

# Analysis of Armenia's Climate

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# 1 Introduction

Climate is the average weather in a given area over a long period of time. The concept of climate includes information about the average temperature of different seasons, rainfall, sunshine, etc. The main features that describe climate are temperature, precipitation, wind examined over several years.

Climate can affect nearly all aspects of population, including energy, food, water supplies. It may have a vital impacts on different social, cultural, and natural resources. Moreover, climate can have influential role for a country's economy as many businesses are closely connected to weather and climate, such as outdoor tourism, commerce, agriculture. Therefore, it is crucial to pay great attention to climate and its changes.

The goal of this study is to present the overall climate of Armenia, highlight the regional variations and offer some possible explanations for the changes that could be observed throughout the years. The study concentrates mainly on three climate indicators: Surface Level Temperature, Precipitation and Wind Speed.

## 2 Data Summary

The study uses visualizations of multiple data sets about climate of Armenia collected from the different sources. The main data sets are extracted from the following sources:

- WORLD BANK GROUP
- ASIAN DEVELOPMENT BANK
- Cosmic Ray Division of Yerevan Physics Institute
- National Centers for Environmental Information

The data includes information about overall climate of Armenia. The data includes information from 1900s to 2022, so more than hundred years. Besides most of our data is actually daily data from several stations which are located in each Armenian Marz, which helps to study yearly, monthly and seasonal trends in temperature, wind and precipitation changes of Armenia during last hundred years. We have several data sets for each climate indicator. First, we have air temperature records including: daily data, extreme values and respected averages. Next, we obtained precipitation dates which includes quantity of the indicator with similar dates, varying from daily and up to yearly average values. Another group of data is used to explore the direction and speed of the wind. We have data for the last ten years of wind variation, as well as information about historical wind speed from 1950 to 2000. Overall, we have data about Armenia in general and also about each Marz with dates going as far as nearly hundred years of recorded observations.

The study uses all of these data sets to test different hypotheses. R programming language is used to analyze and visualize the data. More information about the data's summary can be found in the metadata file.

## 3 Research Methodology

The research behind this project includes analysis of various scholarly articles, books and report papers which are mainly published by foreign organizations. The primary target of those writings is to present the challenges of Armenian climate and provide some forecasts about the future deviations in the climate, without discussing the issues connected to the sources of mentioned changes. Using the information gathered during the research, we have came up with 11 hypotheses concerning specifically the overall changes in Armenian air temperatures, precipitation and wind speeds.

**1. Average Temperature of Armenia increased over years:**

Our first hypothesis is based on the information found in the Asian World Bank Group report which states that average temperatures in Armenia are becoming higher with each year. We support that claim, because indeed, it is evident that over the years we no longer experience extremely cold winters.

**2. Air temperature of Armenia warms uniformly throughout the year and winters don't become much colder:**

Our second hypothesis comes from the same source. The researchers state that Armenia will have consistent warming of air across all seasons. Again, we agree with such claims and assume that our conclusions would back up the hypothesis.

**3. There is no drastic variation in the extreme temperatures of Armenia:**

We have considered some other climate reports by UNDP which claim that temperatures all over the world would change in such way, that we will experience more anomalies. Meaning that winters will become colder, summers will bring extreme hot air and long-lasting droughts. However, as we have never saw such phenomenon in Armenia, we decided to go against the claims. We think that Armenian air temperature is, indeed, becoming hotter, but it happens during all seasons, not only in Summer months.

**4. Seasonal temperature increases except in spring, which could be connected to the fact that in spring vegetation grows, and consumes CO<sub>2</sub>:**

After reading various articles on the issue of seasonal climate changes, we noticed that in Spring, usually the global temperatures do not become warmer at the same fast rate as they do during all the remaining months. We decided to analyze the seasonal data for Armenia to find out if this phenomenon also exists in our country. Moreover, using other sources which discuss potential causes of such interesting event, we connected our hypotheses with one of the possible explanations.

**5. All Armenian Marzes experience temperature increase at approximately same rate:**

Due to the fact that Armenia is a relatively small country we decided to check if there are any variations between the temperatures in Marzes. But, as we do not believe there is a significant difference, we think that the temperature will be changing at the same rate throughout the whole country.

**6. Precipitation decreases throughout Armenia even in the most humid Marzes of the region:**

The UNDP report on “The Socio-Economic Impact of Climate Change in Armenia” states that precipitation for Armenia is highly variable. And their projections indicate an increase in average annual precipitation. Based on those studies, we decided to also include the changes with precipitation in our hypothesis.

**7. Precipitation decrease doesn't depend on whether the area is humid or dry. Eastern and Southern areas are expected to receive the least amount of precipitation:**

We decided to study whether Armenia has many different climate zones or not, in order to understand if we have variation in quantity of precipitation depending on a Marz. We believe that our country has many climatic differences because of our unique location. We know that Armenian vegetation is very diverse and because of that our country is rich with biodiversity. Hence, it must mean that Armenia includes various types of climates depending on the area. Therefore, the amount of precipitation should also depend on the type of specified location.

**8. In the last 100 years, there is no vital change in the precipitation of Armenia, but during the last 5 years, most of the regions experience much less precipitation:**

The reports also tell us that their precipitation forecasts take into account the fact that nowadays, the precipitation patterns are changing much more drastically than during the last century. Therefore, our hypothesis is that we will see more changes during the last 5 years, rather than 100.

**9. The average historical wind speed of Yerevan decreased, mostly in the last decades:**

Some articles claim that wind speeds are becoming more unpredictable, while others say that it is definitely increasing due to abnormal weather pattern. However, we decided to look only at Yerevan's wind speeds, because we read an article about the slowing down of wind speeds due to high rates of development and urbanization of countries. So, we think that Yerevan is actually experiencing wind decrease rather than increase.

