12.9 CHANGES IN HOURLY SURFACE RELATIVE HUMIDITY MEASUREMENTS AND INSTRUMENTS IN CANADA DURING 1953-2003

Lucie A. Vincent* and William A. van Wijngaarden**
*Climate Research Branch, Meteorological Service of Canada, Toronto

1. INTRODUCTION

Changes in instruments, observers and observing practices can create artificial discontinuities in a climatological time series which in consequence can affect the proper assessment of climate trends and interfere with the detection of any real climate change. In Canada, careful examination of temperature and precipitation time series has been made. Changes in instruments exposure and in observing time were often the prime source of discontinuities in the time series computed from daily temperature (Vincent and Gullett, 1999). For precipitation, daily observations are affected by changes in gauges since each gauge type has its own response to wind and wetting loss, and adjustments were applied to daily measured rain and snow amounts (Mekis and Hogg, 1999).

In this study, the relative humidity observations are examined for potential discontinuities due to known changes in instruments and observing procedures. After a detailed investigation of the historical records, it was found that the main changes related to relative humidity include the refinement of the psychrometric tables in the 1960s and the replacement of the psychrometer by the dewcel in the 1970s. This report summarizes how these changes affect the data.

2. DATA AND METHODS

Hourly relative humidity observations were retrieved from the National Climate Data Archive of the Meteorological Service of Canada for 75 airports stations across the country. A station was included if it has operated for a minimum of 40 years during 1953-2003. In addition, the data were checked to ensure than less than 1% of the hourly values were missing; this criteria was relaxed to 5% for the stations in the Arctic.

Corresponding authors address: *Lucie A. Vincent, Climate Research Branch, Meteorological Service of Canada, 4905 Dufferin St., Toronto, Ontario, M3H 5T4; email: Lucie.Vincent@ec.gc.ca

**William A. van Wijngaarden, Physics Dept., York University, 4700 Keele St., Toronto, Ontario, M3J 1P3; email: wlaser@yorku.ca

2.1 Relative humidity histograms

To determine if any major changes in measurements or observing procedures have considerably affected the frequency of the hourly observations over time, histograms were produced and analyzed. The histograms were produced for each decade as follows. Hourly values of relative humidity from the 75 stations were sorted into intervals of 1% and the frequency of observations was obtained for each season. Each curve was normalized to unity which equals the probability sum of observing all possible relative humidity values.

2.2 Detection of steps

A procedure was also applied to determine if the introduction of the dewcel in the 1970s created an artificial discontinuity at the installation date in the seasonal relative humidity series. The procedure consisted of applying two regression models. Model 1 describes an overall trend in a time series while Model 2 describes an overall trend as well as a step occurring at the installation date. Model 1 is given by the following:

$$y_i = a_1 + b_1 t_i + e_i \qquad (1).$$

Here y_i is the seasonal relative humidity for year t_i and e_i is the residual. The estimate of the slope is given by b_1. Model 2 was next applied to the same time series:

$$y_i = a_2 + b_2 t_i + c_2 I + e_i \qquad (2).$$

The estimate of the slope before and after the step is given by b_2. The variable I takes the value zero before the dewcel installation date and one afterwards. The magnitude of the step is given by the parameter c_2.

Models 1 and 2 were compared to determine if the introduction of the variable I (which describes a potential step) substantially improves the fit to the data. The statistic F was obtained:

$$F = [SSE_1 – SSE_2] / [SSE_2 / (n - 3)] \qquad (3).$$

SSE_1 and SSE_2 are the sums of squared errors for models 1 and 2 respectively and n is the number of data points. Model 2 was accepted if the F-statistic exceeds the 95 percentile of the F-distribution with 1 and n-3 degrees of freedom (Neter et al 1985) which suggests a significant step at the dewcel installation date.

