QCE General Maths PSMT
Sample Response

Report	Notes
Introduction The effects of climate change, as a result of mankind's actions, are at the core of today's political question. The following report addresses only a small fraction of the data gathered in recent years regarding climate change, specifically focusing on Canada as its subject. The stimulus report issued by the Canadian government, CCCR-Canada, introduces a statement regarding Canada's average climate warming rate, said to be twice that of the rest of the world: "…[land surface] average temperature in Canada has increased at roughly double the global mean rate, with Canada's mean annual temperature having risen about 1.7ºC (likely range 1.1ºC-2.3ºC) over the 1948-2016 period," (Xuebin Zhang, 2019). The claim was subsequently paraphrased by a further stimulus, a BBC article, reporting much the same conclusion: "Canada is warming on average at a rate twice as fast as the rest of the world, a new scientific report indicates," (BBC News, 2019). The present report, as per the affirmation outlined above, will seek to verify the claim, employing a similar data gathering method as that used to create such argument, but utilizing alternative sources withal: "The CCCR draws primarily from existing sources of information that have been peer-reviewed and are publicly available… Where relevant, quantitative information that has not been through external peer review was considered for inclusion; authors were required to judge the quality and reliability of the information and to maintain a copy of it" (Xuebin Zhang, 2019).	Here, we've started with general statements about the subject that hook the reader in. Try and hint at what the subject of the report will be about. Here is where you mention the claim you're investigating. Don't forget to reference and elaborate. Clearly state the aim of the report, you can use evidence here also. Remember, the more you have, the better.
Origins of the Claim As per the conditions outlined by the assignment task, this report is purposed with verifying the claim originating from the CCCR report itself; in spite of the	This section is not strictly necessary. However, for this

BBC article being a stimulus source, it will not be used as the basis of commencement of the investigation into the claim. This is due to the secondary nature of it; the primary source itself, the statement from the CCCR report shall be utilised instead, as it provides a firmer scientific and mathematical basis for the investigation. The investigation assigned as to validate the CCCR statement should comply as much as possible with the scientific and mathematical parameters of the data utilised to produce it.	example, the claim to investigate was secondary, meaning it came from a report cited in the source. Hence why this paragraph explains where the original source comes from.
Parameters of Investigation The scientific and mathematical parameters and data that have been used to devise the analysis of this report are the following: **TIME:** The CCCR divides its original data into two categories, each with their respective domains of time. For Southern Canada, the average temperatures utilised were recorded between the years of "1900 to 2016." In the case of Northern Canada, however, the mean temperatures were recorded between 1948 and 2016, as "the technology required was only installed 70 years ago" (Xuebin Zhang, 2019). It is thus appropriate, to comply with the claim, that the period to be examined will be condensed to 1948-2016, as the statement considers Canada as a whole. To gather data beginning from 1900 would produce an inaccurate result, as there is a lack of data for Northern Canada during that time. The data presented in this report for all subjects investigated ranges from 1948 to 2012; to account for this lack of specific data points for the following four years, the report will derive a linear equation from a period of fifteen years, to determine a rate of change that will be assumed to remain constant for the four years after 2012 **LATITUDE:** Considering Canada's geolocation in terms of latitude (between 50°N and 90°N), the comparative examples taken to assess the claim will fall in between said latitudes. The term "global" proves vague in terms of the areas compared to Canada's temperatures. Thus, for the purposes of this investigation, the temperate climate areas and those in the arctic circle (that lie between the determined latitude) will be those eligible for consideration. It would be inaccurate, furthermore, to consider either the tropics, or climate zones in the southern hemisphere for such a small time period, as factors	This section is all about setting the parameters of your investigation. Unfortunately, there isn't much structure to this, as each question and piece of evidence will require you to come up with different parameters. The general guidelines that can be given are to try and **identify where your investigation might fall short.** In this case, comparing every nation is impossible, as we are only limited to 10 pages. So 2 countries from across the northern hemisphere were compared to Canada. This is due to the fact that the Northern and Southern hemisphere are not perfect mirrors of each other. This justification is reasonable enough to be included in the parameters.

such as ocean currents and atmospheric changes inflict deep differences in temperature compared to the northern hemisphere (University of Bern, 2014). However, given the assumed general similarity between the location of climate zones of the two hemispheres, an assumed global comparison may result plausible if considering a greater time span than that of the original CCCR Canada report. This last point is beyond the scope of this report.