**10. Wind directions have changed, resulting in less directional variation:**

Similarly, urbanization causes wind speed decrease as well as directional limitations, resulting in highly centralized winds.

**11. The number of calm days (without wind) increased in the last couple of years:**

Lastly, we think that not only the speed is lowering, but also the overall quantity is lessening.

## **4 Literature Review**

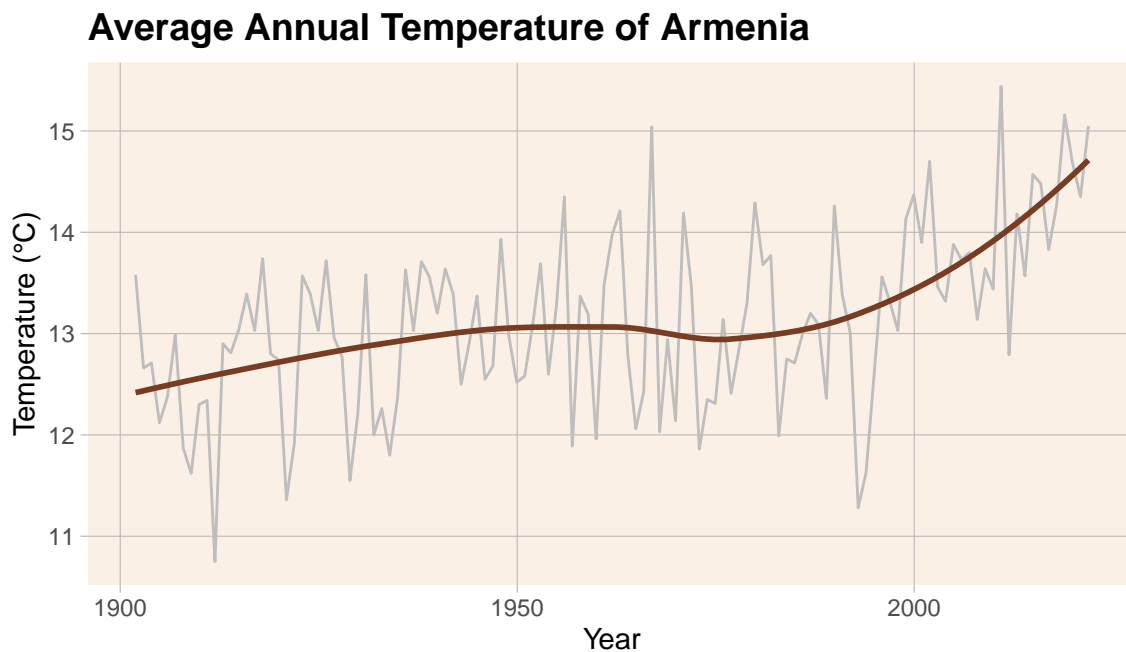
After finalizing our hypotheses and gathering our results, we decided to continue our research on the topic, but with a new target in mind. Our analysis has yielded some quite interesting and unique results, which do not always coincide with the opinions of some climate reviews. Hence, we began to look for possible explanations, causes and events which could back up our findings.

First, let us discuss the deviation in temperatures and mention about our initial hypothesis which actually opposed the information obtained from the articles. As we know, climate researchers often use various models to predict the possible events connected to the whether, and those predictions are based on the current data.

Everything we read about temperature, was concerned with the overall warming, which actually began to happen a long time ago, but the rates of change are starting to become faster with each year which is actually supported by our data. However, what we disagree on is connected to their fact stating that the air temperature is having more anomalies and we see higher temperatures in the Summer and colder ones in the Winter. Yet, our data shows a uniform warming that does not have any anomalies like cold snaps or heat waves. When we consider the precipitation, our research has mainly disagreed with the specialists forecasts and overviews. Some books about Armenian climate suggested that we are witnessing precipitation variations: meaning some places are having more frequent rainfalls, while others experience droughts. But, after looking at the data, we saw a completely different picture. We concluded that it is important to look at each Marz considering what type of climate is actually there. And after analyzing the results, we saw somewhat stable precipitation with minor decreases in humid Marzes. When we discuss the wind, our hypotheses were actually similar with those of the ones mentioned in various reports. People have been saying that urbanization and country development slows down wind speeds, which can be easily seen on our data and is shown on some graphs which were made using R's libraries specifically made for tracking wind speeds and directions.