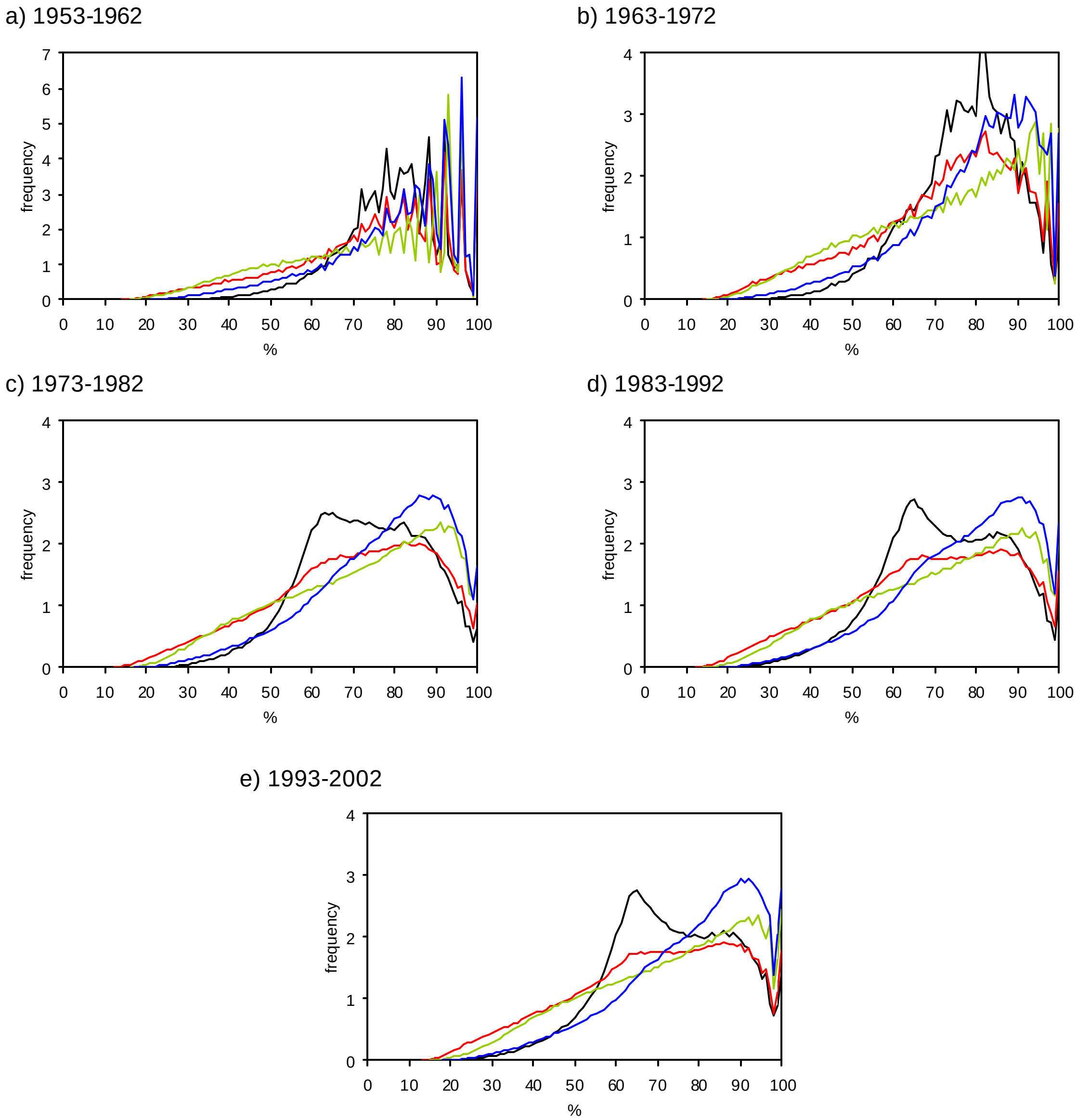

Figure 1. Relative humidity histogram (winter – black; spring – red; summer – green; fall – blue). The frequency is plotted versus the relative humidity.

3. RESULTS

3.1 Refinement of the psychrometer tables

The histograms are presented in Figure 1. Over the 1953-1962 decade, high frequencies of relative humidity occur at fixed values such as 100%, 96% and 93%. This continues in the 1963-1972 decade but to a lesser extent. This is associated with the change in psychrometric tables in the 1960s. Psychrometric tables determined the relative humidity from the observed wet/dry bulb temperatures. The psychrometric tables used until the 1960s had large increments for the temperatures and certain relative humidity values occurred more frequently than others.

In the 1960s, the tables were refined to provide smaller increments of the temperature. Therefore, the histograms show that after the 1960s, the relative humidity frequency curves are smoother. However, since the overall shape of the histograms has not considerably changed over the various decades, it is concluded that the refinement of the psychrometric tables does not produce a major impact on the relative humidity trends.

