J3.7

ADJUSTMENTS FOR TRACE MEASUREMENTS IN CANADA

Éva Mekis*
Climate Research Branch, Meteorological Service of Canada

1. INTRODUCTION

The measurement of trace precipitation in Canada went through several phases over time. Not just the definition of trace precipitation (or the lack of definition) has been modified, but the measuring unit was also changed from imperial to metric system. All data in the Climate National Archive was converted from inches to millimetres with the introduction of metric system, which also caused further inconsistency in the data. Station relocations were often accompanied by new set of instruments and a new observer. The training given to the observers often resulted in a jump in the number of daily trace measurement. Last and not least, the time of observations have also been modified. One trace flag recorded in the daily archive could originate from one, two or four times daily measurement. The objective of this work is to summarize in chronological order the history of trace measurements and to study the effect of the presently applied trace adjustment, using only small precipitation events and days with trace observations at three locations using all available metadata.

2. HISTORY OF TRACE MEASUREMENTS AND OBSERVATIONAL PRACTICES IN CANADA

The measurement of "trace amounts" of precipitation (smaller than a given limit) has not always been practiced. The terminology of trace of rainfall was mentioned as early as 1871 in a preliminary observer manual and in later manuals of 1878, 1893 and 1914 as the following: "*If no appreciable rain was found in the gauge at the proper time for measuring it, and the observer was aware that some rain had fallen since the time of the previous rain observation, he should enter the letter (r) for the depth fallen; but if he had no reason to suppose that the rain had fallen, he should leave the place blank*." (Kingston, 1878, page 180). But the next version of "Instructions to Observers" (J. Patterson, 1930) does not contain any reference to recording traces of rain. Trace was mentioned in 1947 in the 1st edition of Manual of Standard Procedures and Practices for Weather Observing and Recording MANOBS (effective 1st January, 1947) but only under Synoptic Reports (page 47 paragraph 3.1.4): "*A trace of precipitation is defined as 0.005 inches or less instead of less than 0.005 inches*". Finally in Amendment No 8 to MANOBS 3rd edition, (effective 9 June, 1954): contains the first official mention of trace flag (paragraph 11.5.23, page 100) *"...less then 0.01 inches, record this as a trace by entering 'TR'."* Another definition appears in the booklet "How to Measure Rainfall" (Meteorological Branch, 1954), namely "*If the amounts of precipitation are too small to measure, that is less than 0.01 inch of rain or less than 0.1 inches of snow are entered as T, for "Trace", and should not be omitted.*". In the manual of measuring precipitation (Atmospheric Environment Service, 1973) the trace definition is the following: "*If the level is at or below the halfway mark (0.005 inch), the amount is called a trace, which is recorded as T.*"

The homogeneity of trace observation record was also seriously affected by switching from Imperial to the Metric system around 1977 - 1978. The units were given in inches before; the minimum measurable level has been decreased by almost 0.1 mm in the metric system. Table 1 gives a summary of the amounts and units used in both systems for rain and snow separately.

Table 1. Minimum measurable amounts used in different systems.

	Imperial System	Rounded as	Metric System
Rain (010)	0.01 inch = 0.254 mm	0.3 mm	0.2 mm
Snow (011)	0.1 inch = 0.254 cm	0.3 cm	0.2 cm

The Climatological Day definition also changed through the time. At the first order station, the practice of 4 observations per day started only in January 1, 1941; previously the measurements were taken only daily twice, at 7 a.m. and 7 p.m. LST. At climate (or volunteer) stations the precipitation was suggested to be measured also twice a day, but occasionally only one observation was taken in the morning. Since the daily rain and snow archive contain only one flag per day, the probability of getting a trace flag is higher if the observations were taken two or 4 times per day. It is important to find out from the station history files the actual times of observation at each individual location in order to provide proper adjustments for the trace observations.

