Final project MNXB01

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1 Introduction

During the last decades, the scientific community has shown the anthropogenic nature of the climate change, from which the Earth is increasingly suffering. This information are well documented and easily accessible in the IPCC and EPA reports [1], [2] showing how the humankind is affecting the climate and how the climate is changing in different regions of the planet. This last statement is what we want to study along this report. Particularly, we intend to show and compare how the temperatures in two different areas of Sweden are affected by the climate change, to provide a relatively general overview of the Swedish climate change, but also to possibly identify differences and analogies between northern and southern regions. For this purposes, the two areas we have chosen are represented by Umeå, which is settled in the Northeast, and Falsterbo, in the South.

In fact, given the vast land of the Swedish country covering 450.295 km^2, we chose among the places showing a large difference in latitude (°N), principally, and longitude (°E), from the available SMHI data. Finally, in order to provide also a relatively consistent comparison between them, we selected the two regions showing the most similar local conditions such as number and timetable of the measurements, distance from the sea and height above the sea. Therefore, we chose Umeå (63.7947°N, 20.2918°E) and Falsterbo (55.3837°N, 12.8167°E), which are both by the sea at a height below 30 meters, and show a large amount of data acquired at the exact same hours from the past 60 years.

Our analysis is characterized by three different set of plots, shown in section 2. The first one (2.2) is the mean temperature per year from 1962 to 2020, a well known way to quantify and monitor the climate change effect. the second set of plots (2.3) shows the difference between the coldest and the mean temperature for each year, and specularly for the warmest temperatures. The purpose of these plots is to study the behaviour of the so called "extreme conditions", to see possible changes in their frequencies and intensities. The last plots (2.4) show the date of the coldest and warmest day of each year, with the aim of identifying, together with 2.3, changes such as length, timing and variability of seasons that affect seasonal events like growing seasons, snowmelt, birds migration etc. [3]. Data treatment and analysis will be detailed in section 2, while section 3 presents the conclusions of our work.

2 Data treatment and analysis

2.1 Data cleaning

SMHI datasets were cleaned using 'R' with the libraries 'dplyr', 'tidyverse', 'writexl', 'lubridate', 'chron' as shown in the code.

We used the temperature data sets from Umeå and Falsterbo. The dates of both data sets were filtered, we established the date range from 01/01/1962 up to 31/10/2020. The hours were also filtered, we selected the same hours for both cities, in this case, 07:00:00, 13:00:00, 20:00:00.

The data used for the two cities in case of the plots in subsection 2.4 were divided each into two further groups:

1. From day number 1 up to day number 269
2. From day number 270 up to day number 365

The division in two groups allowed us to manipulate the data for better analyzing and visualizing the trend of the coldest and warmest days during the years, as explained in subsection 2.4.

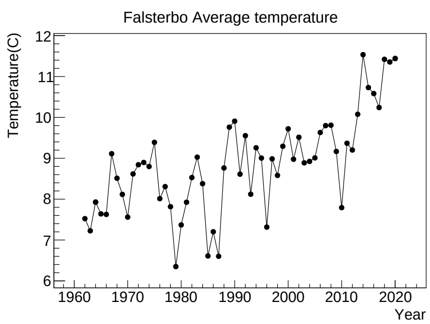
Apart from cleaning and establishing the ranges for the data, we used the potential of 'R' to change the displayed rows or columns and to summarise or to do simple mathematical operations. The data have been furhter adjusted with Excel for few features required for plots in subsection 2.4.

Some mathematical operations used were:

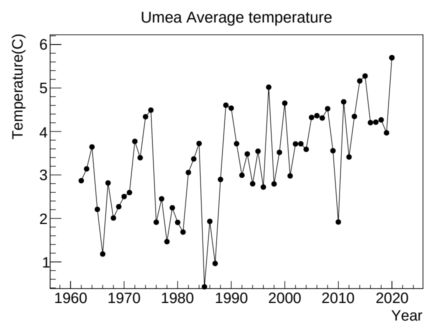
1. **Average:** Useful for obtaining the average temperature of the day with the three hours.
2. **Maximum:** Useful for obtaining the day with the highest temperature.
3. **Minimum:** Useful for obtaining the day with the lowest temperature.

2.2 Mean temperature per year

In order to compare the changes during the years between the two data sets, the mean temperature of each year has been calculated as an average of the measurements acquired at the same time in both the places.



(a) Falsterbo.



(b) Umeå.