TEMPERATURES AND MODELLING: As outlined by the CCCR Report, the data gathered to construct the claim to be explored were the averages of the Land Surface Temperatures (ALST) in Canada; it is thus imperative, to comply with the selfsame parameters of the claim, that only ALST data be considered to prove or disprove the question. As the data is to be taken yearly (it was taken in such a manner by the CCCR report), averages of monthly data will be carried out to reflect a particular year´s mean temperature. Furthermore, considering the statement, the data will mostly be modelled in a linear fashion, using regressions: as the affirmation concerns the rates of Canada's warming climate, the gradients of multiple data sets (from Canada and those countries to be surveyed), will be compared to reach a final conclusion and judgement of the claim. However, where most appropriate, modelling to polynomial functions, and the subsequent differentiation of their linear derivatives will be carried out in pursuit of further accuracy.

SUBJECTS OF COMPARISON: The countries chosen as comparisons to Canada's warming rate will be the UK (comprised between the latitudes of 50°N and 60°N), and Russia, which mostly sits within the established Latitude Range? Not only do these countries present data from 1948 onwards, but further offer an almost complete representation of Canada's climate zone, as they span a considerable distance in terms of Longitude.

Hypothesis The report tentatively foresees the rate of Canada's warming being double that of t. Thus, it would deem the statement true. It also foresees an increasing warming rate in the last 10 to 20-year period, with this being thrice or four times higher than that of the previous years.	State your hypothesis — what do you think your data will show?
Source The non-profit scientific organisation Berkeley Earth was chosen as the provider of raw data for all subjects examined within the report. Its integrity and authoritativeness as a scientific organisation, as well as its specialisation in gathering land surface temperatures render its data profoundly relevant to the present report and to the study of climate change: "We took a data-driven approach to temperature analysis (using five times more data than other groups), and we are now taking a data-driven approach to other areas of energy and climate science" (Berkeley Earth, 2015).	Spare a few words about the source of the claim and its reliability. Consider **where the source comes from, who wrote it, the time it was produced in, as well as the context.** If it is from a well respected science journal, it's more reliable than from just a website page.
A. Canada Data Analysis Figure 1.1 presents the average biennial land surface temperatures for Canada (Berkeley Earth, 2015), interpolated via averaging process from the original monthly data, (Appendix 1.1). The parameters of the claim only require the data to be observed between the years of 1948; the present report abides to such a guideline, yet considers biennial data instead of annual data, due to the possibility that the latter might conceal a general linear trend, or otherwise compromise the gradient of the regression line with too many possible outliers. In order to avoid these instances, the data harvested from the source leaves an interval of just a year between each value, so as to maximise the amount of data points surveyed, and thus the accuracy of the results. In general more data allows for greater accuracy, yet as the purpose of this report is to discern and compare the general rate of temperature increase of specific countries in the Northern hemisphere, not as many data points are needed. The average temperatures of each considered year have been calculated (Appendix 1.2), within the domain of 1948 to 2016, as specified by the claim.	Divide your analysis into appropriate sections that reflect the way you carry out your investigation. In this case, the report was divided into 3 major analysis sections, because three countries were compared.

Table 1.1: **Biennial Average Land Surface Temperature in Canada**

Year	ALST in Canada (°C)	Year	ALST in Canada (°C)
1948	0,83	1982	-5,88
1950	-5,95	1984	-4,63
1952	-2,96	1986	-4,84
1954	-4,73	1988	-4,12
1956	-5,62	1990	-5,02
1958	-4,26	1992	-4,93
1960	4,41	1994	-4,43
1962	4,87	1996	-3,05
1964	-5,46	1998	-0,64
1966	-5,14	2000	-3,32
1968	-4,65	2002	-2,85
1970	-5,1	2004	-3,12
1972	-6,8	2006	-1,03
1974	-5,64	2008	-2,77
1976	-4,71	2010	-0,35
1978	-5,32	2012	-1,6
1980	-4,42		

