Adjusted and Homogenized Canadian Climate Data

1. Overview

Adjusted and homogenized Canadian climate data (AHCCD) are climate station datasets that incorporate adjustments (derived from statistical procedures) to the original historical station data to account for discontinuities from non-climatic factors, such as instrument changes or station relocation. AHCCD was developed for use in climate research, including climate change studies. Long-term data records are often impacted by changes (e.g. site exposure, location, instrumentation, observer, and observing procedures) that are not related to climate. These non-climatic changes were detected and removed using statistical procedures. When necessary, data were corrected for some measurement techniques that are known to possibly lead to underestimations or overestimations. In addition, data from nearby stations were sometimes combined to create longer time series. Table 1.

Table 1. Main Characteristics

Variables and units	Maximum temperature (°C) Minimum temperature (°C) Mean temperature (°C) Rainfall (mm/period) Snowfall (mm/period) Total precipitation (mm/period) Wind speed (m/s) Station level pressure (Pa) Sea level pressure (Pa)
Spatial resolution and geographical coverage	Point locations across Canada
Time period	Time period varies per station, per variable with data availability ranging between 1840 and 2018
Temporal resolution	Monthly, seasonal, and annual

2. Variables and formats

AHCCD provides the monthly, seasonal, and annual mean values for nine different variables:

- Maximum temperature: based on highest daily values. Units are Celsius degrees (°C).
- Minimum temperature: based on lowest daily values. Units are Celsius degrees (°C).
- Mean temperature: computed as the average of Maximum and Minimum temperature. Units are Celsius degrees (°C).
- Rainfall: based on total daily rainfall. Units are millimeters for the period (e.g. mm/month).
- Snowfall: based on total daily snowfall and expressed based on the water content of snow. Units are millimeters for the period (e.g. mm/month).
- Total precipitation: sum of rainfall and snowfall. Units are millimeters for the period (e.g. mm/month).
- Wind speed: based on hourly readings of wind speed. Units are meters per second (m/s).
- Station level pressure: based on hourly readings of atmospheric pressure. Units are Pascal (Pa).

- Sea level pressure: based on hourly readings of atmospheric pressure. Units are Pascal (Pa).

Note: all variables, except sea level pressure, represent surface conditions (typically ~1.5 meter above the ground) at the station's location. Sea level pressure represents the pressure if the station were at the sea level instead of at its actual elevation.

2.1. Homogenized surface air temperature

The homogenized surface air temperature data consist of monthly, seasonal and annual means of homogenized daily maximum, minimum and mean surface air temperatures (degrees Celsius) for 338 locations in Canada. The time periods of the data vary by location, with the oldest data available from the early 1880s at some stations to the most recent update in 2018. Observations at co-located sites were sometimes joined in order to create longer time series. Data availability over most of the Canadian Arctic is restricted to the mid-1940s to present. The data will continue to be updated every year.

2.2. Adjusted precipitation

The adjusted precipitation data consist of monthly, seasonal and annual totals of daily adjusted rain, snow and total precipitation (millimetres) for 464 locations in Canada. The time periods of the data vary by location, with the oldest data available from the early 1880s at some stations to the most recent update in 2017. Observations at co-located sites were sometimes joined in order to create longer time series. Data availability over most of the Canadian Arctic is restricted to the mid-1940s to present.

2.3. Homogenized sea level and station pressure

Homogenized sea level and station pressure data consist of monthly, seasonal and annual means of hourly sea level and station pressure (hectopascals) for 626 locations in Canada. The time periods of the data vary by location, with the oldest data available from 1953 at some stations to the most recent update in 2014. The data will continue to be updated every few years (as time permits).

2.4. Homogenized surface wind

The homogenized surface wind speed data consist of monthly, seasonal and annual means of hourly wind speed (kilometres per hour) at standard 10 metre level for 156 locations in Canada. The time periods of the data vary by location, with the oldest data available from 1953 at some stations to the most recent update in 2014. The data will continue to be updated every few years (as time permits).

3. Methods

The method used to adjust and homogenize station data differs for each variable, as summarized below. Full technical details may be accessed online (Environment and Climate Change Canada, 2018).