Corresponding author address: Éva Mekis, Climate Research Branch, Meteorological Service of Canada, 4905 Dufferin St. Toronto, Ontario, Canada, M3H 5T4;
e-mail: Eva.Mekis@ec.gc.ca

3. SUMMARY OF TRACE ADJUSTMENT APPLIED IN THE ADJUSTED HISTORICAL DATABASE

The problem of adjusting for trace precipitation – which assigned the value of zero in the Atmospheric Environment Service digital archive - has not been often addressed outside Canada, since trace is rarely recorded in other countries and has relatively little significance except in arid climates such as found in the Canadian Arctic. In the Arctic, the combination of very low annual precipitation amounts; extremely low evaporation throughout the long dark winter, plus frequent occurrences of trace observations, makes the accumulation of these minuscule amounts significant to the annual total precipitation and the water balance of the region. Because of the long winters in the Arctic and the high frequency of trace observations during frozen precipitation events, it is important to assign a greater than zero value for traces observed during snowfall or ice crystal events. For completeness, even though rainfall amounts are small in the Arctic, adjustments for rainfall trace were implemented.

Different approaches were applied for rain and snow trace correction. For rainfall, all amounts for the interval 0.0 - 0.2 mm were considered equally probable for events classified as trace and the interval average of 0.1 mm was considered representative of a trace measurement amount (Mekis and Hogg, 1999). Since rain trace is also exposed to evaporation losses prior to measurement, the use of 0.1 mm for the rain only trace adjustment should be conservatively low. As well, rain trace events in the North are rare so they have relatively little effect on the final total precipitation accumulation, so approximation procedures were considered adequate. The adjustment of solid precipitation trace measurements is a more complex problem. Due to the measurement methodology, snow ruler trace measurements are not exposed to wetting and retention losses, sublimation and evaporation losses are minimized by the season. But in Canada the observation of ice crystals are also considered precipitation; each observation of ice crystals is recorded as a trace of precipitation. Ice crystals are recorded at very low temperatures (usually below -20 ^{o}C) and usually contribute extremely little water equivalent to the precipitation totals. For snow trace adjustment the 0.07 mm value was deemed appropriate in southern Canada. However in the North, the value assigned to solid (snow and ice crystal) trace is both less appropriate and more significant, the 0.07 mm/trace is too high for a typical ice crystal event. An additional complicating factor is that the number of ice crystal events increases as latitude increases while annual precipitation decreases. Thus, the appropriate value for the trace adjustment varies with climate and location. For proper adjustment of trace at different locations, the original 6-hourly archive information were classified based on weather-type information of precipitation occurring when trace was recorded (rain, ice crystal and snow trace). The ratio of the number of ice crystal events to the number of solid precipitation trace events was computed and mapped for the arctic regions. This map generates allowances for trace ranging from 0.07 mm in the south to 0.03 mm at Eureka in the high Arctic. These values correspond to earlier results suggested for Canada and the Arctic Islands by Metcalfe *et al.*(1994).

To accommodate the different number of observations taken within a day, the so called Trace Occurrence Ratio (TOR) was introduced. The ratio is determined based on the comparison of 6 hourly and daily archive trace counts. The average number of 6-hourly trace measurements included in one daily trace flag is used to account for the change in the number of precipitation observations per day (i.e. account for changes in trace measurements related to the changes in the observation frequency).

The average annual trace correction applied in the first generation adjusted precipitation dataset is computed and mapped for each of the 495 stations including only the 1950-2000 period (Figure 1). Since the adjusted trace amount expressed in mm has different relative weight depending on the annual total precipitation, the normalized average trace correction is also computed and mapped for the same interval (Figure 2). Precipitation measured as trace amount (T) may increase the annual total precipitation up to 20% in the Arctic.

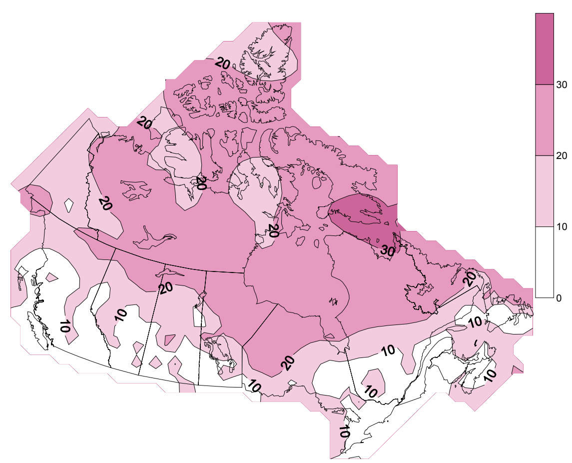


Figure 1. Average annual trace correction of total precipitation [mm] for the 1951-2000 period.