## 5 Analysis

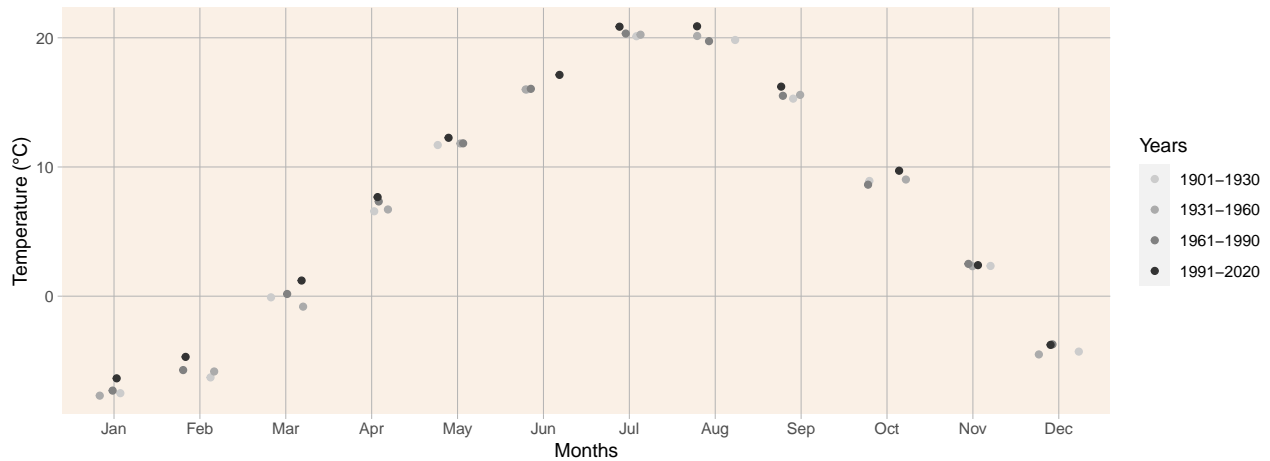
### 5.1 Air Temperature



The above graph presents some evidence about the first Hypothesis. It shows the average temperature of Armenia from the year 1900 up until nowadays. From the brown trend line, we can see that the temperature noticeably increased. However, what is significant here, is the fact that starting from the 1980s we see a much higher rates of temperature increase.

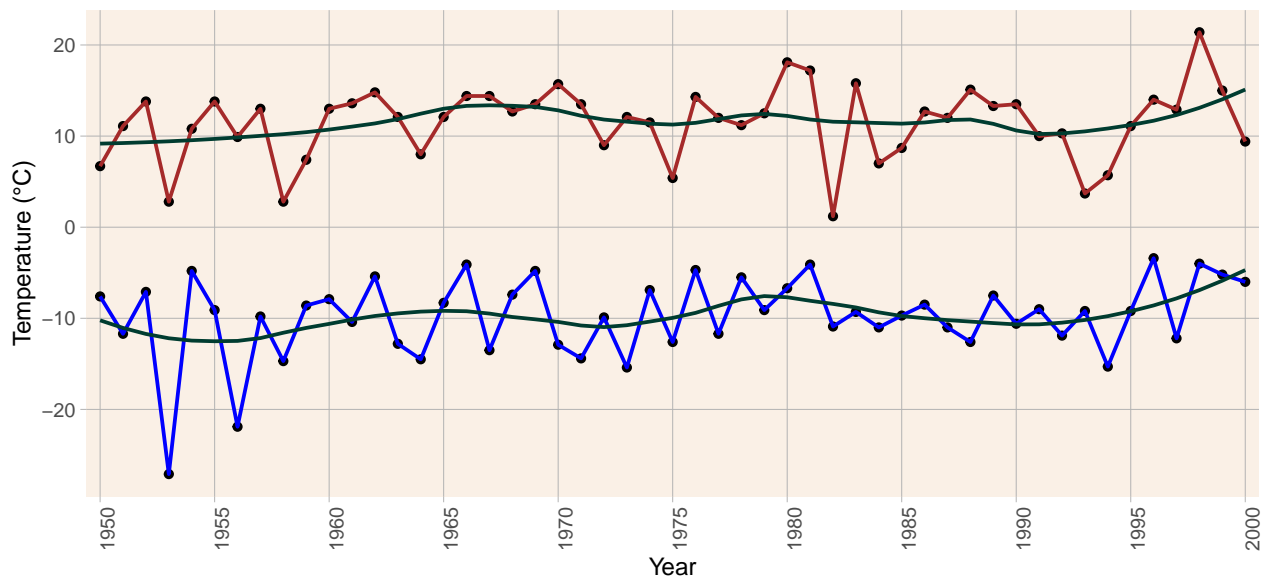
It is important to mention, that temperature is a crucial factor for maintaining stable agricultural yields and various other aspects for the country's development. And even the slightest deviations could cause significant effects. There are various causes that are responsible for the fast growing temperatures, and they range from natural phenomenons to the results of human activities.

