CPS 188 Term Project - Standardized Cover Page

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We affirm that this project is original and is our own work.

Signatures:

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INTRODUCTION

This project explores the intricate analysis of global temperature trends based on extensive data collected by various weather monitoring systems across the globe. The dataset, spanning from the year 1750 to 2015, expresses the monthly land and ocean temperatures. The primary objective of this project is to utilize tools of computer programming to visualize and draw meaningful insights. The data, stored in a CSV format, offers all necessary information, first to be extracted and analyzed. Through trial and error C programming and the utilization of GNUPlot functionalities, this report aims to show temperature trends, deciphering yearly averages, century-wise variations, monthly patterns and more. Upon completion of this project, a comprehensive understanding of our planet's climate evolution will be displayed.

DATA & ANALYSIS

Based on the land average temperature column, the yearly averages for each year between 1760 and 2015:

First 10 Yearly Average Temperatures:		Last 10 Yearly Average Temperatures:	
Year	**Average Temperature**	**Year**	**Average Temperature**
1760	7.185167	2006	9.732165
1761	8.7725	2007	9.431749
1762	8.606502	2008	9.505251
1763	7.49675	2009	9.703083
1764	8.400333	2010	9.516
1765	8.251917	2011	9.507333
1766	8.405665	2012	9.6065
1767	8.2215	2013	9.570667

These values were found by first reading the Land Average Temperature column in the csv file. It first calculated an index, corresponding to a particular year by subtracting the initial year, 1760 from the extracted year value. After it updates the temps sum array and the temp count array, by adding the temperature to the sum already stored, which will allow for the total temperature for the year to be calculated. The count array increments by the count of temperature readings there are for that year. Then it calculated the yearly land average temperature. Which then prints the yearly land average temperature for each year between 1760 to 2015 onto a file.

Based on the land average temperature the century average land temperature for the different centuries:

Century	Average Temperature (℃)
18th	8.214995
19th	8.009103
20th	8.637712
21th	9.542095

By taking the values of the from the extracted year and assigned the extracted years to the appropriate index, if extracted year is less than or equal to 1799 it is given an index of 0, if extracted year is less than or equal to 1899 it is given an index of 1, if extracted year is less than or equal to 1999 it is given an index of 2, and if else then it is given a index of 3. It then updates the century average temperature array with the corresponding index by adding the extracted temp to have the total temperature for that century. The count array increments by the count of temperature readings there are for that century.Then it calculated the century land average temperature. Which then prints the century land average temperature for different centuries and writes the corresponding centuries in text in a table.

Based on the land average temperature the monthly average land temperature for all years combined between 1900 and 2015:

Month	Average Temperature (℃)
January	2.815035
February	3.330681
March	5.395672
April	8.536757
May	11.394818
June	13.540051
July	14.449054
August	13.958490
September	12.166732
October	9.527080
November	6.223164
December	3.811914

By only reading from the extracted month from the extracted year that was only between 1900 to 2015, it takes the values of the from the extracted month and assigned the extracted month to the appropriate index, if extracted month is 01 it is given an index of 0, 02 is given an index of 1, 03 is given an index of 2, 04 is given an index of 3, 05 is given an index of 4, 06 is given an index of 5, 07 is given an index of 6, 08 is given an index of 7, 09 is given an index of 8, 10 is given an index of 9, 11 is given an index of 10, 12 is given an index of 11. It then updates the monthly average temperature array with the corresponding index by adding the extracted temp to have the total temperature for that month. The count array increments by the count of temperature readings there are for that month. Then it calculated the monthly land average temperature. Which then prints the monthly land average temperature for different months and writes the corresponding month in text in a table.