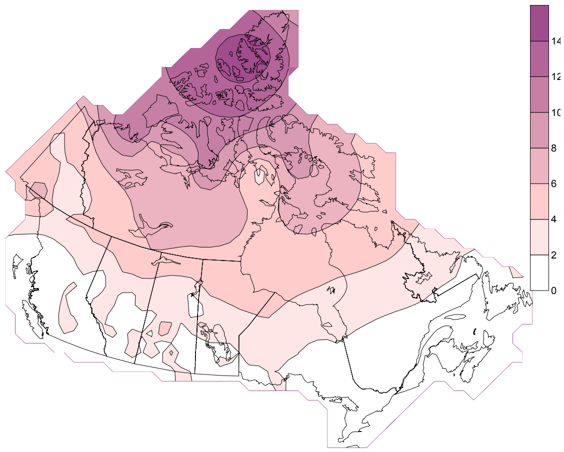


Figure 2. Normalized average annual trace correction [%] of total precipitation for the 1951-2000 period.

4. EFFECT OF TRACE CORRECTION ON SMALL PRECIPITATION AMOUNTS

Since trace precipitation was not consistently measured either in space or in time - in spite of all the above consideration and metadata search - the trace adjustments for each recorded trace flag may have caused artificial inhomogeneities in the current Adjusted Historical Canadian Climate Database (AHCCD). The inhomogeneity may disappear if the observer recorded more rain and snow events in the lower range precipitation instead of trace before the proper definition of the trace precipitation existed. Studying separately the annual time-series of the relatively small adjusted daily precipitation events, including trace adjustments helps to identify the typical characteristics of small precipitation event observations. If the discontinuity is still present in time-series of small precipitation amounts in years when the definition or methodology of trace observation changed, then the trace adjustment procedure needs further refinement.

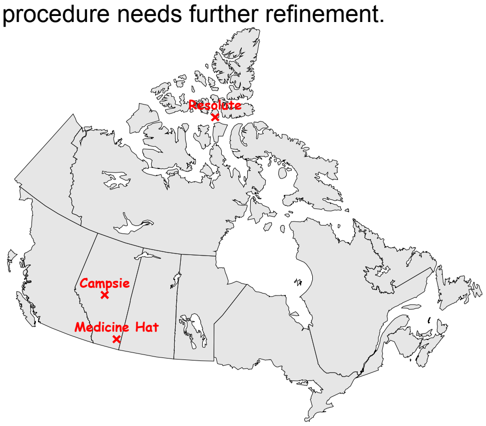


Figure 3. Case study locations.

Three case studies representing different station categories and areas are included here. The locations are plotted on Figure 3. Resolute and Medicine Hat are Class 1 stations, which mean that a full set of instruments were available and the stations were inspected annually. Alternatively, Campsie is a volunteer site (climate station) where precipitation and temperature are measured, and the site is only inspected every 3-5 years. The daily rain and snow observations were obtained from the dly04 Canadian National Archive and all the adjustments described in (Mekis and Hogg, 1999) were then applied. The individual annual time-series were obtained by summarizing only those less than 0.5 mm, 1 mm and 5 mm events separately. The annual number of daily trace observations were also plotted to identify the major dates when changes occurred.

The results for Resolute are presented on Figure 4. Resolute is a Class 1 station located on the high Arctic. Since the precipitation observations started only in 1947, the synoptic program has always had four observations per day. The observation of trace was quite frequent; the average annual trace count is close to 200 out of the 365 days (trace occurred every second day on an average). A small jump can be seen in the number of trace observations around 1960, which is followed by a quite stable annual trace observation frequency (Figure 4/d). Due to the high probability of ice crystal events (63 % of all events), the applied trace correction factor is as low as 0.04 mm per event. The annual average total precipitation is extremely low (230 mm) and the precipitation falls quite often in the form of light precipitation (the annual average of 5 mm or smaller events is 158 mm) (Figure 4/c). The slightly increasing trend in the number of trace observations is not visible in the records of small precipitation (equal or smaller than 5 mm) events.