Identification of Outliers

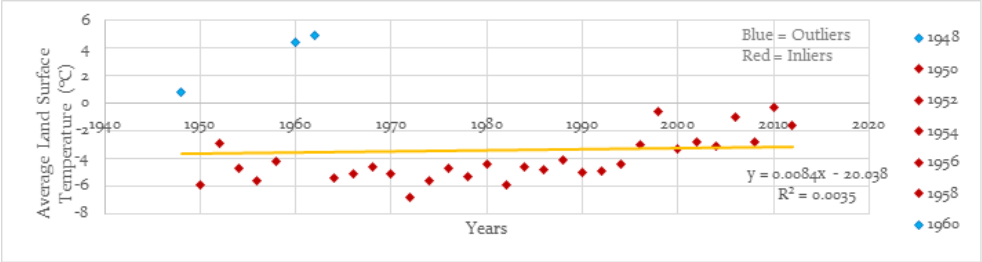
Before any analysis of the raw data, possible outliers must be identified (Appendix 1.3), as these might skew or alter significantly the gradient (rate) of the regression lines. They are determined as follows:

Mild outliers: (1,5 x IQR) +Q3 and Q1 – (1,5 x IQR), $x \geq 0,655$ and $x \leq -8,585$
Q3= -2,81 and Q1= 2,31

Figure 1.2 illustrates the weak qualities of the data's linear relationship when plotted with outliers; the coefficient of determination ($R^2 = 0,0035$) reveals that only 0,35% of the data is linearly correlated in this case.

Try and find an alternative set of data that is similar to that of the claim you are investigating. This is a good way to start your analysis. Is it consistent? Keep in mind that if your data set is bigger than this, you can condense it, or alternatively attach it to your appendix, that is not counted in the page count.

Figure 1.2



Having removed the outliers (Appendix 1.4), Figure 1.3 presents a much stronger linear correlation between all data points considered, with a moderate coefficient of determination of ≈45%, and a correlation coefficient (√0,4524) of approximately 0,7 (70%). The equation of the present regression was corroborated with technologically unassisted calculations (Appendix 1.5).

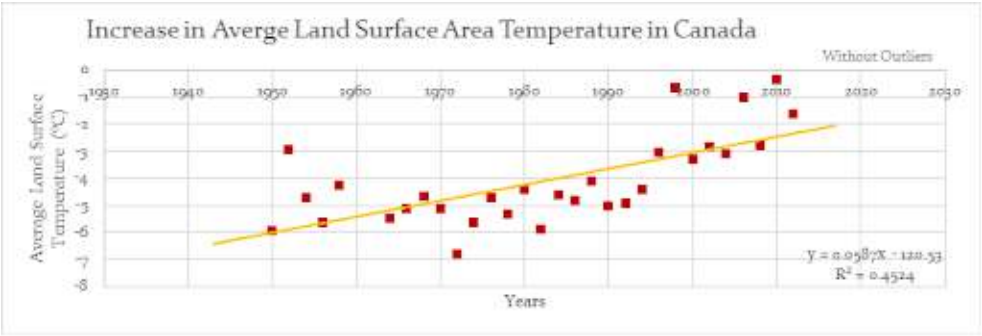


Figure 1.3: Increase in Average Land Surface Temperature in Canada

Although a clear linear trend is evident in the data without outliers, there appear to be numerous changes in the nature of this linear trend, specifically in the rate of temperature change across various sections of the data. For example, the rate of change between 1970 and 1994 appears to be much lower than that from 1994 to 2012. To better identify these significant structural changes, Figure 1.4 takes into consideration a time-series plot of Figure 1.1, yet layered on a three moving mean line interpolated from said data (Appendix 1.6 and 1.7). A three-moving mean was used due to its ability to weaken data fluctuations, without flattening their general trend completely. As shown in Figure 1.4, the significant structural changes are clearly visible, yet not overmuch cancelled by the moving mean effect.

Graphing is extremely important, it will allow you to showcase your mathematical skills. Plot a graph with and without outliers, making sure you state how to remove them. Make sure you include the equation, as well as the correlation coefficient. These will form the body of your analysis.

