ARCTIC TEMPERATURE TRENDS FROM THE EARLY 19TH CENTURY TO THE PRESENT

William A. van Wijngaarden*
Physics Department, York University, Toronto, Ontario, Canada

1. INTRODUCTION

The rate of average global temperature increase has slowed over the past 15 years but the Arctic appears to be experiencing continued warming (Jeffries et al, 2013; Walsh et al, 2011). This has resulted in record low observations for the extent of the Arctic summer ice cap and record melting of Greenland's ice sheet (NSIDC, 2014).

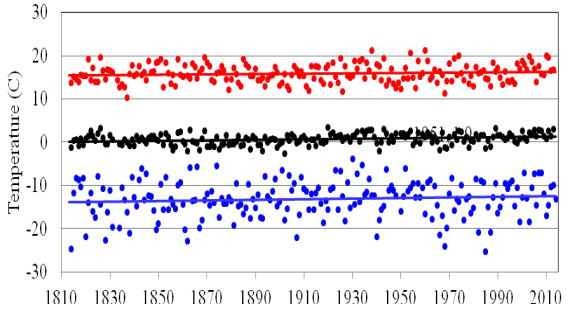
Our group analyzed surface temperatures observed at over 300 stations in North America during 1948-2010 and found stations in Alaska and the Canadian Arctic experienced greater warming in winter than in summer (Isaac and van Wijngaarden, 2012). Recently, we analyzed data at 27 Canadian Arctic stations (van Wijngaarden, 2014a). For each station the difference between the temperature relative to the average found during 1961-1990 was found. The resulting temperature change averaged over all stations was plotted to give a time series covering the period 1895-2014. Trends were found for the January, July and annual temperatures of 3.1, 1.6 and 1.9 ^{o}C per century, respectively. The trend depends on the time period considered due to decadal fluctuations. The annual temperature trend was only 0.4 ^{o}C per century during 1915-1995.

2. DATA DESCRIPTION

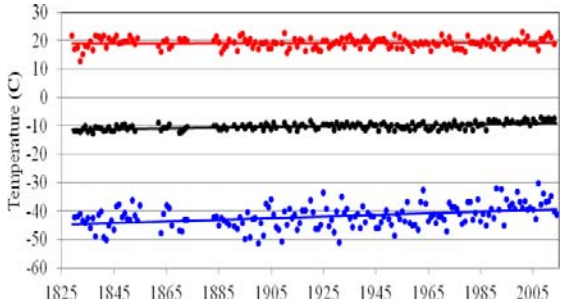
This study examined monthly temperature records archived by the Royal Dutch Archive (KNMI 2014) observed at 118 stations as shown in Fig. 1 (van Wijngaarden, 2014b). A few of these stations had data extending more than 200 years. The average data period for the Arctic stations was 100 years, with recorded observations available for over 90% of all months. The data periods were shorter for Canadian stations, a number of which only began operation after 1940. These were included as the Canadian Arctic archipelago together with Greenland, constitutes the most northerly located land mass. Fig. 2 shows data for four Arctic stations that are located in different quadrants of the Arctic.

Fig. 1: Locations of Arctic stations examined.

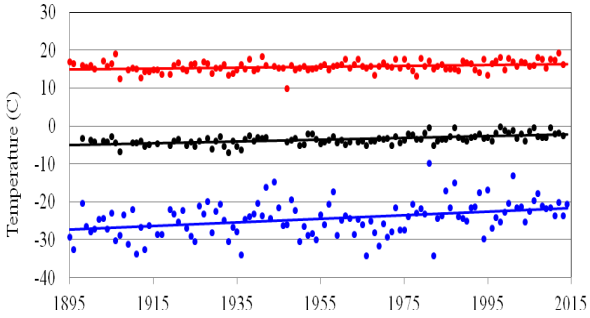
a) Archangel'sk, Russia



b) Jakutsk, Russia



c) Hay River, Canada



*Physics Dept., Petrie Bldg., York University, 4700 Keele St., Toronto, ON, Canada, M3J 1P3; e-mail: wlaser@yorku.ca