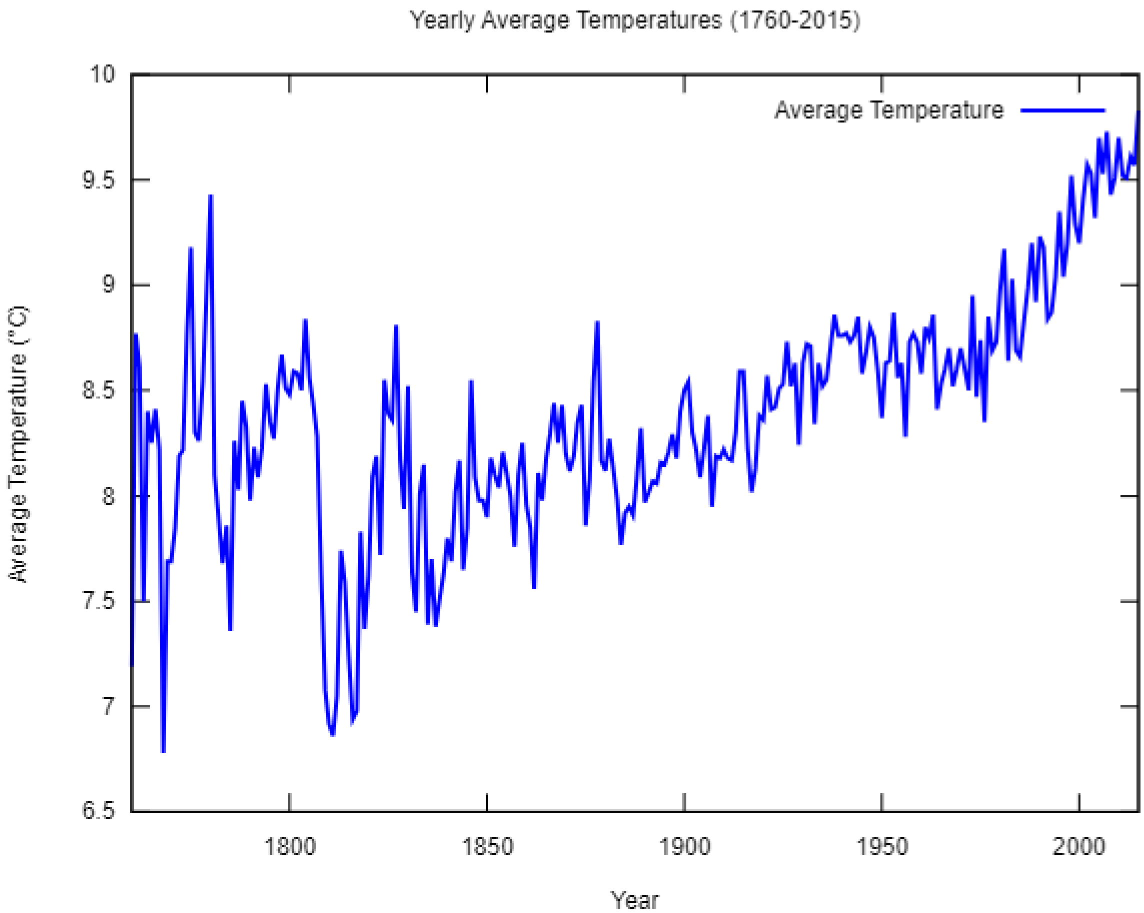
Based on the land average temperature column, the hottest month recorded was July 1761 with an average temperature of 19.021 ℃ and the coldest month recorded was January 1768 with a temperature of -2.08 ℃.

These values were found by first reading the Land Average Temperature column in the csv file. With the use of "if" statements, it checks if the current temperature is greater than the recorded hottest temperature, then updates the hottest temperature variable. Then it copies the name of the month corresponding with the hottest temperature. Then it checks if the current temperature is less than the recorded coldest temperature, then updates the coldest temperature variable. Then it copies the name of the month corresponding with the coldest temperature. Then the hottest and coldest month and temperatures were displayed.

Based on the yearly averages for each year between 1760 and 2015, the hottest year was 2015 with an average temperature of 9.830999 ℃ and the coldest year was 1768 with an average temperature of 6.781333 ℃.