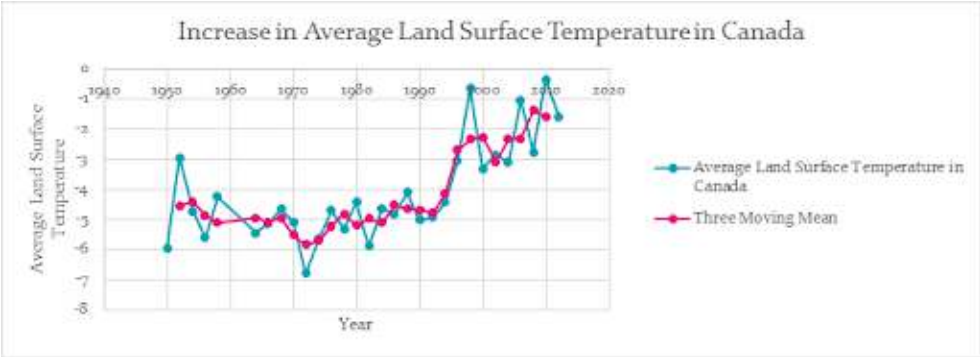


Figure 1.4: Three-moving mean

The adapted data reveals profound structural changes to the overall trend, specifically in the periods between 1948 t0 1970 (where a decreasing rate and gradient is evident), between 1972 and 1994 (where the rate begins to steadily increase), and 1996 to 2012 (where the gradient increases at a much faster pace). Although the overall rate of Land Surface Temperature change is the value to be compared, it is appropriate to subdivide the overall time period of 32 biennial intervals into the intervals discussed above (Appendix 1.8). This is so that the basis of the claim can be verified across multiple intervals, to determine whether it rings true or false compared to these three significantly different rates. This further division of the data will provide a more accurate representation of the warming rates across Canada, as justified by Figure 1.5.

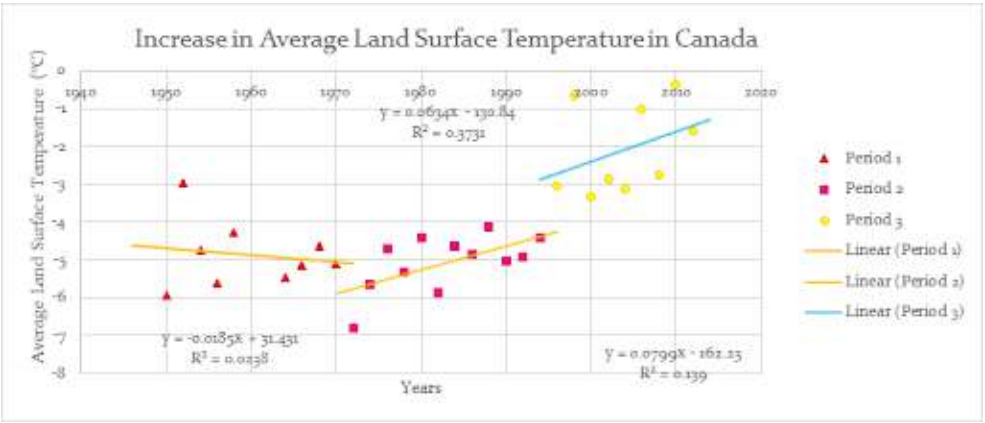


Figure 1.5: Increase in average land surface Temperature in Canada.