### Average Monthly Temperature of Armenia for different year intervals

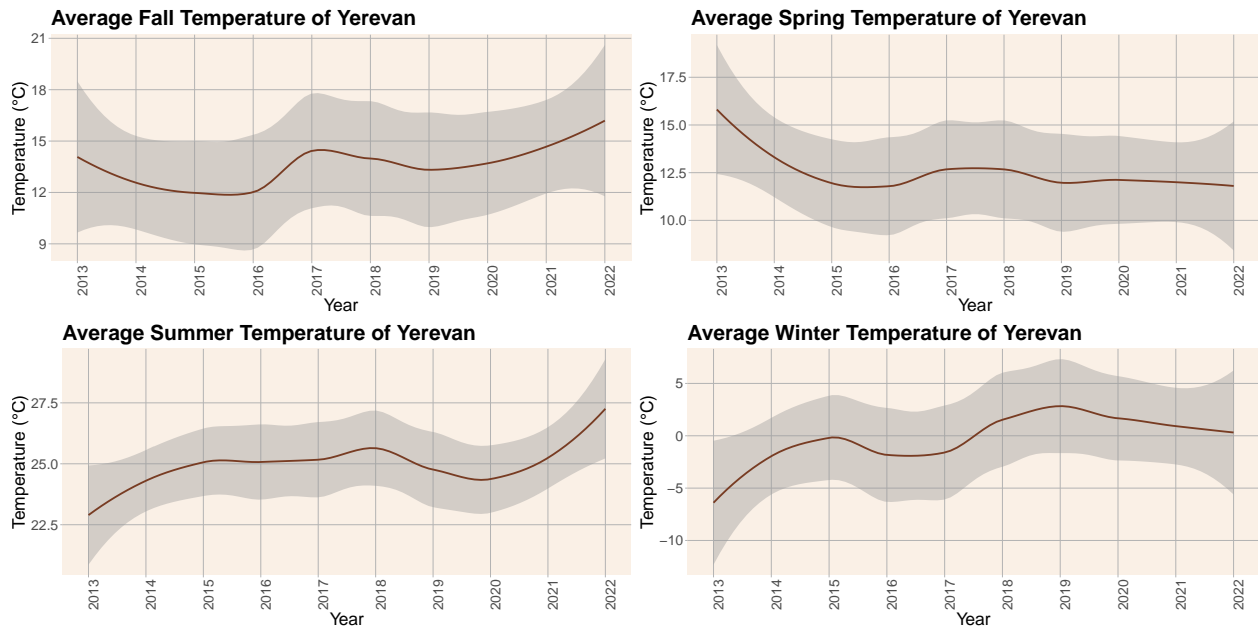


Here we can see how the monthly temperatures for different time intervals vary. The main observation is that for almost all of the months, the temperatures appear to be higher for the period from 1991 to 2020. This is an important finding, because there are various sources which claim that the climate all over the world is changing and the winters are becoming much colder, while the summers much warmer. However, in the case of Armenia, we can clearly see that the air warms uniformly throughout the year.

### Highest and Lowest Temperature of December in Armenia

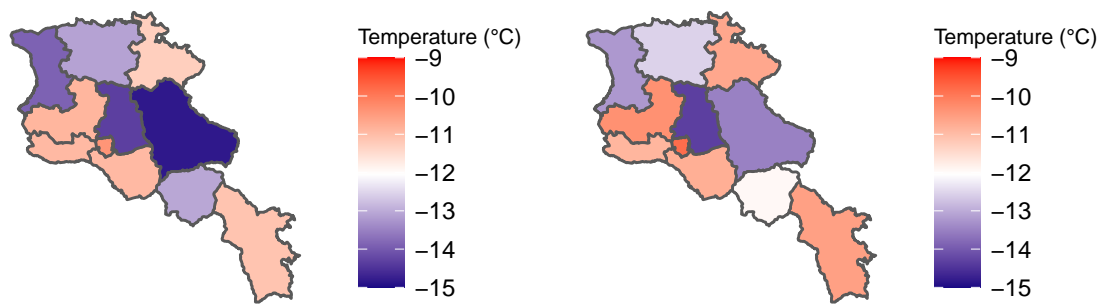


The above graph highlights an evidence about the third Hypothesis. Some studied articles say that nowadays, the climate is witnessing more anomalies and as the years pass, we should see more and more variation in the extreme temperatures. However, this graph shows us that the maximum and minimum temperatures over the past 50 years do not change drastically. Even though we do see some anomalies (in 1953, 1982, 1998), the trend line remains consistent. There is an increase in temperatures if we compare the values in 1950 and 2000, but no major changes in extremes can be witnessed.



With those graphs, we wanted to show the average seasonal temperatures in Yerevan and try to explain some of the variations that could be seen. If we look at the graphs for the Fall, Summer and Winter, we can see a noticeable increase from the year 2013. However, when we look at the Spring season, we see an opposite picture. This is a very important observation which has various explanations. Both the natural environment and the human activities have an effect on the air temperature. For instance, the fact that the Sun spots, which are areas on the sun that release much more heat, are becoming more frequent - is a proved natural phenomenon that increases the temperature all over the Earth. Besides that, human activities ranging from transportation to industrial factories also cause warming due to the release of gases like CO<sub>2</sub>(carbon dioxide). And the cooling in Spring can be directly correlated to the fact that during Spring months, trees and the vegetation begin to grow and they consume the CO<sub>2</sub>. And we read that in Yerevan, after 2013 the tree cover has actually been increasing, which could possibly cause this temperature decrease.

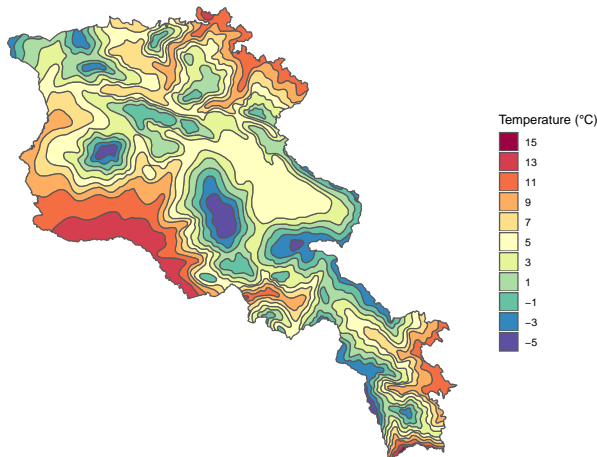
**Average Temperature during Last 20 Years      Average Temperature during Last 5 Years**



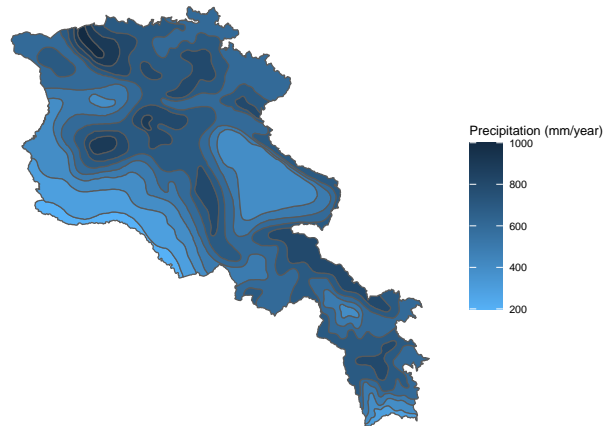
Above we have two Armenia map graphs. The left one shows last 20 years average temperatures. We can see that the regions with purple color include rather dark coloring, which means the temperature in those locations is rather cold. Comparably, the graph on the right shows last 5 years changes and here the previous dark purple regions become more light, which proves that during years all cold regions became less colder. In the same way, the regions with red color, became more red in case of last 5 years graph, which again highlights the temperature increase in all regions of Armenia. So, the two map comparison help to see that all Armenian regions experience temperature increase at approximately same rate.