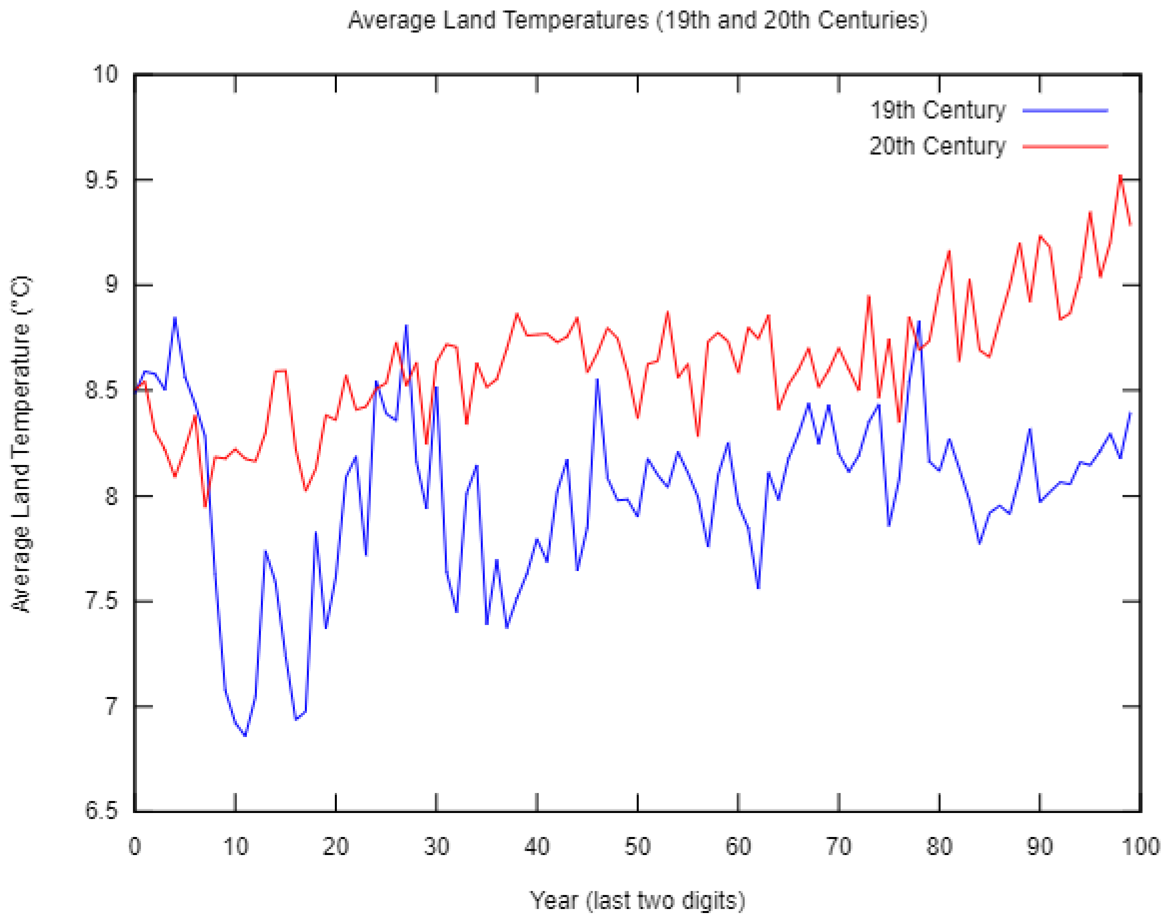
These values were found by first reading the Land Average Temperature column in the csv file. With the use of "if" statements, it checks if the average year temperature is greater than the recorded hottest year temperature, then updates the hottest year temperature variable. To determine the corresponding year to the hottest year temperature, It updates the variable hottest year recorded with the year associated with the current temperature, using the index 'i' with an offset of the start year, 1760 . Then it checks if the current temperature is less than the recorded coldest year temperature, then updates the coldest year temperature variable. To determine the corresponding year to the coldest year temperature, It updates the variable coldest year recorded with the year associated with the current temperature, using the index 'i' with an offset of the start year, 1760. Then the hottest and coldest years were displayed.

Graph of the yearly average temperature for the years 1760-2015:



