# JP1.9 ASSESSMENT OF DISCONTINUITIES DUE TO JOINING PRECIPITATION OBSERVATIONS IN CANADA

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## 1. INTRODUCTION

Long-term homogeneous precipitation records are required for climate trend studies. Adjusted precipitation datasets are prepared for the second version of the Adjusted Historical Canadian Climate Database using 462 stations across Canada. Daily rain and snow measurements are adjusted for known issues related to changes in rain gauge type, snow density and trace related problems (Mekis and Hogg 1999). In the most recent work, joining precipitation observations from nearby stations are examined. In Canada, when a station is relocated, a new identification number is often assigned to the new location and the two sites' observation segments can be potentially merged into one. In addition, when a station is closing, it is sometimes possible to find a neighbour with similar climate characteristics and to join the observations to produce a longer time series. When station observations are joined in time and overlapping observations are existing, precipitation adjustments can be derived by from the Simple Ratio Method (Thom 1966). Unfortunately, this method can only be used when there are concurrent observations from both locations over a period of time. This work presents an alternative method to determine if the join of the precipitation station observations has created any artificial step at the join date; adjustment factors for the precipitation time series are also produced.

## 2. DATA AND METHODOLOGY

Annual and monthly total rain and snow are examined separately. In the present study original data from the National Climate Archive of Environment Canada were used to avoid any potential biases introduced by the adjustment procedure. The first step is the search for neighbour stations which can be used to determine if the join has created an artificial step. Distance, elevation and correlation with the base series are carefully considered. The second step consists of reducing the scale of the precipitation values by applying the natural log on the annual and monthly values of the base and neighbour stations. Finally, the difference between the natural log of the base and natural log of each neighbour station is obtained and the means before and after the joining date are compared using a t-test and the 5% significance level to determine if an artificial step exists at the join.

When a significant step is identified in several months and with more than one neighbour on the annual time series, adjusting the base station is then considered. Let $q_1$ and $q_2$ be the means before and after the step detected in the difference log series, then $r = \exp(q_2 - q_1)$ represents the adjustment that should be applied to the base series prior to the step. Since $r$ is a ratio, then all monthly (or annual) values prior the step are multiplied by the adjustment $r$ to produce the new adjusted series.

## 3. EXAMPLE

The precipitation observations of the station Iron River, Alberta were joined in 1954 with those of Cold Lake in order to produce a time series for the 1926-2004 period. The distance between the joined stations is 46 km and the elevation difference is 8 metres. Five neighbour stations were carefully identified for the assessment of the join. They are located at a distance varying from 78 to 142 km from Cold Lake and their correlation with the annual total rain and annual total snow of the base station varies from 0.42 to 0.76 (Table 1).

The monthly and annual time series of the base and five neighbour stations are first transformed using the natural log. Then the difference between the base and each neighbour are obtained. The t-test is used to compare the means of difference natural log series before and after 1954. Table 2 shows the monthly and annual steps with statistically significant steps highlighted. The results indicate that a significant rain step was

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**Table 1:** Information on the base and neighbour stations.

| | Station | Period | Distance (km) | Elevation (m) | Correlation Rain | Correlation Snow |
|---|---|---|---|---|---|---|
| Base | Iron River/Cold Lake | 1926-2004 | | 549/541 | | |
| Neighbour 1 | Elk Point | 1912-1997 | 78 | 605 | 0.64 | 0.62 |
| Neighbour 2 | Ranfurly | 1905-1989 | 140 | 686 | 0.43 | 0.51 |
| Neighbour 3 | Vermillion | 1946-1981 | 124 | 619 | 0.57 | 0.53 |
| Neighbour 4 | St Walburg | 1912-1973 | 112 | 640 | 0.67 | 0.59 |
| Neighbour 5 | Turtleford | 1920-1964 | 142 | 587 | 0.42 | 0.76 |

**Table 2:** Significant steps identified in the difference between the natural log of the base and neighbour stations. The "y" indicates a step significant at 5% level, "n" a non-significant step, and "m" too many missing values to perform the test.

