4.4 EXAMINATION OF POTENTIAL BIASES IN RADIOSONDE TEMPERATURE AND HUMIDITY RECORDS IN CANADA

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1. INTRODUCTION

It is well known that changes in instruments and in observing practices can create artificial discontinuities in climate time series. In Canada, considerable work has been done on the homogenization of surface temperature and adjustments of precipitation. For temperature, a statistical procedure was applied to detect and adjust discontinuities due to change in instrument exposure and observing time (Vincent et al. 1998). For precipitation, adjustments were applied for known changes in instruments since each gauge has its own characteristic for wetting loss and response to wind (Mekis and Hogg 1999). The detection and adjustment of artificial steps can be quite difficult at times, in particular when the observations are to a large extent based on subjective assessment which is often the case for certain cloud elements (Milewska 2004).

Changes in instrument type and in radiation correction are the most obvious sources of discontinuities in radiosonde temperature (Gaffen 1994). These changes do not always produce steps of the same magnitude and direction and their impact may differ with altitude. For example, high-altitude sensing instruments may have a high bias due to poor ventilation and radiation error, and caution is advised when stratospheric trends computed on raw observations show cooling. For humidity, the introduction of new sensors and changes in data processing are the prime cause of discontinuities (Elliott and Gaffen 1991). A good history of the upper stations facilitates the identification of the problems. However, such reports are not readily available in Canada and it is often necessary to contact directly technicians and inspectors to assemble enough information in order to reconstruct the history.

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This study presents a preliminary assessment of the potential biases in the radiosonde temperature and humidity records in Canada. It attempts to determine the main sources of biases although a meticulous homogeneity assessment remains to be done at individual station. More work is certainly required to fully understand the impact of the identified changes on the radiosonde data and to properly adjust the time series for a better estimate of the climate trend.

2. DATA AND METHODOLOGY

Radiosonde observations have been taken at more than 50 locations across the country since the early 1960s. However, only 20 stations were used in this study since their record covered the 1961-2004 period. Temperature, altitude and relative humidity were observed every day at 00 and 12 GMT. These observations were retrieved from the National Climate Data Archive of Environment Canada at 13 pressure levels (surface, 95, 85, 70, 50, 25, 20 15, 10, 5, 2, 1 and 0.2 kPa). Values taken at 00 and 12 GMT were examined separately. Monthly averages were obtained if less than 10 values were missing in a month. Annual and seasonal averages were computed only if all months were present. The seasons were defined as follows: winter (December of the previous year to February), spring (March to May), summer (June to August) and fall (September to November). Averages of 00 and 12 GMT were also computed for each time period.

For upper air stations, it is expected that systematic network-wide changes in instrument type and observing practices will affect the stations over a common time interval. Therefore, the preliminary assessment consisted of a visual inspection of the national time series. In this way, a main bias affecting most stations could be visually identified. Departures from the 1971-2000 were obtained at each station, and then station departures were averaged together to generate national time series. The national series graphs were produced for temperature and relative humidity, 00 GMT, 12 GMT, and average of 00 and 12 GMT, for annual and seasonal means and the 13 pressure levels separately: all together, a total of 390 graphs were examined for the identification of discontinuities.

3. RESULTS

3.1 Temperature

The national temperature departures for annual and summer means are presented in Figure 1 for six pressures levels. The series shows a warming of the troposphere over 1961-2004 which is mostly evident at the surface, 95, 85, 70 and 50 kPa, but the trends are becoming less pronounced at higher elevation in the atmosphere. The transition zone between the troposphere and stratosphere shows very little temperature change (25, 20 and 15 kPa). A cooling is then observed in the lower levels of the stratosphere (10, 5 and 2 kPa), which become more pronounced with higher pressure levels. These trends are generally observed in all annual and seasonal means. Many missing values occur at 1 and 0.2 kPa which interfere with the interpretation of the results.