d) Sykkisholmur, Iceland

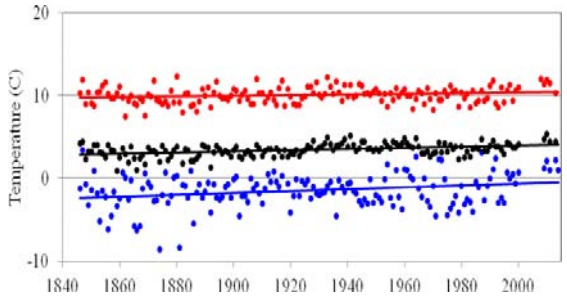
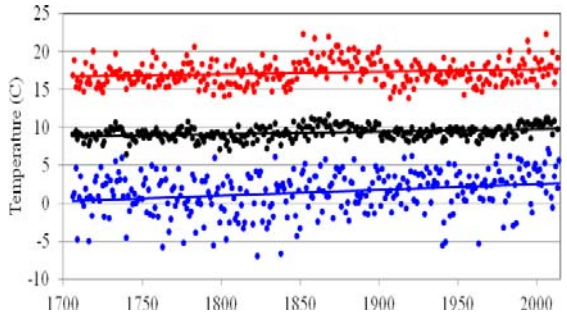


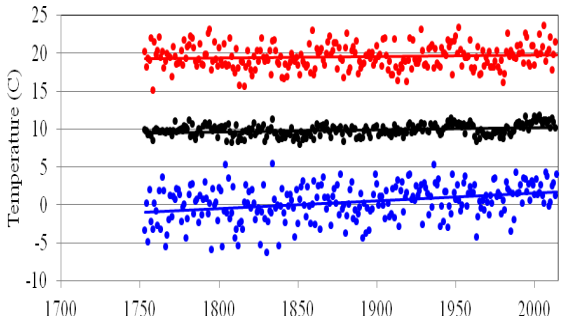
Fig. 2: Temperature time series for January (blue), July (red) and annual (black). For Archangel'sk the trendline slopes are 0.6, 0.4 and 0.6 °C per century for the January, July and annual data, respectively. The corresponding January, July and annual trends in units of °C per century are: 2.9, 0.1 and 1.3 at Jakutsk; 4.9, 1.1 and 2.4 at Hay River; and 1.1, 0.4 and 0.7 at Stykkisholmur.

Temperatures were also studied for 50 European stations that constitute the world's longest record of temperature observations. An average of over 200 years of data with observations listed for over 95% of all months was available for each station. A few stations had over 300 years of data. Fig. 3 shows data for 3 stations.

a) De Bilt, Netherlands



b) Geneva, Switzerland



c) St. Petersburg, Russia

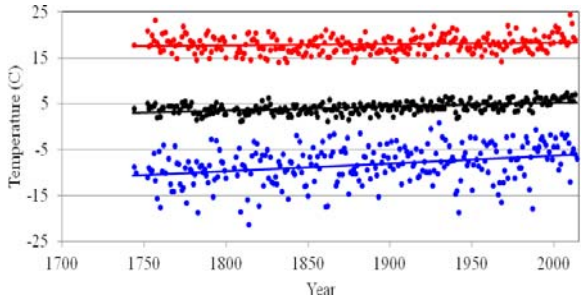


Fig. 3: Temperature time series for January (blue), July (red) and annual (black). For De Bilt, the trendline slopes are 0.8, 0.3 and 0.3 °C per century for the January, July and annual data, respectively. The corresponding January, July and annual trends in units of °C per century are: 1.0, 0.2 and 0.3 at Geneva and 1.7, 0.3 and 0.9 at St. Petersburg.

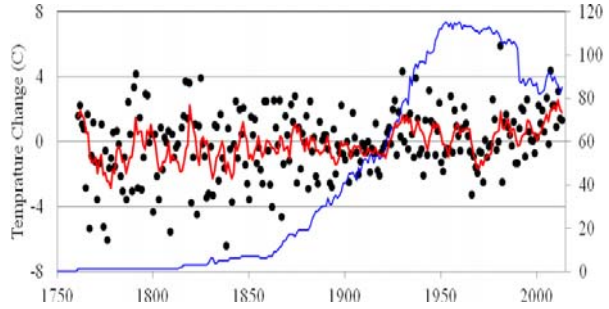
3. DATA ANALYSIS AND RESULTS

Trends were found for the January, July and annual temperatures. The annual temperature was only computed if all monthly values for a given year were present. Station measurements were sometimes missing during periods of great civil strife, notably the Second World War and the Russian Revolution. A significant number of stations closed during the 1990s as a result of the breakup of the Soviet Union and reduced government funding in Canada and the U.S. The temperature change relative to 1961-1990 was found at each station.