| a) Rain | Jan | Feb | Mar | Avr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elk Point | | | | n | n | n | **y** | n | n | n | | | n |
| Ranfurly | | | | n | n | n | **y** | **y** | n | n | | | n |
| Vermillion | | | | n | n | n | **y** | n | n | n | | | **y** |
| Walburg | | | | n | n | n | n | n | n | n | | | n |
| Turtleford | | | | n | n | n | n | n | n | n | | | n |

| b) Snow | Jan | Feb | Mar | Avr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elk Point | **y** | **y** | n | n | | | | | | n | n | **y** | **y** |
| Ranfurly | **y** | **y** | **y** | n | | | | | | n | **y** | **y** | **y** |
| Vermillion | **y** | n | n | n | | | | | | n | n | n | **y** |
| Walburg | n | n | n | **y** | | | | | | n | n | n | n |
| Turtleford | m | m | m | m | | | | | | m | m | m | m |

identified in July with three neighbours. There is only one station that indicates a significant step in the annual values. However significant step was detected in several snow months using four neighbours. Three stations show a significant step in the annual total snow. The station Turtleford did not have enough snow observations after 1954 to perform the test. Therefore, it seems that the join of the precipitation observations had created a significant step which is more consistent in snow than in rain.

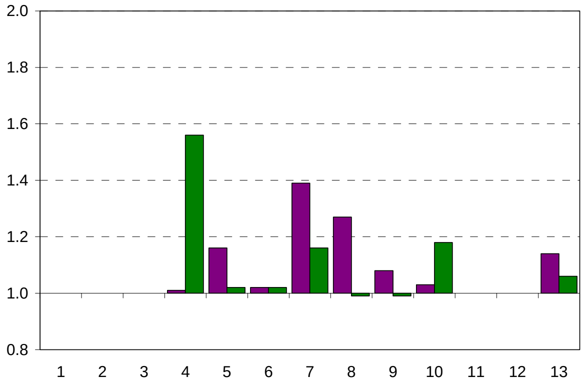
The monthly and annual adjustments *r* values were calculated using each neighbour separately and their average over the five neighbours are presented in Figure 1 (in purple). The monthly rain adjustments are near to 1.0 with the exception of July and August and the annual rain adjustment is 1.14. However, since the means before and after 1954 were not significant, the procedure suggests not adjusting the time series. On the other hand, the snow adjustments are much larger and significant for almost every month. The annual values show a snow adjustment of 1.48. Therefore, the snow time series should be adjusted.

## 4. VALIDATION

To validate this method, all available concurrent observations from both locations, Iron River and Cold Lake, were examined over 1953-1975. The ratios between the monthly and annual rain and snow totals (second segment Cold Lake divided by the first segment Iron River) were averaged over the 23 years and they are presented in Figure 1 (in green). In order to use the monthly ratios, it is important to examine the climate characteristics of the location. There is almost as much rain as snow through the year. The main rainy period extends from May to September, and only 2% of rain falls in the shoulder months of April and October. The typical snowy months of the area are from November to March. For validation purposes only the main rain and snow seasons should be included. In problematic cases, the annual ratio values are suggested to be used for adjustment.

For rain, it seems that the ratios are small and close to one (with the exception of April). There are some difference between the adjustments proposed by the logarithmic method and those obtained by overlap but overall these are all small (Figure 1a). In Figure 2a, the annual total rain of Iron River and Cold Lake are compared. It is obvious that the years with more rain alternate between both stations.

a) rain



b) snow

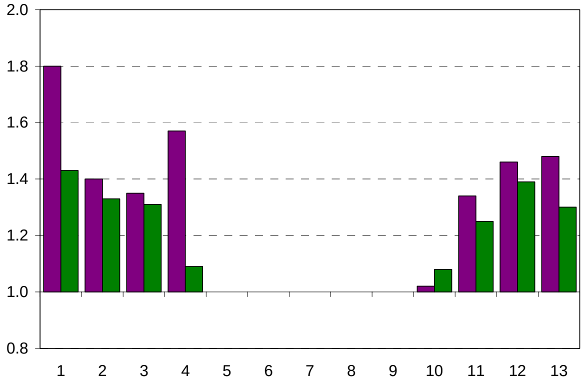
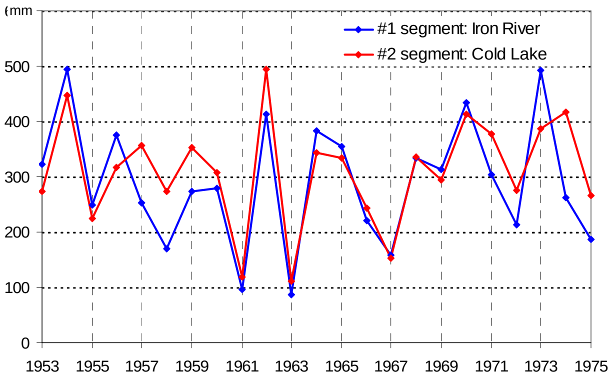