An increasing step (or a change in variability) is often observed in 1995 in the lower levels of the troposphere (surface, 95 and 85 kPa). The step seems to be more evident in the summer, fall, and winter and it is visible for 00 and 12 GMT. On the other hand, there is a decreasing step in 1995 in the lower to middle stratosphere (5, 2 and 1 kPa) which is mostly evident in the annual and spring means. A second decreasing step is also observed in 1984 in the lower to middle stratosphere mainly during the summer and fall (Figure 1).

Our incomplete recollection of the station history indicates that 1980s and 1990s were years of important changes in the Canadian upper air station network. From June 1980 to May 1981, the ADRES-GMD system was implemented at all stations. This was a semi-automated system that did not require as much data processing from the observers. From mid-1980s to mid-1990s, ADRES-GMD was gradually replaced by NAVAID systems from Beukers-VIZ and Vaisala (Loran-C, OMEGA and VLF) at first, and later by Vaisala alone. Bulk of the conversions happened in early 1990s. By mid 1990s most stations were switched to Vaisala systems and RS-80 radiosondes (Gurdebeke 2006). It seems that the decreasing step in 1995 detected in the stratosphere could be due to the introduction of a radiation correction implemented in the RS-80 system (Devine 2006). The few remaining stations were converted to Vaisala in 1999. Since then there is basically no manual intervention with the collected and archived observations, although there is still quality assessment done for atmospheric models.

3.2 Relative humidity

The national relative humidity departures for the annual and summer means are presented in Figure 2 for the six same pressure levels. It is impossible to determine if there are any consistent trends over 1961-2004 since the data show several major discontinuities. An increasing step is observed in 1967 in annual, winter, spring, and fall means of the troposphere (95, 85, and 70 kPa) in both 00 and 12 GMT values; another increasing step becomes apparent in 1974 during the spring and summer (Figure 2). In the stratosphere (levels 25 kPa and higher), there are very few relative humidity observations made prior to the beginning of the 1980s. As in temperature, a step is visible around 1995. Its direction is down in most cases, but its magnitude vary greatly from a season to season, and for the different pressure levels. For example, at 20, 15 and 10 kPa levels the relative humidity step identified in 1995 is decreasing by about 8 to 10%.

The station history indicates that during 1966 to 1968, the lithium chloride was replaced by the carbon element in the humidity sensors. In 1973, it seems that a new humidity duct was introduced to improve the readings at high solar elevation angle. Finally by 1995, most sensors were switched to humicap during conversion to Vaisala RS-80.

4. CONCLUSION AND FUTURE WORK

This work presents a preliminary assessment of the potential biases in radiosonde temperature and humidity records in Canada. The temperature time series suggest warming of the troposphere and cooling of the stratosphere over 1961-2004. However, the magnitude of the trends is affected by instrument and practices changes and further work is required to homogenize the time series. It is almost impossible to determine if there are any consistent changes in relative humidity since the time series show several major steps during 1961-2004 and they are also in need of adjustment.