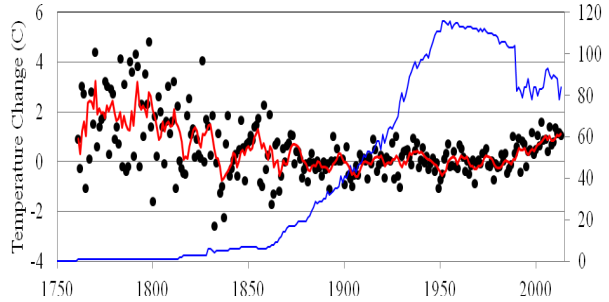
The stations shown in Fig. 2 have very different climates, yet all have experienced rising temperatures. January temperatures trends are significantly greater than those for July although the year to year scatter of January temperatures is much larger. Only seven of the 118 Arctic stations had negative annual temperature trends and about two thirds of the stations had larger January than July temperature trends.

The temperature change averaged over all 118 stations is shown in Fig. 4. Prior to 1820, there is significant scatter in the data because data is available from very few stations. The trends listed in Table I are strongly affected by the period considered due to decadal fluctuations such as the rise in temperatures evident during the 1990s.

a) January



b) July



c) Annual

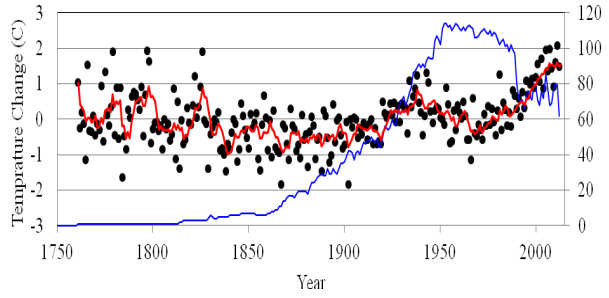


Fig. 4: Temperature Change for a) January, b) July and c) Annual relative to the temperature during 1961 to 1990 for Arctic stations. The red curve is the moving 5 year average while the blue curve is the number of stations.

The annual temperature trends were also examined for the four different longitudinal quadrants of the Arctic. The trends in units of ^{o}C per century for the period 1900-2014 are 1.0 (Northern Europe), 1.6 (Western and Central Siberia), 1.6 (Far Eastern Siberia, Alaska and Western Canada) and 1.0 (Eastern Canada, Greenland and Iceland). During the 1900s, all four regions experienced increasing temperatures until about 1940. Temperatures then decreased by about 1 ^{o}C over the next 50 years before rising in the 1990s.

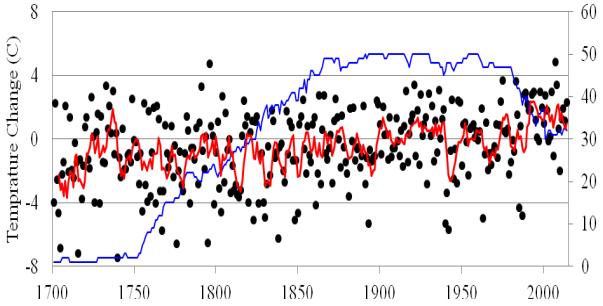
Period	Trend ^{o}C/Century	
	1820-2014	1820-1990
January	1.0	0.7
July	0.0	-0.3
Annual	0.7	0.4

Table I. Arctic Temperature Trends

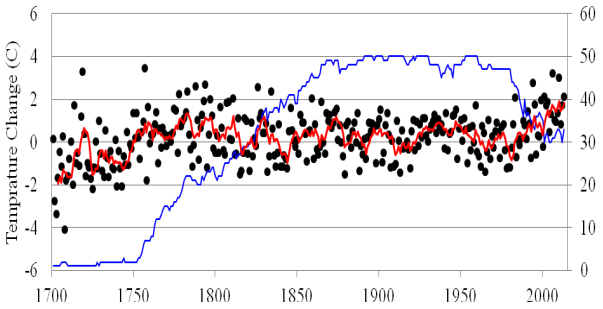
Fig. 3 shows positive January, July and annual temperature trends at De Bilt, Netherlands; Geneva, Switzerland; and St. Petersburg, Russia. Over 85% of all European stations had larger January than July temperature trends. Only three of the 50 stations exhibited a decreasing annual temperature trend.