## 5.2 Precipitation

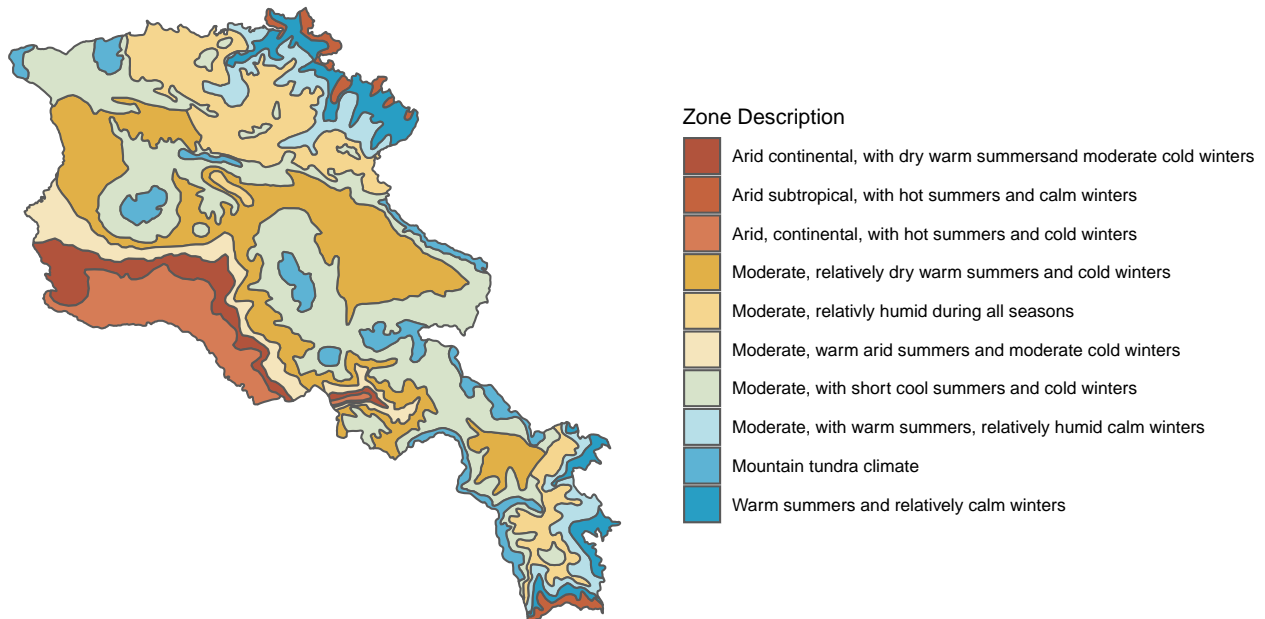
Average Historical Temperatures in Armenia