3.1. Homogenized surface air temperature

In the homogenized surface temperature datasets, non-climatic shifts were identified by comparing a station to other nearby stations. If a shift in the data was seen at one station, but not at nearby stations, it's possible that the shift may be due to non-climatic causes. Once a shift has been identified, station metadata is used to identify what may have caused the shift, and what corrective measure should be applied. Following this, adjustments were applied to the daily temperatures to address the bias due to the non-climatic causes, if adjustments are warranted.

Further, adjustments were applied to the daily minimum temperatures at synoptic stations (mainly airports) to address the bias due to the change in observing time in July 1961 (Vincent et al. 2009). Techniques based on

regression models were used to detect non-climatic shifts in temperature monthly series (Wang et al. 2007; Vincent, 1998). A new procedure was applied to derive the adjustments; for more information, please see Wang et al. (2010) and Vincent et al. (2012).

3.2. Adjusted precipitation

Adjusted precipitation datasets accounts for a number of known errors in precipitation measurements. First, rain gauge measurements of precipitation are known to underestimate amount of actual precipitation due to the loss of rain water from the instruments during periods of high intensity rainfall (Molini et al. 2005). Field experiments have been undertaken at various locations to quantify these biases and correct them for the types of rain gauges used by the Meteorological Service of Canada.

Second, ruler measurements have been used historically to measure snow depth and an assumed density of 100 kg m^{-3} was used to convert snow depth to snow water equivalent. However, AHCCD data use more accurate density estimates that vary geographically across the country. Snow tends to be denser in the east and north of the country, and less dense in the west. Also, daily precipitation amounts below a minimum measurable amount were set to a value of zero in the past. However, the accumulated impact of these trace amounts can become significant, especially in areas like the Arctic where precipitation amounts are low. Adjustments were applied to account for this underestimation by assigning a value to these trace days: 0.1 mm was applied for rain, whereas for snow the adjustment factor ranged from 0.03 to 0.07 mm depending on the station location. Finally, nearby observations were sometimes joined and adjustments were applied based on a simple ratio computed using available periods of overlapping data. For more information, please see Mekis and Vincent (2011).

3.3. Homogenized wind speed

Surface wind speed datasets were homogenized in two steps. First, metadata were used to adjust hourly wind speeds measured from a non-standard height to the standard 10 m height using information about the instrument set up. For example, if a wind gauge was on the tower at 2m off the ground, an adjustment would be made to estimate what the reading would be if it were at the standard 10m height.

Second, the monthly mean wind speeds were tested for non-climatic shifts by comparing observed wind speeds with large-scale modelled wind speeds. Because winds are driven by gradients in pressure, the large-scale modelled pressure can be used to estimate what wind speeds would be at a specific location; if the observed wind speeds exhibit shifts that are not seen in the modelled results, wind speed shifts are assumed to result from non-climatic causes and are removed. For more information, please see Wan et al. (2010).

3.4. Homogenized sea level and station pressure

For homogenized sea level and station pressure datasets, systematic non-climatic shifts were detected in station observations. Non-climatic shifts are mainly due to the use of non-updated station elevation, station relocation, and other errors occurring during the digitization of information originally recorded on paper.

When possible, the main causes of these inhomogeneities were identified through historical evidence such as the inspection reports. There were a number of potential errors in the data that were flagged: unusually high or low values; sudden extreme, physically implausible, changes in pressure; instances in which the recorded pressure was constant for an extended length of time; cases in which the station pressure and mean sea level pressure were identical; and cases in which the pressure data recorded are physically inconsistent. Where possible, a correction was made for each of the different inhomogenities identified. For more information, please see Wan et al. (2007).

4. Methods for trend calculation

Trends are calculated using the Theil-Sen method using the station's full period of available data. The availability of trends will vary by station and variable; if more than 5 consecutive years are missing data or more than 10% of the data within the time series is missing, a trend was not calculated.

5. Station list

A list of AHCCD stations for each variable is available on the Canadian Centre for Climate Services' Climate Data Viewer. Also listed are the station lists for each variable in Microsoft Excel.