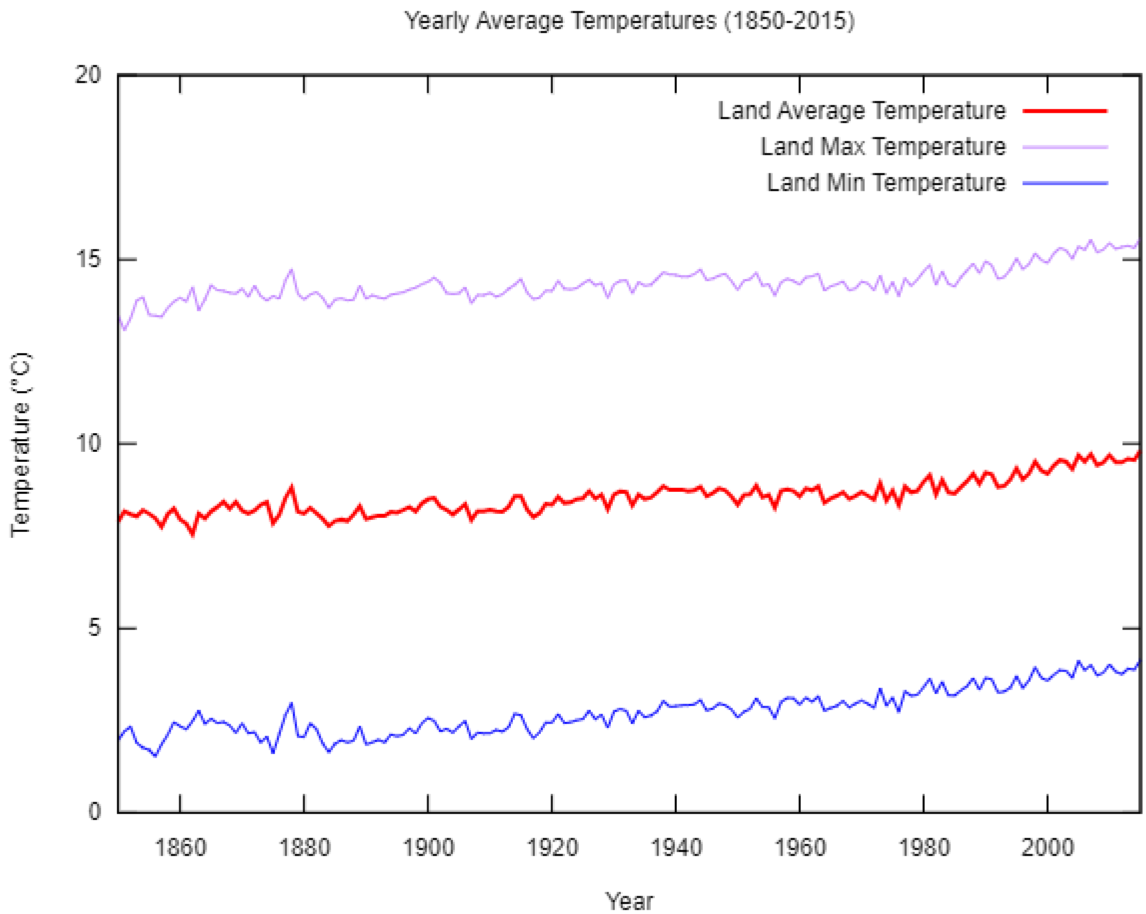
Using the data file of the yearly average temperature which was collected earlier from the C program, the data file was read on a GNUplot program. the title, x-axis, and y-axis were labeled for the graph. The x-axis range was set from 1760, the star year to 2015, the end year. The line style was formatted with a thinker line and the color blue. It plots the data from the file, it uses the second column as the y-axis data and the first column data as the x-axis. Then the graph of the yearly average temperature for the years 1760-2015 are displayed.

Graph of the average land temperatures for the 19th and 20th centuries:



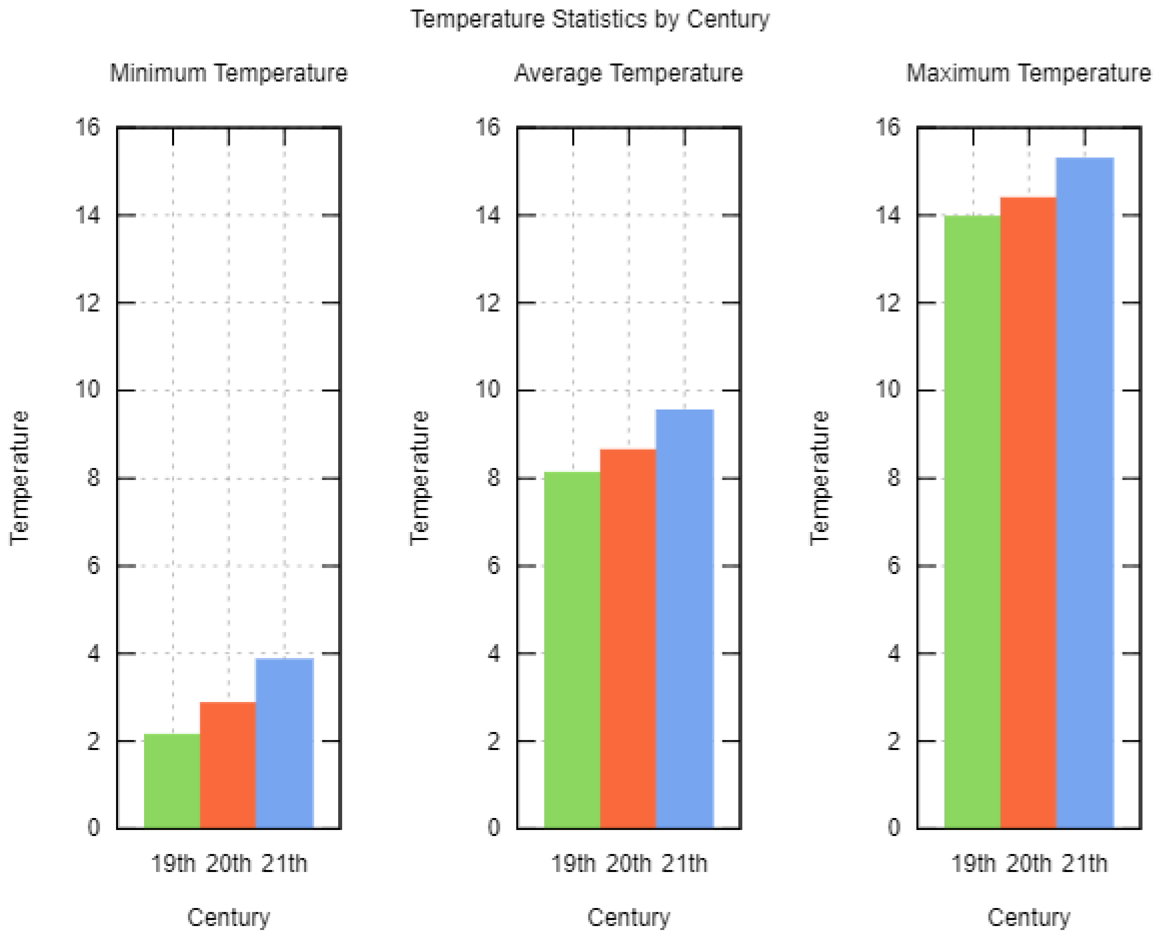
The data that was used to plot the graph was first found by reading the Land Average Temperature column in the csv file. Within a loop it calculates the value that represents the year within the century, by taking the remainder of the year divided by 100. Then within the loop it determines whether the year is within the 19th century, between 1800-1899 or the 20th century, between 1900-1999. If it is within the century, it calculates the average temperature and is assigned to the corresponding index , “avg19th” or “avg20th”. It also marks the year as having data by setting the index in the “count19th” or “count20th" array to 1. Then the data is printed onto a data file to be prepared for the GNUPlot. The data file was read on a GNUplot program. The title, x-axis, and y-axis were labeled for the graph. The line style was formatted with blue for the 19th century and red for the 20th century. It plots the data from the file, it uses the first column data as the x-axis, the second column for the 19th century and the third column for the 20th century. Then the graph of the average land temperatures for the 19th and 20th centuries are displayed.