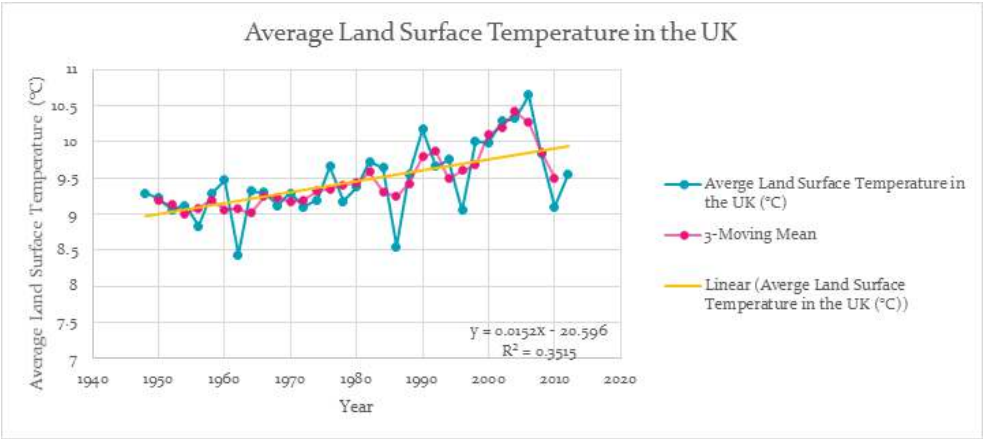
Don't be afraid to analyse the graph through a smoothed mean. This will showcase the breadth of your skill in manipulating data.

B. UK Data Analysis

The first subject of comparison was chosen to be the UK (Berkeley Earth, 2015), as representative of the European longitude. Situated at 0° west, the country is comprised between the parameters of the determined latitude, and furthermore serves to define a 'midpoint' between the temperature of the west and the east subjects. Such is the main reason why the UK was chosen. Although its borders do not stretch into the arctic circle like Canada's, its data will account for the more temperate climate zones that Canada also possesses, ensuring a fair comparison between the two rates. Data from the arctic circle that is suitable for comparison is presented by Russia.

In contrast with Canada's data, the UK's (Appendix 1.8) presents no significant structural changes, as illustrated by the three-moving mean applied in Figure 1.7.

Figure 1.7



The data is moderately correlated in a linear fashion, with a correlation coefficient of almost 60% (R ≈ 0,593). Although there is an apparent steady rise in Land Surface Temperatures, the magnitude of fluctuations can be seen increasing via the 3-moving mean across the third period of the data (previously defined as between 1996 and 2012). If considered by itself, this specific section of the graph also appears unsuited to a linear model, with a

The same procedure done to analyse data for Canada has been carried out in the other analysis sections. You might feel this is repetitive, however it is important that you assess the data with the same methods, to make sure accuracy and validity of your results are maintained.

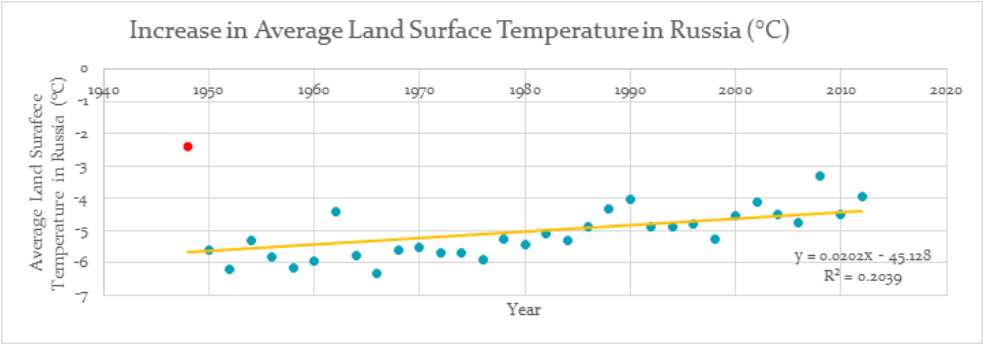
correlation coefficient of only 0,05, too low to be determined as a linear correlation (Appendix 1.9). The period 3 data (appendix 2.0) has thus been manipulated to suit a parabolic model instead, so that a linear rate may be derived, suitable for comparison with Canada's period 3 data.

C. Russia Data Analysis

The second subject of comparison was chosen to be the Russian Federation (Berkeley Earth, 2015), as its landmass spans 17 major meridians and covers a combined longitude of 160°. It is thus the landmass that is most representative of the eastern longitudes of the northern hemisphere, while still comprised within the determined latitudes (this is true for most of the country; the effects of such a fact upon the data are explored further in section E). Primarily due to its vastness, the Russian Federation stretches into both the arctic circle and the temperate climate zones that Canada is subjected to, making the country an exemplar subject of comparison.