3.2 Replacement of the psychrometer by the dewcel

Figure 1 also shows a considerable increase in the frequency of relative humidity occurring near 60%,

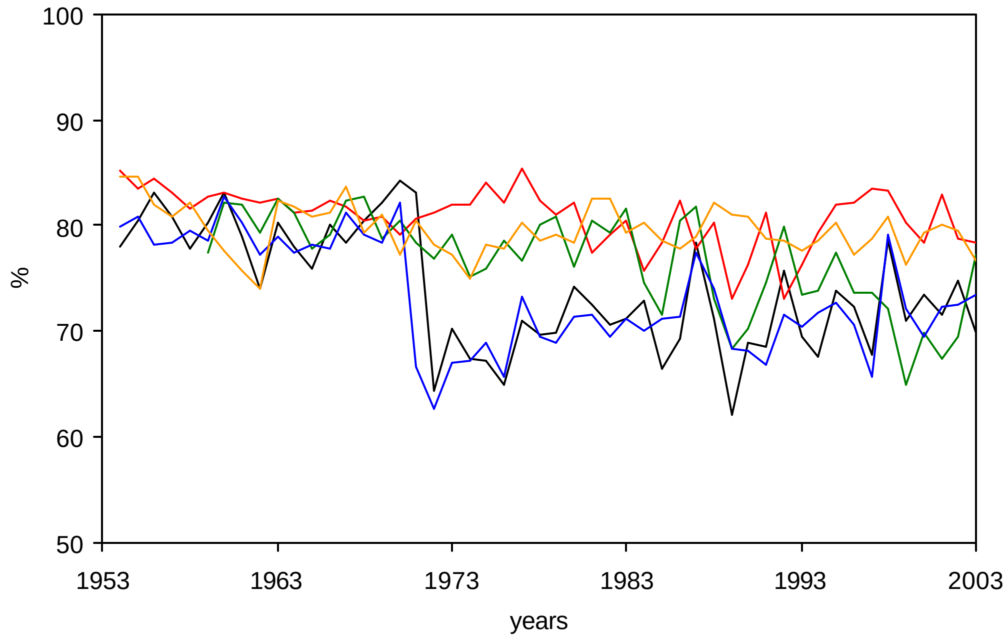

Figure 2. Winter relative humidity time series over 1953-2003. Dates of dewcel installation are: The Pas – 1971 (black), Hay River – 1970 (blue), Peace River - 1993 (green), and Wiarton – 1975 (red). A dewcel has never been used at Greenwood (orange).

mostly in the winter starting from the 1973-1982 decade. This increase appears to be associated with the introduction of the dewcel in the 1970s. Concerns have been expressed regarding the reliability of the psychrometer relative humidity observations particularly in producing higher values of relative humidity at very cold temperatures (Déry and Steiglitz, 2002; Anderson, 1994; and Makkonen, 1996).

The seasonal relative humidity time series at individual stations were visually inspected. A decreasing step was identified in the early 1970s in the winter at several sites. Figure 2 provides the winter time series for five stations. In this figure, the stations The Pas and Hay River clearly show a decreasing step at the dewcel installation date. Dewcel installation dates were found from the historical records for 58 of the 75 stations.

The statistical procedure described in section 2.1 was applied to all seasonal time series for these 58 stations. Figure 3 shows the significant F-statistics exceeding the threshold value. These correspond to the stations for which model 2 was accepted. The magnitude of the F-statistic was found to be proportional to the step magnitude. All identified steps represent a sudden decrease in relative humidity (i.e. with $c_2 < 0$) with the single exception of an increasing step which occurs at Estevan during the summer (located in southern Canada). The figure shows that the steps are generally larger during the winter and spring. In fact, the magnitude of the step varies from -3.5% to -18.3% in winter and from -3.4% to -11.4% in the spring. It seems that dewcel steps are associated with stations experiencing cold temperatures. Indeed, all Arctic stations north of 60^o N latitude experience a dewcel step during winter and spring. In contrast, southern and coastal stations seem to be less affected.

4. CONCLUSION

It is critical to examine the relative humidity data for discontinuities due to changes in procedure and instruments in order to produce a reliable assessment of the trends. It appears that the refinement of the psychrometric tables has not affected the relative humidity trends but that the introduction of the dewcel has created a significant decreasing step at many stations experiencing cold temperatures. These concerns have to be taken into consideration before a proper assessment of the trends in relative humidity (van Wijngaarden and Vincent, 2004).