Average Historical Precipitation In Armenia

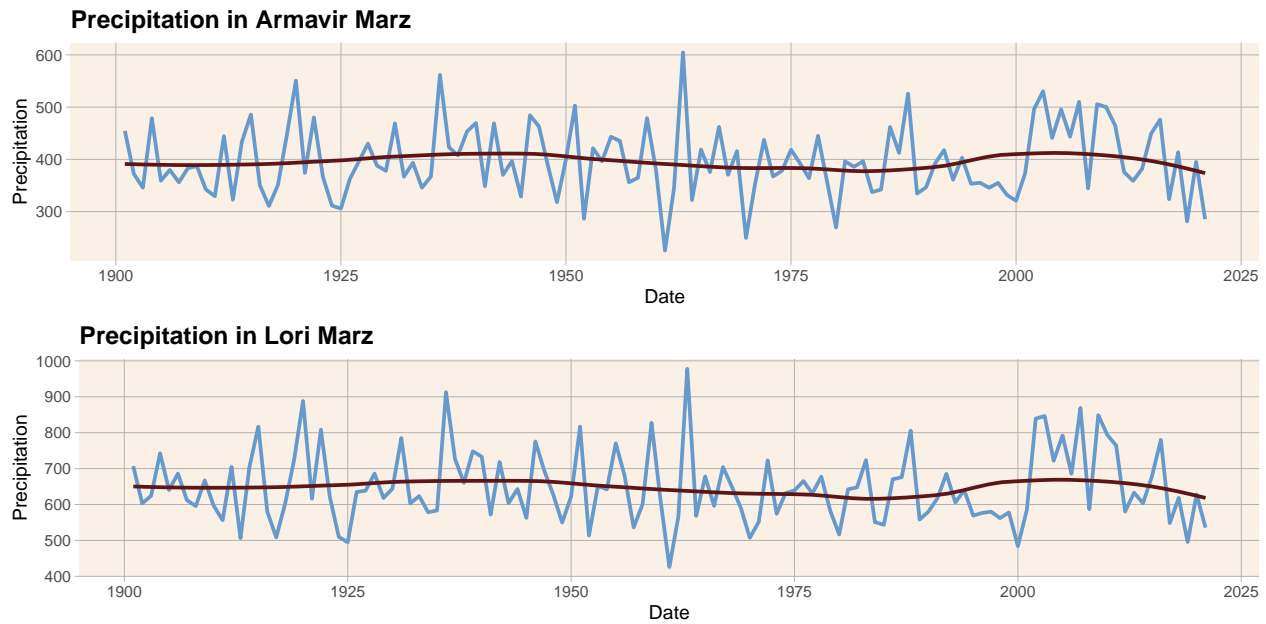


Climate Zones of Armenia



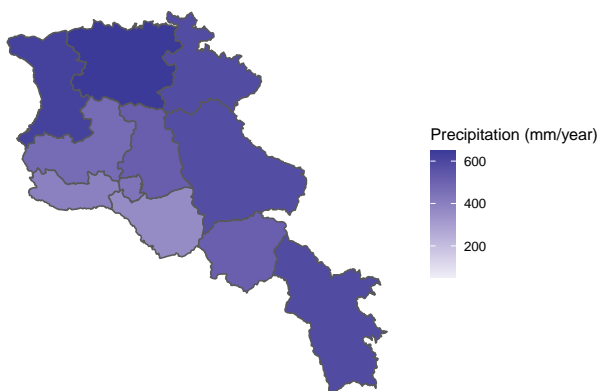
Next, we wanted to analyze the precipitation data. However, in order to do that, we first need to understand where in Armenia we can see different climate zones. Because precipitation varies much more than temperature (the scale is diverse: from 100 millimeters up to 1000), it is important to understand what is the current type of climate in each Marz. So, on the Climate Zones map, we can see that Armenia has 10 different climate zones, and most Marzes include many of them. We can see that arid areas have much higher average temperature and much lower average precipitation compared to more humid and moderate areas. Therefore, we can see 3 completely different maps with separate border lines, but the combination of those two actually produces this map of zones which allows us to know which Marzes actually have fewer climate variation. So now, we know that to compare precipitation, we must look at Marzes like Armavir and Gegharqunik vs Shirak and Lori because they have completely opposite and less varying climate zones.



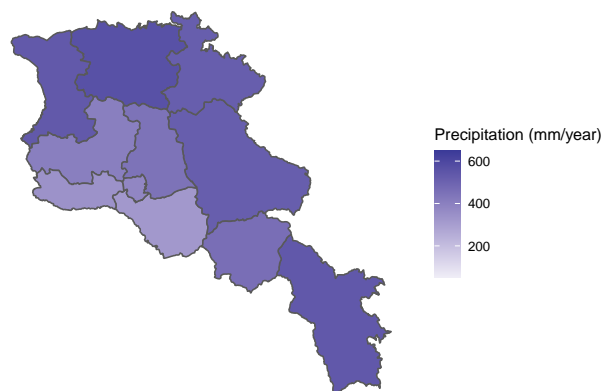


Now, if we analyze the data from each Marz, we can see that more humid Marzes experience somewhat of a decrease in precipitation, while hotter places have almost no major variation since 1900 up until now. However, if we look at places like Syunik, we cannot obtain a lot of valuable information because Syunik is a very diverse region. Here is the graph of the average precipitation in Armavir from 1900 to nowadays. It shows us that Armavir sees very little precipitation (only about 400 mm/y) and that over the years, the value actually stayed stable. If we compare it to Lori precipitation, we see that the value has actually gone down, but the overall precipitation is much higher. Those findings suggest that instead of variation in precipitation all over Armenia, we see a completely different picture. Our graphs show that precipitation in humid Marzes of Armenia, where the precipitation is already quite high, the value actually decreased over the years. Nonetheless, arid and hot Marzes do not see any variation or decrease, and their precipitation has not been changing over the years.

**Average Precipitation during Last 100 Years**



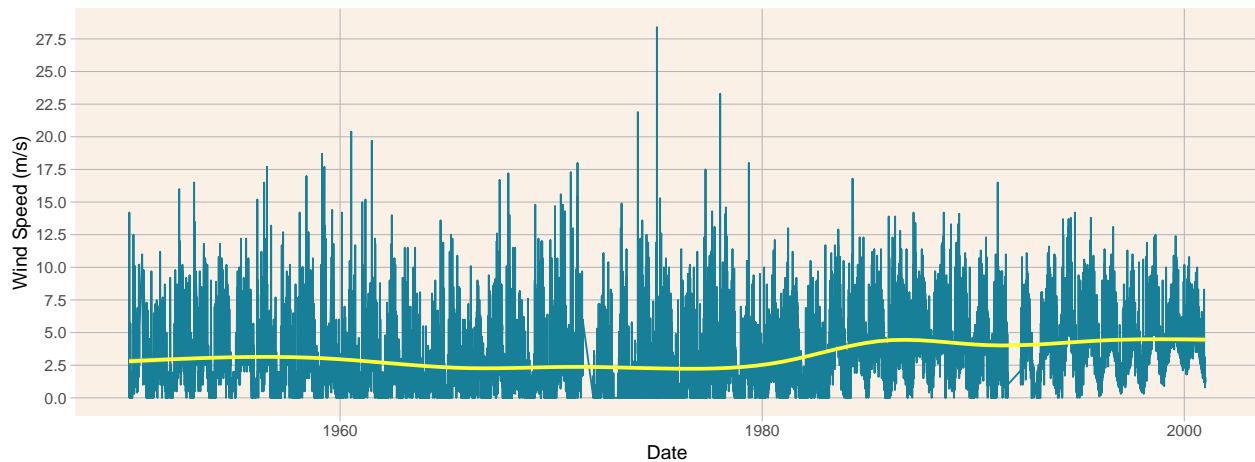
**Average Precipitation during Last 5 Years**



Moreover, we also wanted to show you how the average yearly amounts of precipitation have changed. From the map of the last 100 years we see a darker colored map with average value around 600 millimeter. However as we switch to the last 5 years, the colors became somewhat lighter, with average value around 450 millimeter.