Figure 1: Mean temperature per year

The two plots have been fitted using linear, quadratic, and exponential models, which yield the chi-2 parameters shown in table 1 and 2.

Model	Chi-2
Linear	45.1794
Quadratic	37
Exponential	43.5234

Table 1: Chi-2 parameters for Figure 1(a)

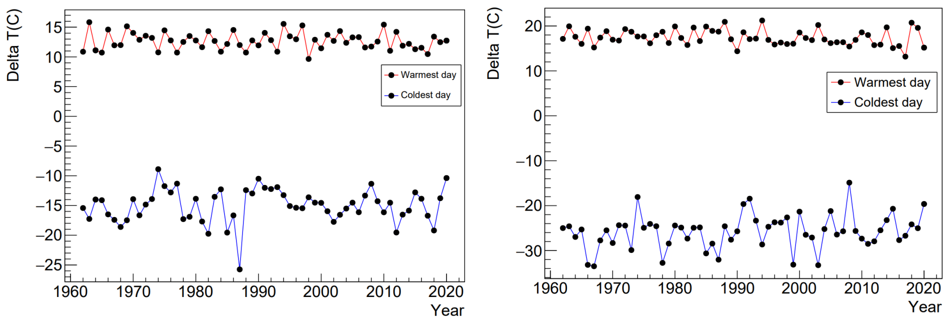
Model	Chi-2
Linear	53.4473
Quadratic	49.9518
Exponential	51.8294

Table 2: Chi-2 parameters for Figure 1(b)

From the plots, it is immediately visible the effect of the so-called "Global Warming", which is indeed causing an increase of the temperatures in the whole world. The chi-2 parameters of the fitting models, with a generous approximation, could even suggest there is a quadratic growth of the temperatures within the years, in both places. However, if we look at the average temperature calculated from the last years, namely from 2010 to 2020, with respect to the one calculated from 1962 to 1972, we can say that the realtive growth of the temperature in Falsterbo is higher (+2.3°C) than the one in Umeå (+1.6°C), suggesting a stronger effect of climate change in the south of Sweden.

2.3 Coldest and warmest temperatures with respect to the mean temperature for each year

In this analysis, we report the difference in temperature (Delta T) between the coldest (T min) or the warmest (T max) temperatures with respect to the mean ones (T mean), i.e. T max - T mean and T min - T mean, respectively, for each year in each place.



(a) Falsterbo. (b) Umeå.

Figure 2: Difference with respect to the mean temperature of warmest and coldest temperature per year

Analysing quali-quantitatively these plots is not trivial, as there is an intrinsic, natural, variability of the shown values and trends between adjacent years. Since we are looking at small changes taking place in tens of years, we decided to compare, for each plot in figure 2, the average values calculated in the first decade available (1962-72) with the data of the last one (2010-2020), summarized in table 3 and 4.

Decade	average lowest DeltaT	average highest DeltaT
1962-72	-16°C	13°C
2010-20	-15.4°C	12.4°C

Table 3: Falsterbo

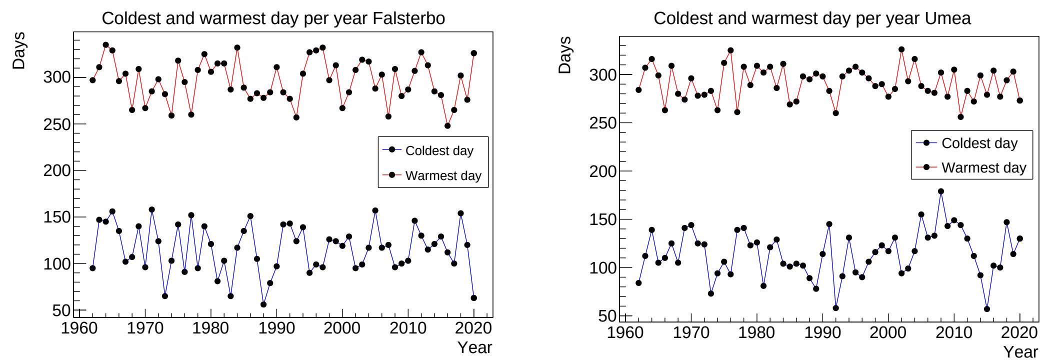
Decade	average lowest DeltaT	average highest DeltaT
1962-72	-27.1°C	17.6°C
2010-20	-25.2°C	17.2°C

Table 4: Umeå

First, from a qualitatively point of view, is immediately visible how, in both towns, the warmest temperatures of the years look more stable than the coldest ones, namely showing a lower standard deviation. Interestingly, looking at the values in the tables 3 and 4, we can argue that in both towns the highest and lowest temperatures are "getting closer" to the mean temperature of the year (which is increasing as reported in the previous subchapter). We could speculate that this effect is attributed to a larger amount of rains, which mitigates the temperature. A mitigation of the temperature affects the timing and length of seasons, described in the next subchapter. Finally, by comparison between Falsterbo and Umeå, seems that the winters in the north are the most affected by this effect, showing anomalously warm temperatures.