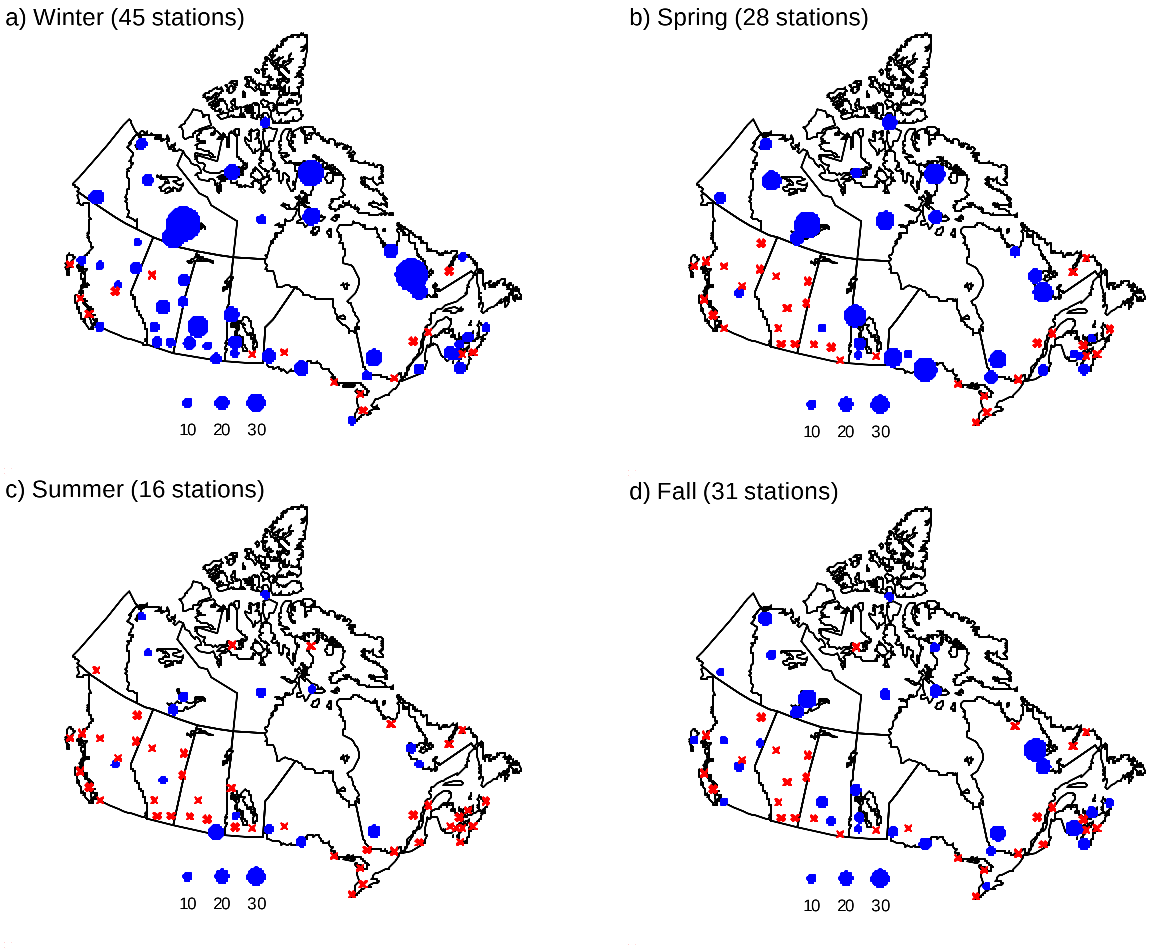

Figure 3. F-statistic exceeding the significant threshold. The number of stations experiencing a dewcel step is given in brackets. Crosses represent stations not having a dewcel step.

5. REFERENCES

Anderson, P. S., 1994: A Method for Rescaling Humidity Sensors at Temperatures well below Freezing. *Journal of Atmospheric and Oceanic Technology,* 11, 1388-1391.

Déry, S. and M. Steiglitz, 2002: A Note on Surface Humidity Measurements in the Cold Canadian Environment, Boundary-Layer Meteorology, 102, 491-497.

Makkonen, L, 1996: Comments on a Method for Rescaling Humidity Sensors at Temperatures Well below Freezing. Journal of Atmospheric and Oceanic Technology, 13, 911-912.

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

Neter, J., W. Wasserman, and M. H. Kutner, 1985: Applied Linear Statistical Models. Second Edition. Irwin, 1127 pp.

Van Wijngaarden, W.A., and L.A. Vincent, 2004: Examination of discontinuities in hourly surface relative humidity in Canada during 1953-2003. Submitted to the Journal of Climate.

Vincent, L. A., and D.W. Gullett, 1999: Canadian historical and homogeneous temperature datasets for climate change analyses. International Journal of Climatology, 19, 1375-1388.