*</b>	<b>NA*</b>		
FLNRO-WMB	141	N	NA	NA	N	NA	NA		
FLNRO-WMB	132	N	NA	NA	N	NA	NA		
FLNRO-WMB	129	N	NA	NA	N	NA	NA		
FLNRO-WMB	151	N	NA	NA	N	NA	NA		
FLNRO-WMB	155	N	NA	NA	N	NA	NA		
FLNRO-WMB	144	N	NA	NA	Y	<b>NA*</b>	<b>NA*</b>		
FLNRO-WMB	148	N	NA	NA	N	NA	NA		

**Table B.2 cont'd:** Summary of homogenization results for stations in the Williston Basin region. NA\* indicates that a station has a potential changepoint based on the PMF test, but the record is too short for application of the PMT test.

Network Name	Native ID	T Max				T Min			
		CPs		Reference		CPs		Reference	
		with PMF?	PMT?	Station Used	with PMF?	with PMT?	Station Used		
FLNRO-WMB 140		N	NA	NA	N	NA	NA		
FLNRO-WMB 124		N	NA	NA	N	NA	NA		
FLNRO-WMB 136		N	NA	NA	N	NA	NA		
MoTle 41093		Y	N	1096450	N	NA	NA		
MoTle 41092		N	NA	NA	N	NA	NA		
MoTIm 41002		N	NA	NA	N	NA	NA		
MoTIm 43101		N	NA	NA	N	NA	NA		
MoTIm 44003		Y	NA*	NA*	N	NA	NA		
MoTIm 43003		N	NA	NA	N	NA	NA		
MoTIm 41001		N	NA	NA	N	NA	NA		

# Appendix C: Data Organization

The results from the quality control and the homogenization work are available via the web at:

[https://pacificclimate.org/~fanslow/homogenization\\_results/](https://pacificclimate.org/~fanslow/homogenization_results/) .

. The archive's structure is presented in **table C.1** and the most critical elements of the data will be described here. The raw data, pre-processing are in the directory `original_data` which is organized into two subfolders by region. These are further separated by network then leading to the raw data.

Quality control results are given under the directory `QC` where subfolders divide the networks and regions and further subfolders separate the individual stations. Within each station directory is a "log" directory which contains plots and a table of any errors found in the data.

The results of homogenization are in two directories -- `rhtest_raw_output` and `rhtest_processed_output`. The raw output file simply contains all of the adjusted data files from the application of RHtests. The filenames indicate if the station underwent only the PMF test or both the PMT and PMF tests. The latter results are longer file names with an Environment Canada station ID midway through the filename. This ID indicates the reference station that was used for changepoint detection. The data in `rhtest_processed_output` are organized by region and then network. The adjusted data is to be found in the network directory. Within that are directories 'changepoints' and 'plots'. The `changepoints` directory contains lists of changepoints found for each station as well as statistics on those results. The `plots` subdirectory contains the plotted results similar to what is shown in **Fig. 9**.

Finally, the lists of the three nearest AHCCD stations to each station in the analysis is given under the `ahccd_station_lists` directory.

**Table C.1:** The directory tree for the delivered homogenized data

ahccd_station_lists	Continued from previous column
original_data	
Campbel River Data	
BCH	
BCH	
FLNRO_WMB	
FLNRO-WMB	
MoTIE	
MoTIE	
MoTIM	
MoTIM	
Williston Data	
BCH	
BCH	
FLNRO_WMB	
FLNRO_WMB	
MoTIE	
MoTIE	
MoTIM	
MoTIM	
QC	
BCH_Campbel	
RCLimDex_ASH	
log	
RCLimDex_CMX	
log	
...	
BCH_Willston	
RCLimDex_AKI	
log	
RCLimDex_AKN	
log	
...	
FLNRO_WMB_Campbel_daily	
19	
log	
23	
log	
...	
FLNRO_WMB_Willston_daily	
1030	
log	
124	
log	
...	

...

MoTIE_Campbel_daily	
63094	
log	
64093	
log	
MoTIE_Willston_daily	
41092	
log	
41093	
...	
MoTIM_Campbel_daily	
63001	
log	
64001	
log	
...	
MoTIM_Willston_daily	
41001	
log	
41002	
log	
...	
rhtest_processed_output	
Campbell_River	
BCH	
changepoints	
plots	
FLNRO_WMB	
changepoints	
plots	
...	
Williston	
BCH	
changepoints	
plots	
FLNRO_WMB	
changepoints	
plots	
...	
rhtest_raw_output	