The plotting of the original data (appendix 2.1) visually reveals an outlier, that compromises the otherwise strong linear relationship between the data points in Figure 1.9. Consequently, the resultant overall rate is altered, and thus unsuitable for comparison. With the removal of the outlier (appendix 2.2), the data assumes an even stronger linear correlation, that is more representative of the bulk of the data, as opposed to a singular point as demonstrated by Figure 2.

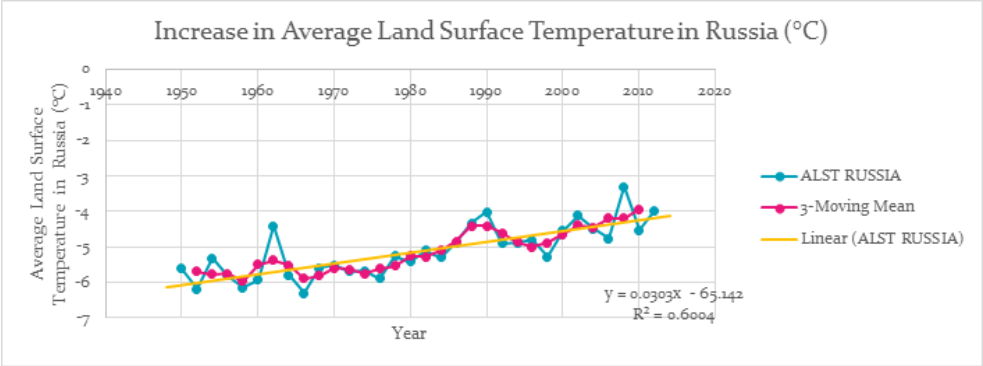
Figure 1.9



Russia's data without outliers presents little fluctuations, and reveals most prominently a constant rate of change that is strongly linear, with a coefficient

of determination of 60%, and a correlation coefficient of almost 80% (0,77), as demonstrated by figure 2. A three-moving mean curve has been applied to the data, to illustrate further the absence of major fluctuations or structural changes that may require further subdivision of the data. It is not the case in this instance, as per the linearity of the trend conveyed by the three-moving mean.

Figure 2



Due to the data's substantial linear correlation, and the absence of significant fluctuations, the data for period 3 (appendix 2.3) was modelled linearly (appendix 2.4). Such an approach is justified by the period 3 data's correlation coefficient of 0,601 (with 36% of data points linearly correlated); thus, a polynomial model of the data is unnecessary, as the rate of the period 3 data will be taken directly from its linear model.

D. Strengths of the Model

The collective data examined by the present report utilises, as a source, a reliable non-profit organisation specialized in land surface temperature analysis for studies on climate change. The source thus represents a considerable strength, given the authoritative qualities of Berkley Earth and their widespread platforms and scientific infrastructure.

The comparability of Canada's climate zone to that of the two subjects chosen is a further strong point: the claim finds validity in the comparison of similar climate zones, that consequently gift the results with further accuracy

Think about what your model has that is better compared to the original investigation. Yes, you may not have had as many words, expertise or time, but looking at things through a restricted field of view makes your observations more accurate.

and limit criticisms based on natural and climatic factors that could alter the results, if other subjects from different climate zones were chosen. The manipulation and generation of data at biennial intervals via averaging processes remains an asset to the report, ensuring a more holistic consideration of the rate of temperature change across the whole time period examined.	
## E. Limitations of the Model The use of multiple sources of data as scientific corroboration would have further enhanced the validity of the data examined by this report; at present, although the use of Berkley Earth as a source remains a strength, the lack of corroborating scientific data from alternative agencies (that could have gifted the evaluation of the claim with further relevance and accuracy), represents a limitation. Such setbacks could easily be eliminated via the examination of a second or third source, with scientific authoritativeness similar to that of Berkeley Earth. The lack of data points for the remaining four years of the time domain considered by the original claim represents an additional disadvantage to the report. Despite the extrapolation of a derivative linear rate for these missing data via differentiation, such a process has weaknesses, as it assumes that the rate of change be unchanged for the missing period. Realistically, however, there is a possibility that the rate of temperature rise might have increased or decreased, and that the period 3 general polynomial trends from which the regression has been extrapolated might have altered during the course of those years. Whilst this would not have significantly affected the gradient of the regression across the entire time domain surveyed by the original claim and by the present report, the results drawn here regarding the last fifteen to twenty years could ultimately prove inaccurate. Such an obstacle can be easily surmounted by the inclusion of data from alternative sources to cover the missing period. A further limitation concerns the choice of Russia as a subject of comparison; most of the country's landmass is located within the latitudes examined by	It is always good to be overly critical of your model, to show the examiner that you know the level of detail needed for an accurate and successful investigation. Problems such as lack of time, lack of instruments and data are almost always going to apply, so don't forget these. Try and expand on this section as much as you possibly can.