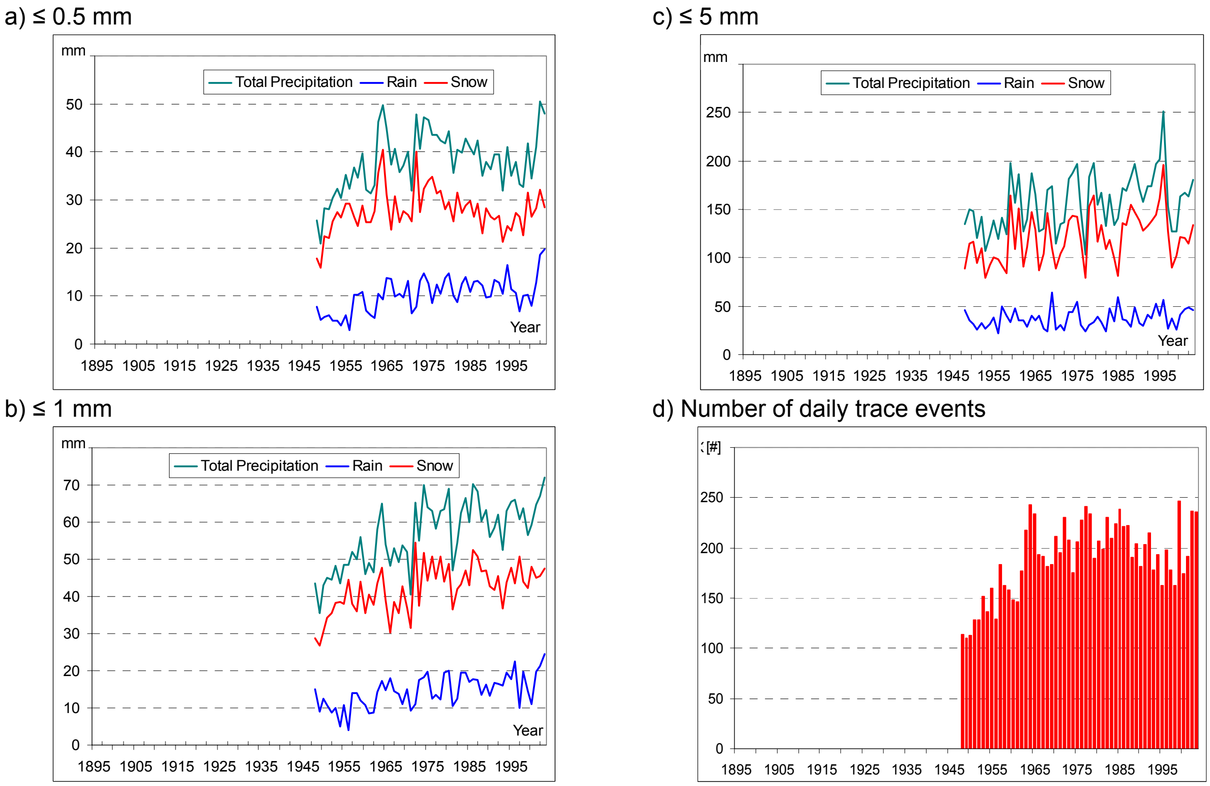


Figure 4. Annual total of adjusted daily precipitation events at Resolute.