Graph of land average temperature, land max temperature and land min temperature for the years between 1850 and 2015:



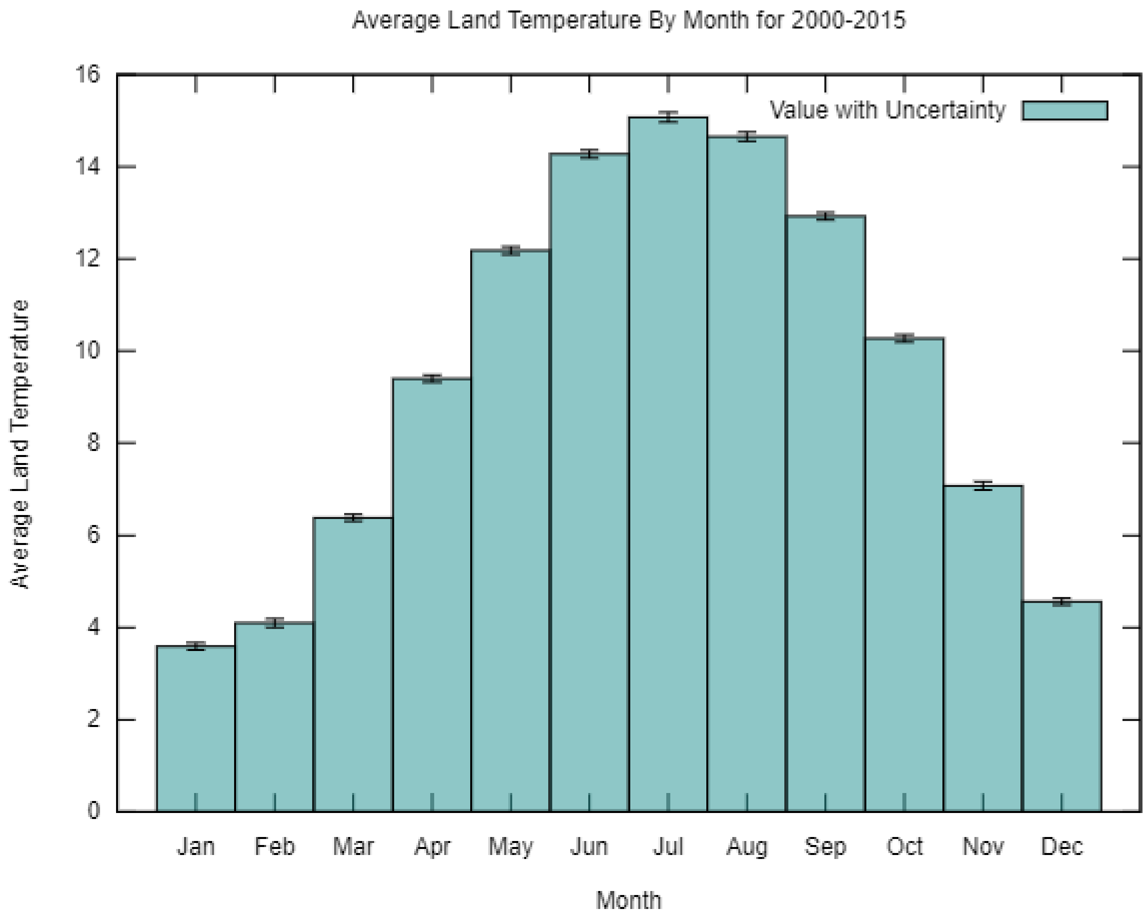
The data that was used to plot the graph was first found by reading the Land Average Temperature, Land Max Temperature, and Land Min Temperature column in the csv file. It first calculated an index, corresponding to a particular year by subtracting the initial year, 1850 from the extracted year value. After it updates the temps sum array and the temp count array, by adding the temperature to the sum already stored, which will allow for the total temperature for the year to be calculated. The count array increments by the count of temperature readings there are for that year. Which then prints the yearly land average temperature, yearly land max temperature, and yearly land min temperature for each year between 1850 to 2015 onto a data file to be prepared for the GNUPlot. The title, x-axis, and y-axis were labeled for the graph. The x-axis range was set from 1850, the star year to 2015, the end year. The line style was formatted with a thinker red line that represented the land average temperature, a normal blue line for land min temperature and a normal purple line for land max temperature. It plots the data from the file, it uses the first column data as the x-axis, the second column as the y-axis data for land average temperature, the third column as the y-axis data for land max temperature, and the fourth column as the y-axis data for land min temperature. Then the graph of land average temperature, land max temperature and land min temperature for the years between 1850 and 2015 are displayed.