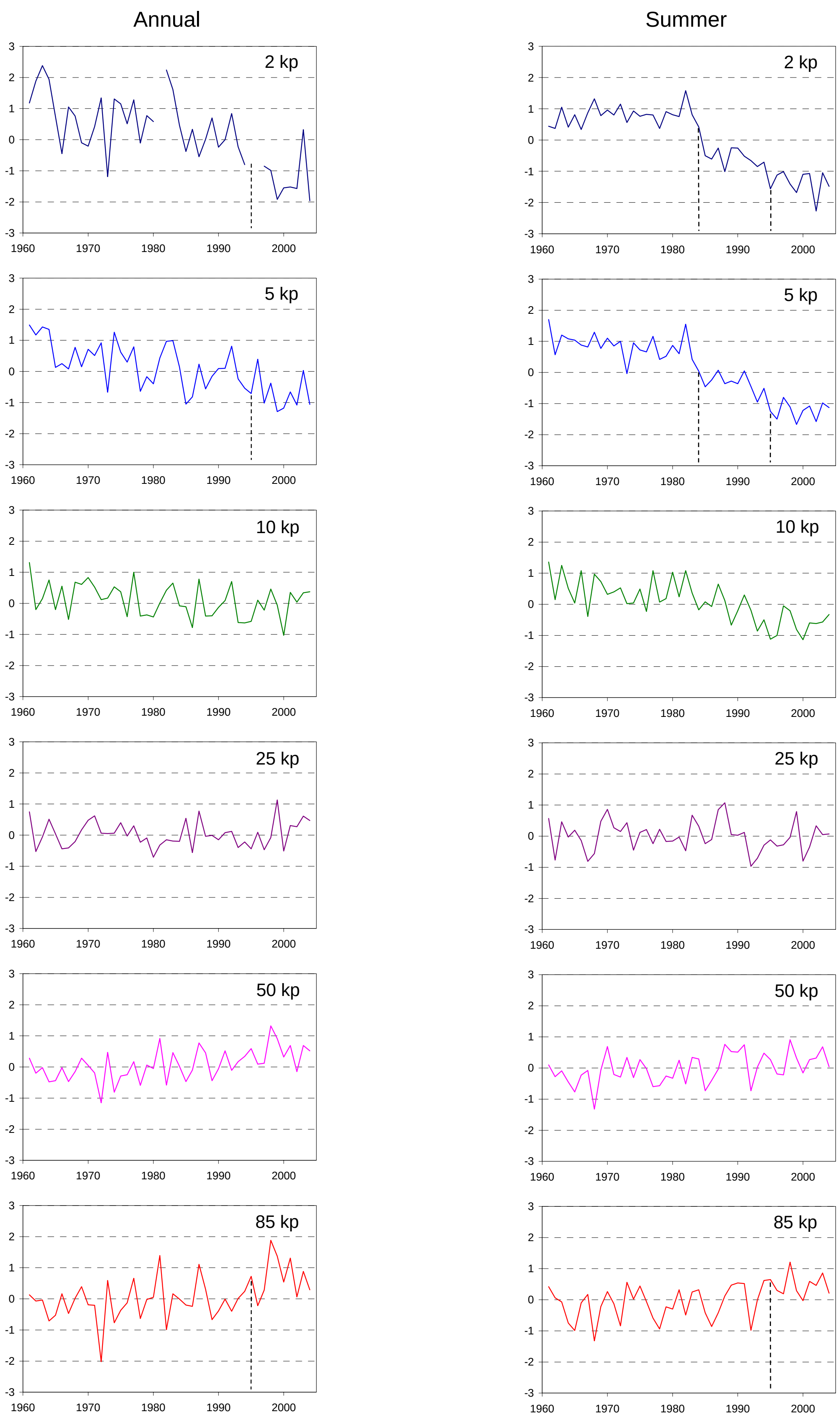

Figure 1: National temperature departures for 6 pressure levels (°C). Observations taken at 12 GMT.