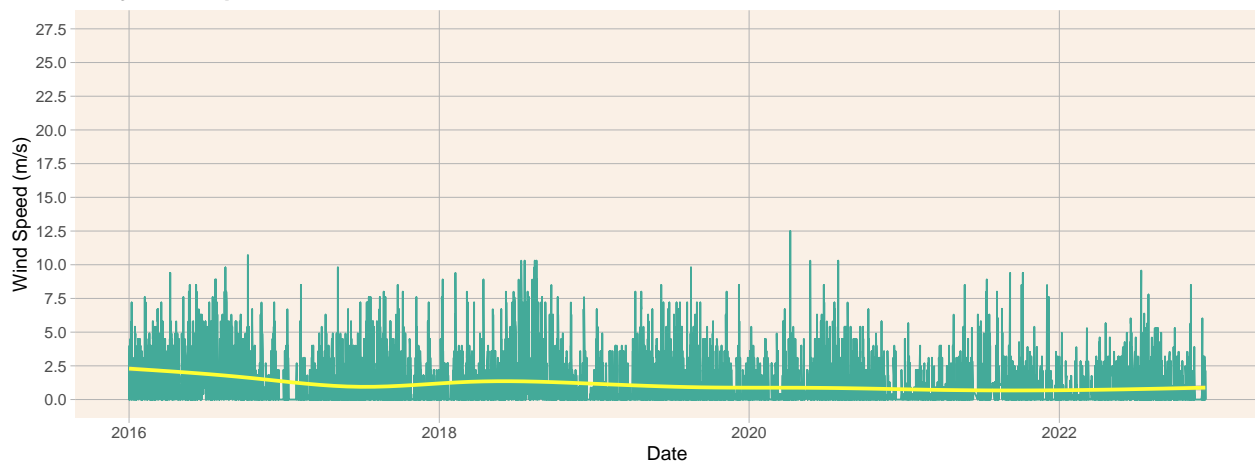
## 5.3 Wind

**Historical Daily Wind Speeds of Yerevan**



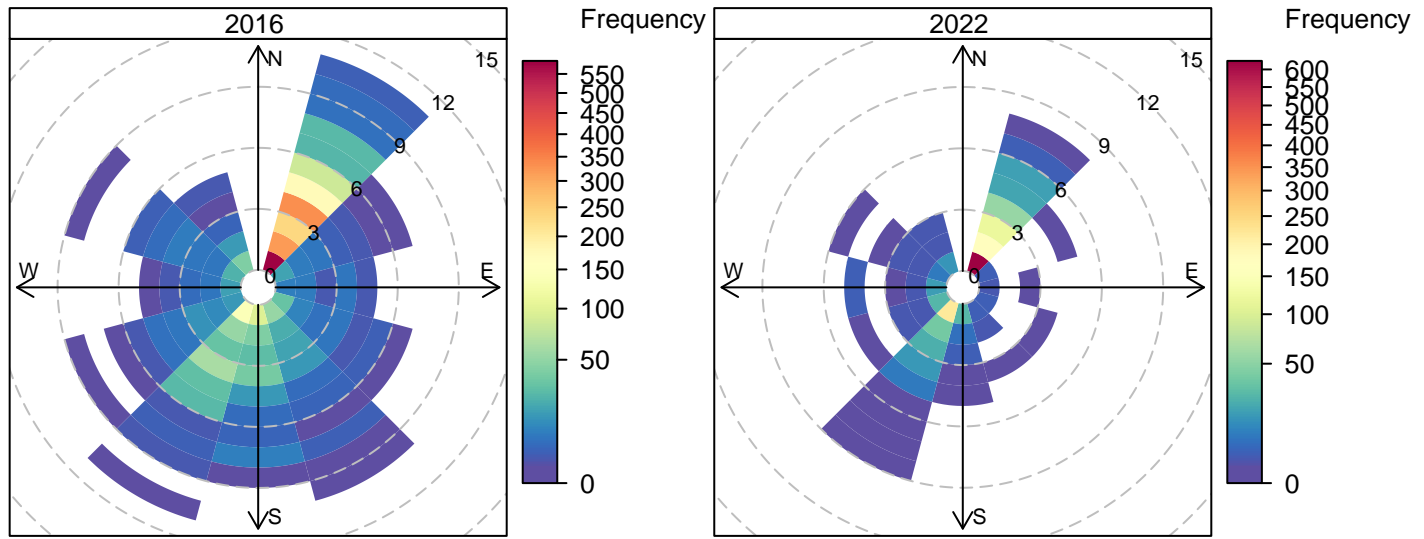
The above graph presents the historical Wind speed map of Yerevan, we can see the trend line, which suggests that the average speed is around 2.5 meters/second before 1980 and around 5 after. We cannot know for sure what the speed was before 1980 because the data is a result of various models, but for our further findings, it does not play a major role. The main observation here is that the average speeds never went down below 2.5.