Graph of the average, low and high temperatures for each of the three centuries:



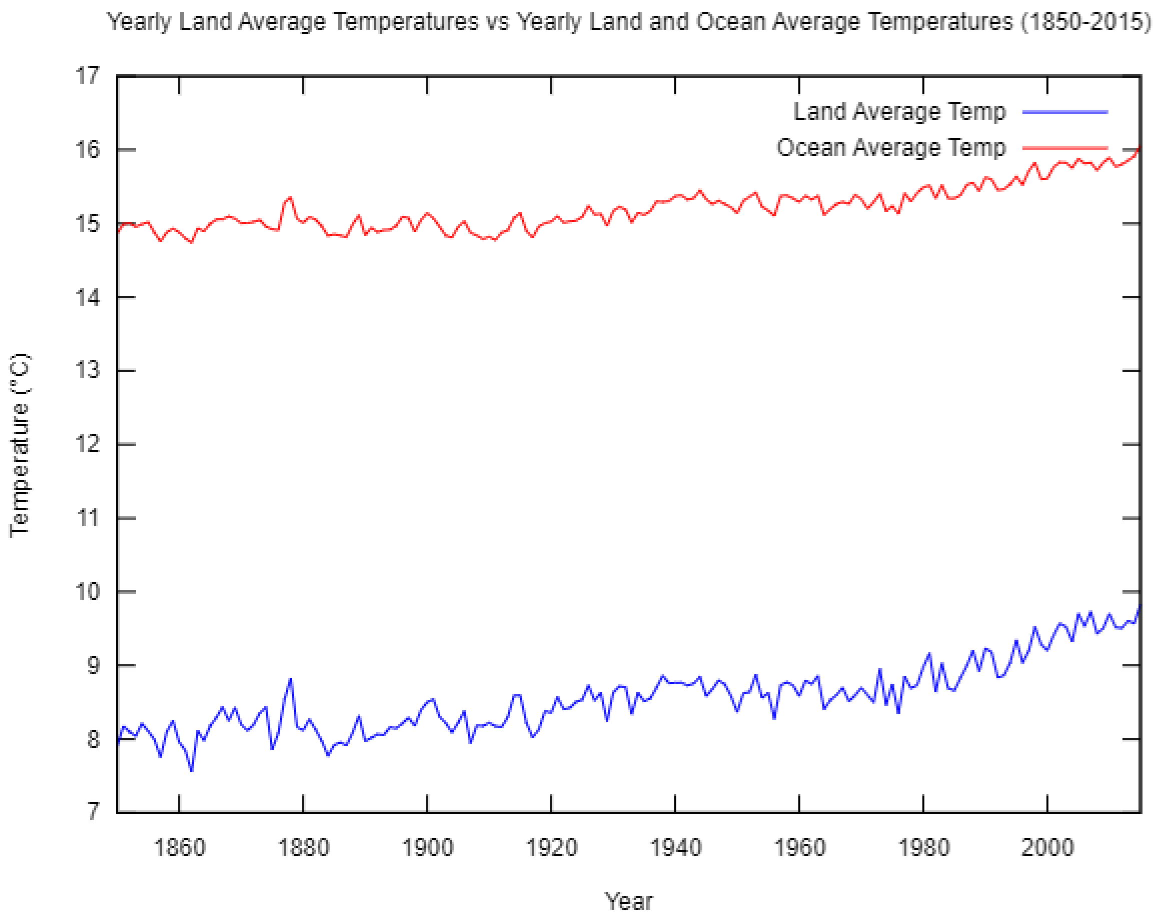
The data that was used to plot the graph was first found by reading the Land Average Temperature, Land Max Temperature, and Land Min Temperature column in the csv file. By taking the values of the from the extracted year and assigned the extracted years to the appropriate index, if extracted year is less than or equal to 1899 it is given an index of 0, if extracted year is less than or equal to 1999 it is given an index of 1, if else then it is given a index of 2. It then updates the century temperature array with the corresponding index by adding the extracted temp to have the total temperature for that century. The count array increments by the count of temperature readings there are for that century. It then calculated the century Then it calculated the century land average temperature, the century land max temperature, and the century land min temperature for the 19th, 20th, 21st centuries. Then prints the data onto a data file to be prepared for the GNUPlot. The title, x-axis, and y-axis were labeled for the graph. The x-axis range was set from 18-22, which reflected the centuries. The data was separated using multiplot with allowed average, minimum, and maximum temperatures to have its own plots within the same figure. It plots the data from the file, it uses the first column data as the x-axis, the second column as the y-axis data for the second plot, the third column as the y-axis data for the third plot, and the fourth column as the y-axis data for the first plot. Then the graph of land average temperature, land max temperature and land min temperature for the years between 1850 and 2015 are displayed.