**Figure 1:** Monthly adjustments obtained by the logarithmic method using the neighbour stations (purple) and by overlapping period (green).

For snow, the adjustments obtained by overlap are similar to those proposed by the new logarithmic method (Figure 1b). The annual ratio of the two segments is 1.3 compared to 1.48 computed with the new method. It seems that the logarithmic method suggests more adjustment for January and April than required. But overall the positive step is confirmed by Figure 2b which indicates that the annual total snowfall of Iron River is less than the annual snow of Cold Lake almost every year. Therefore there is a need for adjusting the snow data of Iron River in order to join its observations with those of Cold Lake.

Iron River's annual total snow was adjusted using the ratios obtained with the logarithmic method. Figure 3 shows the original and adjusted time series. Before adjustment, the time series suggests an increase in the annual total snowfall over 1926-2004. However, after adjustment, the series suggests a small decrease which also corresponds to an increase in the temperature trend.

a) rain



b) snow

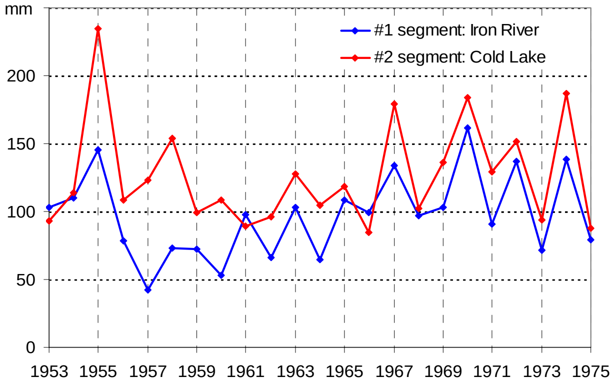


**Figure 2:** Annual total rain and annual total snow for Iron River and Cold Lake.

## 5. CONCLUSION

This study presents a preliminary method for adjusting precipitation observations when two stations are joined together. This method highly depends on the availability and quality of the

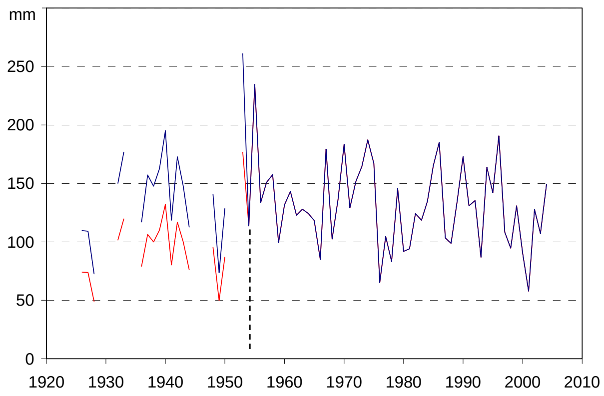


**Figure 3:** Iron River/Cold Lake annual total snow before (red) and after (blue) adjustment.

neighbour stations. In addition, it is suspected that this method does not perform well for the shoulder seasons when many zero rain or snow events occur in the time series and this should be further examined. Future work will involve the application of the logarithmic method to many other cases for which concurrent observations exist for a period of time from both locations. This is required in order to determine if the adjustment ratios are reliable. The final ratios will also be compared to other existing methods. The combination of this method's output and the ratios obtained from the overlapping observations will be considered for the preparation of precipitation datasets for the second version of the Adjusted Historical Canadian Climate Database.

## 6. REFERENCES

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

Thom, H.C.S., 1996: Some methods of climatological analysis. WMO Technical Note No. 81, 7-9.