**Daily Wind Speeds of Yerevan**



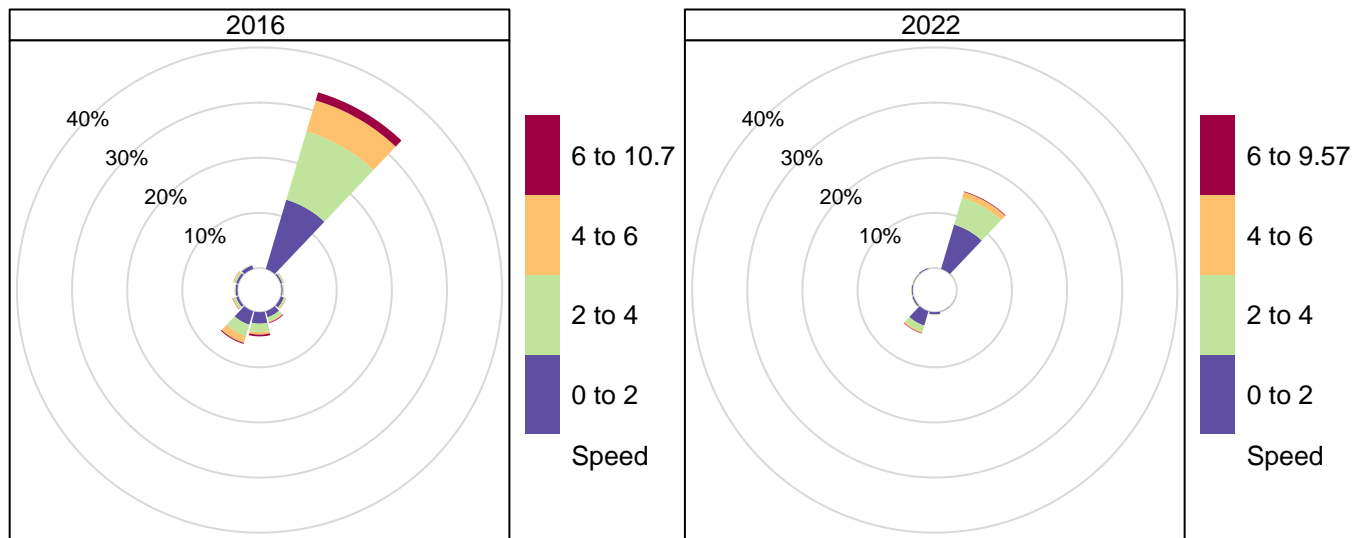
However, on this graph, we see a significant dip in wind speed after 2016, reaching as low as 1 meter/second. As we do not see such phenomenon with wind before 2000s, we decided to concentrate only on the last decade and show the sudden deviations for this climate indicator. There are various possible explanations for such findings and the main one is related to urbanization. We believe that the speeds could have been significantly affected by the new high-storied buildings. Furthermore, we know that before 2000s the main type of apartments in Armenia included 5-10 storied buildings with majority not exceeding above 5 stories. However, as our economy is beginning to grow at faster rates, and most of the Soviet time buildings are either too weak to withstand earthquakes or too old to consider any renovations, we see a major increase in the number of the newly built apartments. We know that still, the industry is growing and more buildings are being built, and we believe that Yerevan's wind speeds will continue to decrease further on.

### Wind Speed and Direction in Yerevan



The following graphs show the comparison between the wind speed and direction in 2016 and 2022. We see that in 2016, we have observations almost for all the directions while in 2022 the wind is centralized in 2 main directions. Moreover, we see that most of the values for 2016 reach 12m/s while in 2022 the speed was mainly below 9 and even 6 m/s.

### Amount of Wind by Direction in Yerevan



In those graphs we see the amount of wind for the same years. The main observation is that we see more extreme values for the year 2016 and while 48% of the days in 2016 were calm, in 2022 the value reaches 79%. Lastly, the mean wind speed for 2016 is 1.9 m/s and for 2022 it is 0.7 m/s.

The results of all analyses are deployed and available on the Internet. To view the app use the link [https://krgh.shinyapps.io/Group\\_Project/](https://krgh.shinyapps.io/Group_Project/), where you can interactively change the graphs to see your desired visualizations.

## 6 Conclusion

To conclude our analysis, we can say that our work has shown to agree with some of the hypotheses taken from climate research papers, however, we also notice some significant differences between some of the statements in those books and our graphs.

It is evident that the results about temperature increase mainly coincide with the findings. Our graphs show that the average temperature in Armenia has been increasing at much faster rates during the last decades. Yet, some researches suggested that winter climate in Armenia will be much colder, while summers will bring extreme temperature rises. This hypothesis is actually opposed by us because our analysis shows no such phenomenon in Armenia. On the contrary, we see results which show uniform warming in the country, without any unexpected anomalies.

Furthermore, our findings about seasonal temperature changes are actually quite unique, with evident decrease during Spring months. To back up our result, further research yielded some possible causes of Spring cooling connected to the fact that CO<sub>2</sub> levels decrease due to vegetation growth. Such statements were concluded due to the fact that the relationship between CO<sub>2</sub> and air temperature has been proven to exist. Moreover, we looked at information about forest covers in Yerevan, and show that from 2013, we actually plant more trees than cut them, resulting in net positive.

Moving forward, we can discuss the hypothesis about the precipitation variability in Armenia. Before performing our analysis, we read that, in the future decades, the precipitation in Armenia will change drastically and unexpectedly. However, after looking at the data, we see that only humid Marzes actually experience any change in precipitation connected to the slow decrease. The remaining, hotter places like Armavir or Aragatsotn do not show changes at all, their rainfalls are staying stable as the years pass.

Last but not least, we have the analysis of wind speeds and directions. We decided to specifically take into account the data from Yerevan to focus on one place and be able to find some causes for possible variations. Our hypothesis on this indicator mainly came from some foreign articles about the situation in other countries because there was almost no information on wind analysis from Armenian sources. After our work, we were able to conclude that wind speeds in Yerevan are decreasing due to some factors like urbanization. Moreover, we saw that wind direction is also becoming less and less diverse, with more or less centralized winds occurring in the last couple years.

Overall, we see that some articles have been suggesting quite reliable information about the climate changes in Armenia, however some of them tend to make the forecasts too extreme or too over dramatized, which could be rather misleading. We believe that it is important to follow such changes and try to do everything to mitigate their damaging outcomes, but if we do not have precise foundation to build upon, we would not be able to concentrate on the more important issues that could require our immediate attention.

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