Graph of the error bar plot of the average land temperature by month for 2000-2015:



By only reading from the extracted month from the extracted year that was only between 2000 to 2015, it takes the values of the from the extracted month and assigned the extracted month to the appropriate index, if extracted month is 01 it is given an index of 0, 02 is given an index of 1, 03 is given an index of 2, 04 is given an index of 3, 05 is given an index of 4, 06 is given an index of 5, 07 is given an index of 6, 08 is given an index of 7, 09 is given an index of 8, 10 is given an index of 9, 11 is given an index of 10, 12 is given an index of 11. It then updates the monthly average temperature array and the monthly average temperature uncertainty with the corresponding index by adding the extracted temp to have the total temperature for that month. The count array increments by the count of temperature readings there are for that month. Then it calculated the monthly land average temperature and the monthly land average temperature uncertainty. Which then prints the monthly land average temperature and the monthly land average temperature uncertainty for each month between 2000-2015 into a data file to be prepared for the GNUPlot. The title, x-axis, and y-axis were labeled for the graph. The x-axis range was set from -1 to 12, and the y-axis range was set to 0-16. A “xtic” was added to replace the values on the x-axis from numbers to text which the index was related to its corresponding month. It plots the data from the file, it uses the first column data as the x-axis, the second column as the y-axis data for monthly land average temperature, and the third column as the errorbar data for land max temperature unceruncertaintyiety. Then the graph of the error bar plot of the average land temperature by month for 2000-2015 were displayed.

Graph of the Yearly Land Average Temperatures vs Yearly Land and Ocean Average Temperatures for the years 1850 to 2015:



These values were found by first reading the Land Average Temperature column and the Land and Ocean Average Temperatures column in the csv file. It first calculated an index, corresponding to a particular year by subtracting the initial year, 1850 from the extracted year value. After it updates the temps sum array and the temp count array, by adding the temperature to the sum already stored, which will allow for the total temperature for the year to be calculated. The count array increments by the count of temperature readings there are for that year. Then it calculated the yearly land average temperature and the yearly land and ocean average temperature. Which then prints the yearly land average temperature and yearly land and ocean average temperature for each year between 1850 to 2015 onto a data file to be prepared for the GNUPlot. The data file was read on a GNUplot program. The title, x-axis, and y-axis were labeled for the graph. The line style was formatted with blue for the land average temperature and red for the land and ocean average temperature. It plots the data from the file, it uses the first column data as the x-axis, the second column for the land average temperature and the third column for the land and ocean average temperature. Then the graph of yearly land average temperatures vs yearly land and ocean average temperatures for the years 1850 to 2015 are displayed.