2.4 Coldest and warmest day of each year

The coldest and warmest day of the year have been selected according to the lowest or highest temperature, respectively, reached during the hours available from the cleaned data. In a few cases, we have encountered years that reached the same minimum temperature in more than one day, in these cases we chose to select the day with the lower average temperature between them. To better visualize the trends of the date of the coldest and warmest days during the years, we chose to plot the days (Y-axis) starting from September, instead of January, but without losing part of the data. The reason for this choice, which may seem confusing at first sight of the plot, relies on the fact that some of the coldest days were measured in January, and others in December, hindering the visualization of a possible trend of the coldest days. To modify the Y-axis order, we shifted upwards (by +95 days) all the measurements obtained from January to September, and downwards (by -270 days) the ones from September to January. This could not make complete sense and seems confusing in terms of chronological order during the single year, but does not affect the whole trend during the years and allows better visualization of the data. We decide to call this order of the months from September to August "Academic Year" because it reminds the academic calendar.



(a) Falsterbo.

(b) Umeå.

Figure 3: When the warmest and coldest day of each year take place.

Taking into account that we made the shift in the calendar so we could see the coldest days in the same stripe of days, we can now analyze the resulting plots. As in the previous chapter, we compared the average values between the first and last decades, summarized in table 5 and 6.

Decade	average coldest day	average warmest day
1962-72	128	300
2010-20	118	292

Table 5: Falsterbo

Decade	average coldest day	average warmest day
1962-72	119	290
2010-20	116	286

Table 6: Umeå

In both cases, we can observe that during the last decade the warmest and coldest days shows up earlier, suggesting an anticipation of the seasons. Despite these changes are very small, they can still represent a remarkable effect on season timing [3].

In the case of Umea, we find that the shift is less prominent than Falsterbo. However, on the coldest days, we can observe that the width of the stripe is the biggest one of all, as we can find the coldest day in 2008 around April, while in 2015 around October. This could be related to the last statement in 2.3, where we claim that the winters in Umeå are the most susceptible to climate change, despite again now Falsterbo shows the biggest changes when the whole year is considered, in agreement with 2.2.

3 Conclusion

Not surprisingly, Global Warming has been clearly demonstrated in 2.2, particularly causing a quadratic growth of the temperature during the years, according to our fittings. Furthermore, considering the first and last decades average temperatures, Falsterbo appears more affected than Umeå by Global Warming, showing a higher relative increase in temperatures. From 2.3 and 2.4, the data show that for both the places there is a tendency of warmest and coldest temperatures to get closer to the mean temperature of the year, namely their standard deviation is reducing. Also, we can argue that the coldest temperatures in Umeå show the biggest relative shift, suggesting that the winters in the north are actually the most susceptible to climate change, despite Falsterbo showed the biggest changes if the whole year is considered. Indeed, winter in Umeå are characterized by more anomalously high relative temperatures with respect to Falsterbo. Furthermore, we found that in both places there is a shift in coldest and warmest days, which all appear anticipated, especially in falsterbo, despite Umeå here shows the highest variability in the occurence of coldest days, again suggesting the higher susceptibility of winters to climate change in the north. As the mentioned consequences are function of a combination of multiple, complex, effects, these provided information are of course not straightforward and are still quite general, they would require much more detailed analysis and larger amount of data to derive more consistent conclusions. However, they point out the effect of climate change, especially on seasonal events, such as seasons timing, length and variability, which affect relevant environmental features such as growing seasons, snowmelt, birds migrations etc. connected with humans, animals and plants health, social economy and agriculture [3].

References

[1] The intergovernmental panel on climate change. https://www.ipcc.ch/. (Accessed on 06/11/2022).

[2] United states environmental protection agency. https://www.epa.gov/. (Accessed on 25/11/2022).

[3] Epa. 2021. seasonality and climate change: A review of observed evidence in the united states. u.s. environmental protection agency, epa 430-r-21-002. https://www.epa.gov/climate-indicators/seasonality-and-climate-change. (Accessed on 25/11/2022).