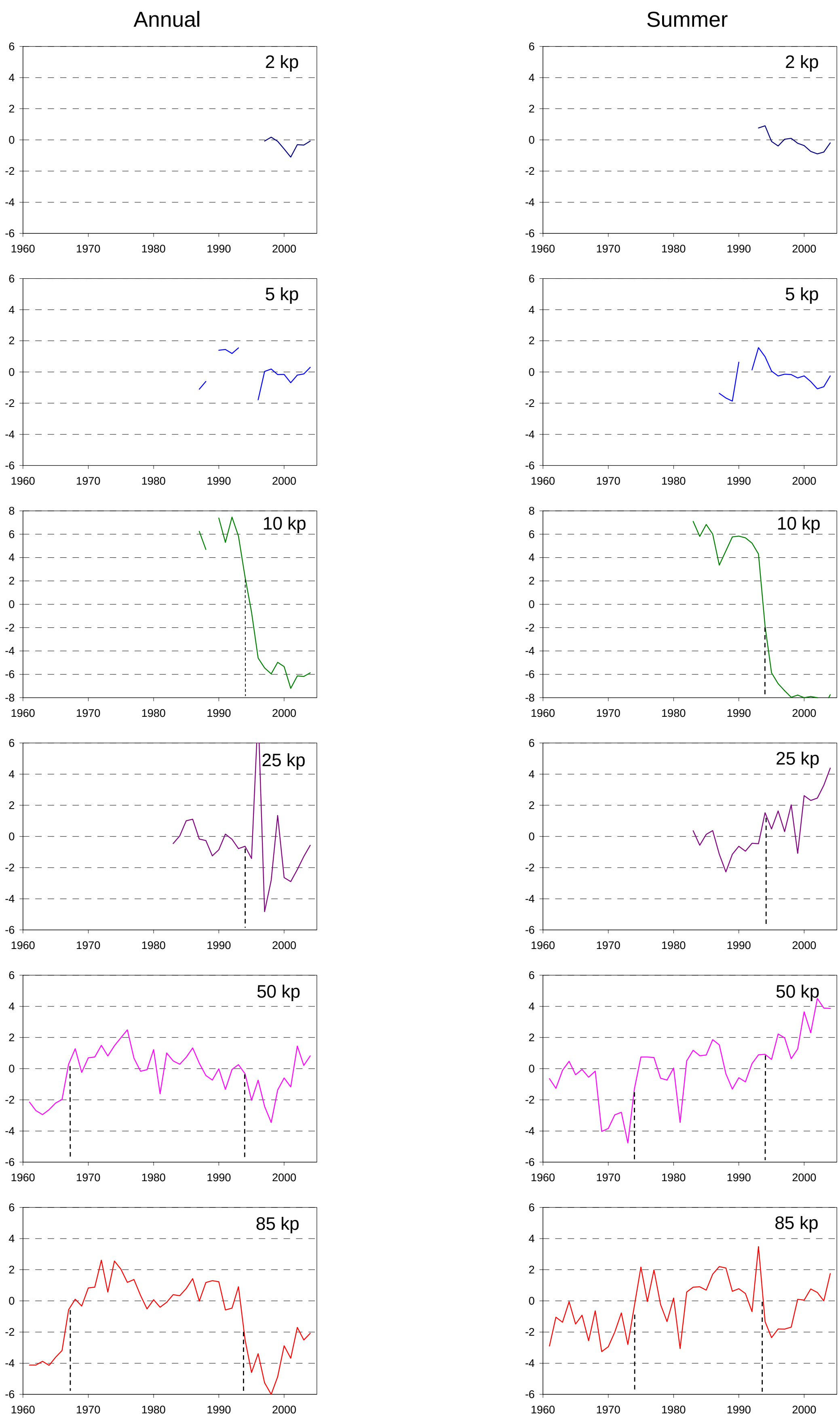

Figure 2: National relative humidity departures for 6 pressure levels (%). Observations taken at 12 GMT.

Future work will involve the detection of discontinuities at individual stations using an approach based on regression models. The station monthly anomalies will be closely examined to identify the dates of the potential changes. In addition, a more complete history of the upper air stations will be prepared to better understand the cause of the steps and to facilitate a more accurate adjustment.

5. REFERENCES

Devine, K. 2006. Historical changes in the Canadian Upper Air Network. Personal communication.

Elliott, W.P. and D.J. Gaffen, 1991: On the utility of radiosonde humidity archives for climate studies, Bulletin of the American Meteorological Society, 72, 1507-1520.

Gaffen D.J., 1994: Temporal inhomogeneities in radiosonde temperature records, Journal of Geophysical Research, 99, 3667-3676.

Gurdebeke, T. 2006. Instrumentation Changes Affecting the Aerological Network. 2006. Meteorological Service of Canada. Internal Report, 2 pp.

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

Milewska E. J., 2004: Baseline cloudiness trends in Canada 1953-2002, Atmosphere-Ocean, 42(4), 267-280.

Vincent, L.A., X. Zhang, B.R. Bonsal and W.D. Hogg, 2002: Homogenization of daily temperatures over Canada. Journal of Climate, 15, 1322-1334.