CONCLUSION

From the analysis of the data, most of the GNUPlot graphs and tabulated results depict a clear increasing trend. At this point, graph representations, in fact, become clearer with the rise in average land temperature over the 19th and 20th centuries. The data reveal, in fact, that while the beginning of the 19th century was characterized by an annual mean temperature of 6.86ºC, the end of the 20th century noticed the hottest annual mean temperature of 9.52ºC. Notably, 2015 emerged as the warmest year, and 1768 emerged as the coldest year, further reinforcing the fact of the temperature increasing with time. This trend becomes a pointer to some relation with current issues: steady temperatures increase can hence relate to intensified emissions from factories and vehicles, therefore worsening the global warming temperature effects.

This project has really boosted our competence in C programming and plotting scientific data. Effective communication and deliberation through team meetings discussing ways to move forward with every assigned task really helped us move swiftly in this journey. Group knowledge sharing and revisiting class materials helped us very much in developing our skills. In spite of quite a number of challenges that forced us to rewrite all of our first codes, distributed leadership helped tremendously, with everyone being given their fair share of work to do, based on their respective strengths. The learning attitude of doing things, such as and when required, was formulated in the classroom. This project helped in the practice to become the master of a lot of skills and provides an insight into the occupational setting related to programming. It underlined the importance of team spirit and adaptability, which were tested to the full extent in the project. Indeed, much struggle had to be made, spending more time than necessary due to the collective lack of familiarity with GNUPlot was a large problem. This, however, has been a true nourishment: learning how to adapt our thoughts with each new obstacle and finally succeed in this project.

THE ACTUAL OUTPUTS FROM THE PROGRAM

```
============================================================
 Welcome to the Climate Explorer!
 Dive into centuries of temperature data with us.
============================================================
Analysing data...
.........................................................................................
...........
Data analysis complete!

------------------ Question 1 ----------------------
The whole dataset for Question 1 is too large to display in the console. Please check the
 file 'Q1_Yearly_averages.txt' for the results.
First 10 Yearly Average Temperatures:
1760    7.185167
1761    8.772500
1762    8.606502
1763    7.496750
1764    8.400333
1765    8.251917
1766    8.405665
1767    8.221500
1768    6.781333
1769    7.694582

Last 10 Yearly Average Temperatures:
2006    9.532500
2007    9.732165
2008    9.431749
2009    9.505251
2010    9.703083
2011    9.516000
2012    9.507333
2013    9.606500
2014    9.570667
2015    9.830999
-> Yearly Average temperature insights ready for exploration in 'Q1_Yearly_averages.txt'.
```

```
------------------ Question 2 ----------------------

Century Averages:
Century AverageTemperature
18th      8.214995
19th      8.009103
20th      8.637712
21th      9.542095

------------------ Question 3 ----------------------

Monthly Averages:
Month   AverageTemperature
Jan       2.815035
Feb       3.330681
Mar       5.395672
Apr       8.536757
May       11.394818
Jun       13.540051
Jul       14.449054
Aug       13.958490
Sep       12.166732
Oct       9.527080
Nov       6.223164
Dec       3.811914

------------------ Question 4 ----------------------
-> The hottest month on record was Jul 1761 with a blistering 19.021000 C.
-> The coldest month ever recorded was Jan 1768, chilling at -2.080000 C.

------------------ Question 5 ----------------------
-> The hottest year on record was 2015 with an average temperature of 9.830999 C.
-> The coldest year recorded was 1768 with an average temperature of 6.781333 C.
```

```
------------------ Question 6 ----------------------
Data for Q6 GNUPlot prepared in 'Q1_Yearly_averages.txt'.

------------------ Question 7 ----------------------
Data for GNUPlot prepared in 'Q7_19_20_Centuries.txt'.

------------------ Question 8 ----------------------
-> Yearly Average temperature, Max Temperature, Min Temperature insights ready for explor
ation in 'Q8_Temperature_averages.txt'.

------------------ Question 9 ----------------------
-> Yearly Average temperature, Max Temperature, Min Temperature insights ready for explor
ation in 'Q9_Century_averages.txt'.

------------------ Question 10 ----------------------
-> Data for GNUPlot prepared in 'Q10_AVG_LandTemp_Monthly.txt'   .

------------------ Question 11 ----------------------
-> Data for GNUPlot prepared in 'Q11_AVG_LandTemp_Yearly.txt'   .
```