Fig. 5 shows the change in temperature relative to that found for the period 1961-1990 averaged over 50 European stations. The trends

a) January



b) July



c) Annual

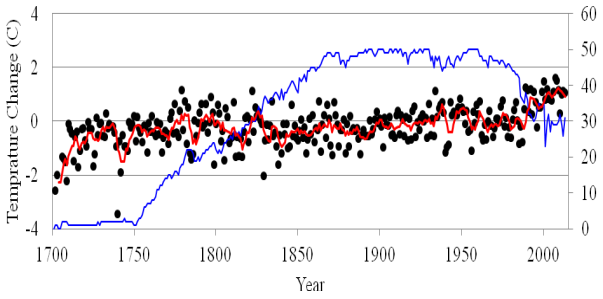


Fig. 5: Temperature Change for a) January, b) July and c) Annual relative to temperature during 1961-1990 for European stations. The red curve is the moving 5 year average while the blue curve shows the number of stations.

in Table II were found beginning in 1750 when data was available for a nontrivial number of stations.

Period	Trend °C/Century	
	1750-2014	1750-1990
January	1.0	0.8
July	0.0	-0.2
Annual	0.3	0.2

Table II. European Temperature Trends

A comparison of the change in annual temperature of the Arctic and European stations is shown in Fig. 6. The five European Arctic stations (Archangel'sk, Bergen, Helsinki, Stykkisholjmur and Trondheim) were removed from the curve representing the European temperature change. The two curves representing the 5 year moving average of the Arctic and European data very closely follow each other. The average difference between the two curves is 0.0 °C. It is particularly striking that the decadal fluctuations evident in the two curves are closely synchronized.

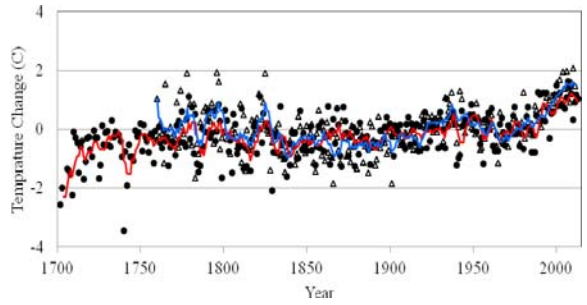


Fig. 6: Comparison of Annual Temperature Change relative to the temperature during 1961-1990 for European stations (black dots) and Arctic stations (open triangles). The red (blue) curve is the moving 5 year average for the European (Arctic) data.

4. CONCLUSIONS

Arctic temperatures increased during 1820-2014. The warming has been greater in January than in July. Siberia, Alaska and Western Canada have warmed slightly more than Eastern Canada, Greenland, Iceland and Northern Europe. The warming has not occurred at a steady rate. Much of the warming found for 1820-2014 occurred in the late 1990s and temperatures levelled off after 2000. The July trend is even slightly negative for the period 1820-1990. Multidecadal fluctuations are evident in the time series.

European stations experienced an increasing annual temperature trend of 0.3 °C per century during the period 1750-2014. January temperatures have increased but not July temperatures. Most of this increase occurred in the 1990s. These results are consistent with other studies (Brázdil et al, 2010).

An interesting result of this work is that the change in Arctic temperatures closely tracks changes in European temperatures. The Arctic has warmed at the same rate as Europe over the past two centuries. Heretofore, it has been supposed that any global warming would be amplified in the Arctic (Serreze and Barry, 2011). Both Europe and the Arctic experienced a sudden increase of about 1 °C in the annual temperature in the 1990s. For the previous 250 years, there was no statistically significant change in the European annual temperature. This behaviour was not predicted by global climate models and shows the desirability of further research to improve the accuracy of their projections.

6. Acknowledgements

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7. References

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