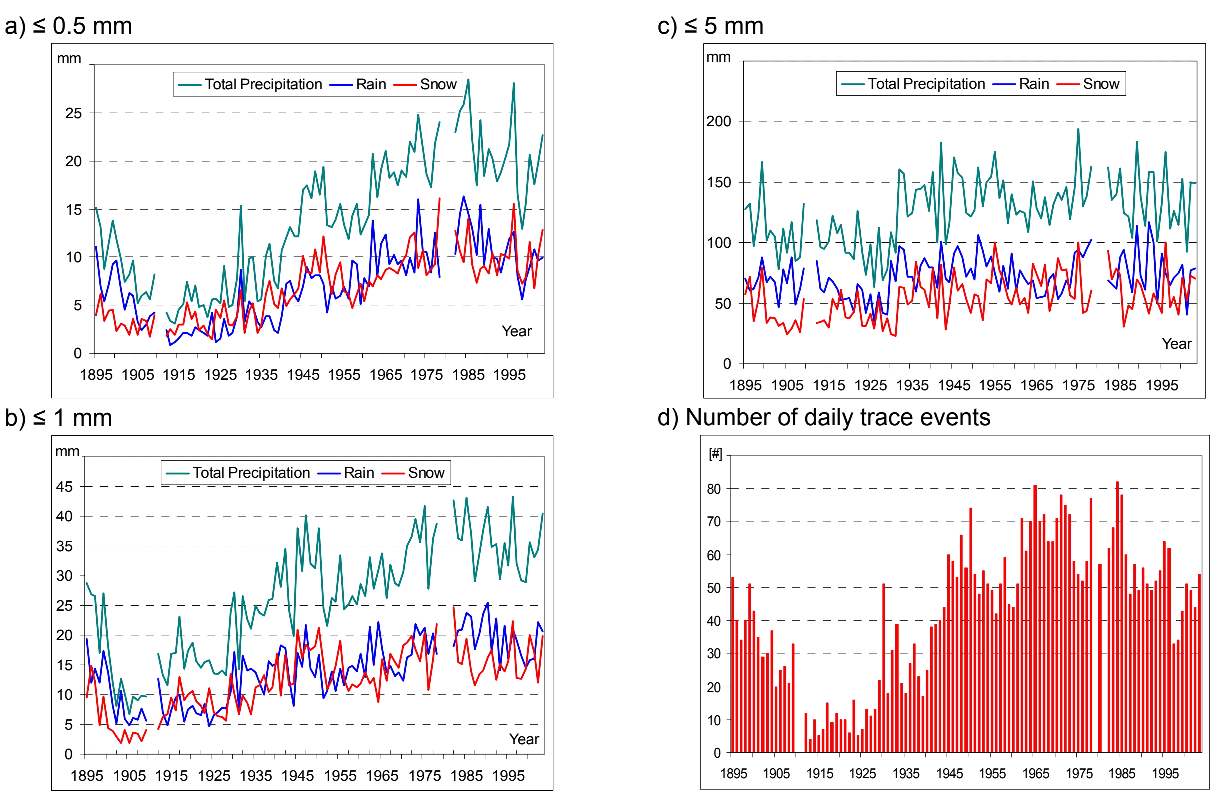
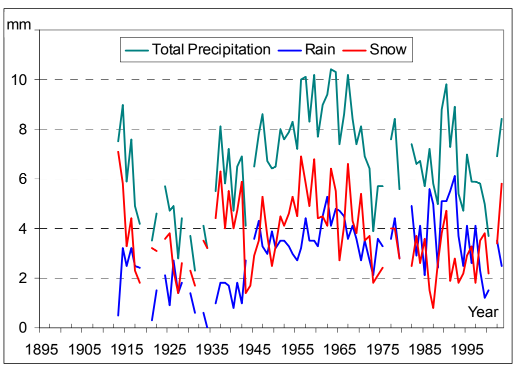


Figure 5. Annual total of adjusted daily precipitation events at Medicine Hat.

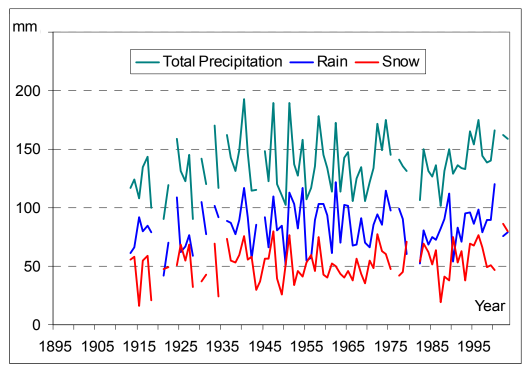
Medicine Hat is also a synoptic station, located in southern Alberta. The record starts as early as 1883; it was always a first order station. The annual total precipitation is around 600 - 700 mm, trace observations occurred only on every fifth day on an average. The record is quite consistent, but the number of observations per day changed through the time. Before 1924 the observation was taken at 0700 LST only once per day. Then the frequency increased to two daily observations. It is only in January 1, 1941 when the 4 observation per day program was introduced. The variability of trace count is also inconsistent (Figure 5/d). The lower number of trace observations may effect the sum of the 0.5 mm or smaller events (Figure 5/a), but the connection is less obvious if the limit is increased up to the 5 mm events (Figure 5/c).

The third station studied, Campsie is a climate station, where measurements were always taken by a volunteer observer. On this site the effect of different instructions and a switch from once per day to twice per day measurements is possible (not documented). The frequency of trace observation is again low compared to the Arctic locations (1 observation in every 9 days); the total precipitation is around 500 – 600 mm annually. The graph of the number of daily trace events (Figure 6/d) shows an obvious step at 1945 which can be still be detected in the total of ≤ 0.5 mm events (Figure 6/a). But the step is not visible when the limit is increased to 1mm (Figure 6/b).