Homogenized temperature station list: ftp://ccrp.tor.ec.gc.ca/pub/AHCCD/Temperature_Stations.xls
Adjusted precipitation station list: ftp://ccrp.tor.ec.gc.ca/pub/AHCCD/Precipitation_Stations.xls
Homogenized pressure station list: ftp://ccrp.tor.ec.gc.ca/pub/AHCCD/Pressure_Stations.xls
Homogenized wind station list: ftp://ccrp.tor.ec.gc.ca/pub/AHCCD/Wind_Stations.xls

6. Application

The AHCCD dataset was created to assess long-term trends in Canada's climate, accounting for non-climatic factors. For example, the relocation of a monitoring station from beside a building to the end of a runway would affect the station's temperature; using statistical procedures, such effect is removed from the data.

Users are urged to assess whether the AHCCD datasets are suitable for their application. AHCCD datasets differ from the official Meteorological Service of Canada in situ station records and therefore should not be used for legal purposes. Users interested in the original observations made at a given site should use the Meteorological Service of Canada station data.

7. Limitations

It should be noted that there may be missing values in the AHCCD dataset, which may vary by variable, station and time. In addition, AHCCD dataset are site-specific datasets. If you require a gridded observed dataset, please consider the Canadian gridded dataset (CANGRD). CANGRD datasets include historical gridded temperature and precipitation anomalies, interpolated from AHCCD station data at a 50km resolution across Canada.

8. Other Considerations

AHCCD station data are derived from observations made at the weather stations from the Meteorological Service of Canada (MSC). AHCCD stations use the same ID as MSC stations; this allows users to compare the raw station data to homogenized and adjusted data.

Further, it should be noted that ongoing research may result in future revisions of the AHCCD dataset (e.g., updated methodologies) to provide a better spatial and temporal representation of the climate trends in Canada.

9. Use limitation

10. Contact Information

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11. References

Environment and Climate Change Canada (2018). Adjusted and homogenized Canadian Climate data. Accessed August 15 2018. Website: https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/adjusted-homogenized-canadian-data.html.

Mekis, É., & Vincent, L. A. (2011). An overview of the second generation adjusted daily precipitation dataset for trend analysis in Canada. Atmosphere-Ocean, 49(2), 163-177.

Molini, A., Lanza, L. G., & La Barbera, P. (2005). The impact of tipping-bucket rainguage measurement errors on design rainfall for urban-scale applications. Hydrological Processes, 19, 1073-1088.

Vincent, L.A. (1998). A technique for the identification of inhomogeneities in Canadian temperature series. Journal of Climate, 11, 1094-1104.

Vincent, L.A., Milewska, E.J., Hopkinson, R., & Malone, L. (2009). Bias in minimum temperature introduced by a redefinition of the climatological day at the Canadian synoptic stations. Journal of Applied Meteorology and Climatology, 48, 2160-2168. DOI: 10.1175/2009JAMC2191.1.

Vincent, L. A., Wang, X. L., Milewska, E. J., Wan, H., Yang, F., & Swail, V. (2012). A second generation of homogenized Canadian monthly surface air temperature for climate trend analysis. Journal of Geophysical Research: Atmospheres, 117, D18110.

Wan, H., Wang, X. L., & Swail, V. R. (2007). A quality assurance system for Canadian hourly pressure data. *Journal of Applied Meteorology and Climatology*, *46*(11), 1804-1817

Wan, H., Wang, X. L., & Swail, V. R. (2010). Homogenization and trend analysis of Canadian near-surface wind speeds. Journal of Climate, 23(5), 1209-1225.

Wang, X. L., Chen, H., Wu, Y., Feng, Y. & Pu, Q. (2010). New techniques for detection and adjustment of shifts in daily precipitation data series. Journal of Applied Meteorology and Climatology, 49, 2416-2436. DOI: 10.1175/2010JAMC2376.1.

Wang, X. L., Wen, Q. H., & Wu, Y. (2007). Penalized maximal t test for detecting undocumented mean change in climate data series. Journal of Applied Meteorology and Climatology, 46 (6), 916-931. DOI:10.1175/JAM2504.1.