the report. Yet, the southern end of the country, neighbouring Azerbaijan and Kazakhstan, lies outside of the parameters of latitude. It is so, consequently, that results collected by Berkeley Earth anywhere south of Volgograd are invalid for the purposes of the claim, and might have minorly altered the overall yearly averages with warmer temperatures. Even so, due to the small size of the area compared to the rest of the Russian Federation, the possible alteration would have been minor, and not significantly affected the general gradient of the overall regression. It is important to notice that the results for this particular subject present very little fluctuations, as demonstrated by the analysis of the three-moving mean.

The claim's parameters regarding "…the rest of the world…" also pose a considerable limitation. The original CCCR report utilised the annual average of global data as a subject of comparison to Canada which, although this does not account for the considerable differences between the climate zones in the northern and southern hemisphere, provides a global comparison to Canada. Such a perspective remains absent in this report, a fact that limits its assessment on the global validity of the claim. The average data from around the globe could've been utilised in combination with the results drawn in the present report to provide a more comprehensive examination of temperature increases in the southern hemisphere, and thus their rate compared to Canada's.

F. Evaluation of the Claim

This report's conclusion regarding the claim is two-fold: its findings consider the results gathered from the comparison of gradients from each subject across the time period surveyed by this report, as well as the rate of temperature increase over the last sixteen years (1996 – 2012). The latter point is purposed to validate the original claim by providing a projection (under the assumption that the rate of period 3 would remain constant) of the four years after 2012, to account for the missing data points for all subjects of comparison, needed to meet the claim's requirement of data up to 2016.
The gradients of the linear regressions of figures 1.3, 1.7 and 2 are below compared, to assess the claim; the gradient of figure 1.3 (Canada's temperature increase) is divided by that of the other two subjects of

Time to bring everything together here. This section isn't a conclusion, but a summary relevant to your question.

Cite analysed data, the most important of your results, and try and frame your agree or disagree statement on the same level and style of your stimulus. This will make it easier to see the comparison between your results and the stimulus.

comparison, to determine the factor in question (this should at least be =2 for the claim to ring true).

Rate of change = 0,0587 ÷ 0,0152 = 3,86 Canada's temperature increase results to be approximately four times that of the UK.

Rate of change = 0,0587 ÷ 0,0303 = 1,93 Canada's temperature increase proves to be approximately two times that of the Russian Federation.

Both results confirm the claim, as both factors either equal or surpass the factor 2 specified in the statement (the results were rounded as to produce a one-significant-figure result, as a broad factor that resembles that of the CCCR report.

However, the claim does not find validity when the linear gradients of all period 3 data are considered; once again, the gradient of Canada's derivative will be divided by the gradient of each of the subjects' derivative, to establish a factor.

Rate of change = 0,0216 ÷ -0,0358 = -0,63352 In this case, the factor is negative, indicating a decrease in temperature. Such result disproves the claim for the fifteen to twenty years leading up to 2016.

Rate of change = 0,0216 ÷ 0,3615 = 0,05975 The factor here is positive, yet the result illustrates Canada's temperature increasing at only half the rate of the Russian federation in the twenty years leading up to 2016.

G. Conclusion

It is thus evident that the results across the period of time examined (if considered in its entirety) corroborate the claim forwarded by the CCCR Canada Report. However, the claim can be challenged if examining the results that comprise the last fifteen to twenty years, where Canada's warming rate is much lower than that of the compared subjects.

Sum everything up in two sentences — no data needed here, and you're done!