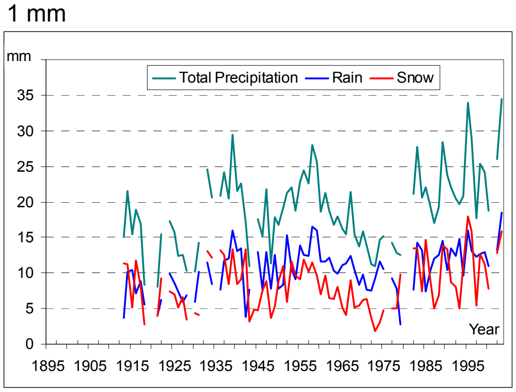
a) ≤ 0.5 mm



c) ≤ 5 mm



b) ≤ 1 mm



d) Number of daily trace events

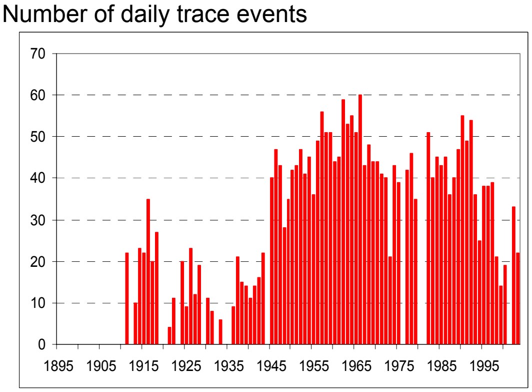


Figure 6. Annual total of adjusted daily precipitation events at Campsie.

5. CONCLUSION

The inconsistent trace recording in Canada both in time and space makes it difficult to adjust for traces in the historical climate dataset. The thorough review of available manuals and instructions on trace observations helped us to identify important dates and issues that must be known for proper adjustments. But it is also possible, that the observer was recording small amounts of rain or snow with higher frequency instead of trace observations. Three locations were selected to study the small precipitation amounts together with adjusted trace events. It has been found that by increasing the limit the pronounced step around the years where the trace observation count jumped up or down decreased or diminished. But it is also true, that each station have different characteristics. Trace correction is most important in the north, where more than 10% of annual precipitation falls in the form of trace. These stations usually have a more consistent trace record, since the stations operated only in the second half of the century when the trace observation was included in the official manuals. Searching the station history files helped us to identify the reasons for discontinuities, and better adjustment takes us closer to the actual water balance cycle which is quite essential for several research areas.

6. ACKNOWLEDGEMENTS

The author wish to acknowledge the extensive contribution of Ken Devine to this project through trace measurement history searches and consultation on measurement procedures. Monique Lapalme also provided invaluable help regarding station history records and metadata information for the case study stations.

7. REFERENCES

Environment Canada, Atmospheric Environment, 1973: Precipitation, AE0063-9057.

Kingston, G.T., 1878: Instructions to Observers Connected With the Meteorological Service of the Dominion of Canada.

Mekis É. and W.D. Hogg, 1999: Rehabilitation and analysis of Canadian daily precipitation time series. Atmosphere-Ocean, 37, 53-85.

Metcalfe, J.R., S. Ishida and B.E. Goodison, 1994: A corrected precipitation archive for the Northwest Territories. Environment Canada - Mackenzie Basin Impact Study, Interim Report #2, 110-117.

Meteorological Branch, 1954: How to measure Rainfall. 63-9056

Meteorological Division, Department of Transport - Canada 1947: Manual of standard procedures and practices for weather observing and reporting, short title MANOBS – Effective 1st January, 1947.

Meteorological Division, Department of Transport - Canada 1949: Manual of standard procedures and practices for weather observing and reporting, MANOBS 2nd Edition – Effective 1st January, 1949.

Meteorological Division, Department of Transport - Canada 1951: Manual of standard procedures and practices for weather observing and reporting, MANOBS 3rd Edition – Effective 1st October, 1951.

Patterson, J., 1930: Instructions to Observers.

Related important links:

Adjusted Historical Canadian Climate Data AHCCD web site: http://www.cccma.bc.ec.gc.ca/hccd/