

Climate Change

1. Introduction

Climate change is one of the unintended consequences of the rapid economic growth experienced by most countries since the Industrial Revolution. It is a critical topic for policymakers since governments must first assess the severity of the problem before deciding how to reduce it.

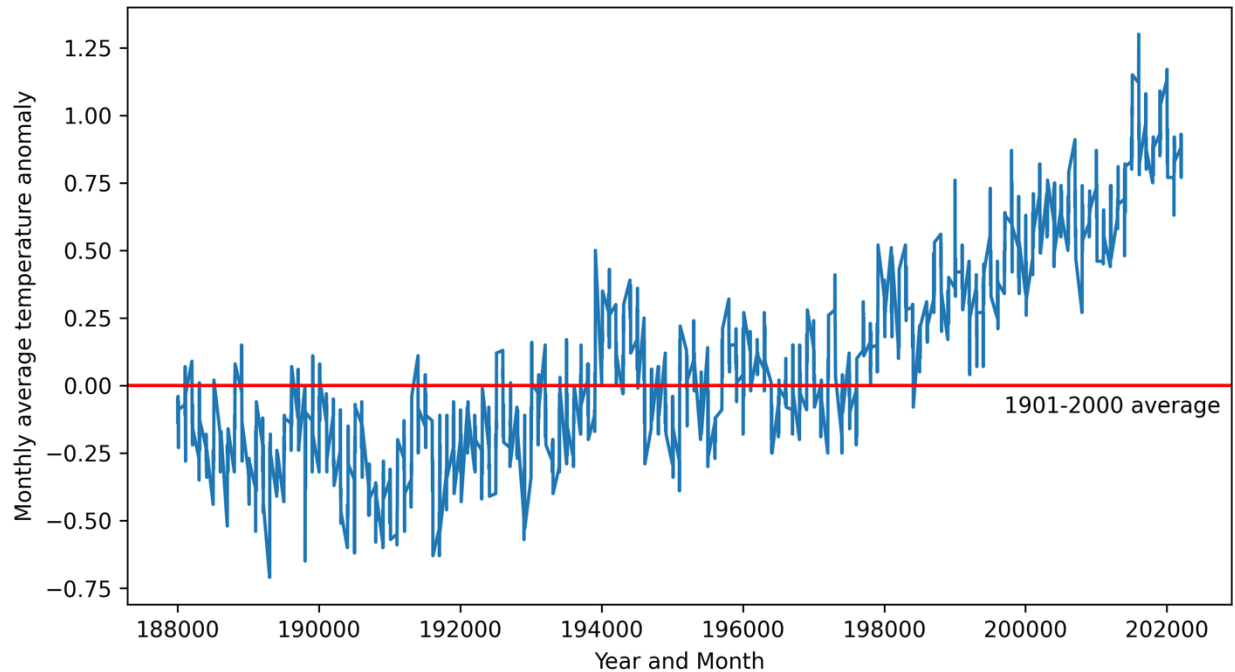
Meanwhile, many people are still doubtful about whether climate change is actually happening. To address this skeptic's question, we examine the behavior of environmental variables across time to see if there are any general trends in environmental conditions that could indicate climate change. This assignment investigates the behavior and distribution of temperature as the main environmental variable from 1880 to 2022.

2. Behavior of global land and ocean temperature anomalies over time

The temperature anomalies are based on the land and ocean temperature anomalies dataset as published by NOAA - National Centers for Environmental Information¹. The temperature anomalies are given in degrees Celsius relative to the average temperature over the period 1901-2000. These values are at the global level and month unit from January 1880 to June 2022. Temperature anomalies are chosen instead of absolute temperature to minimize as much as possible the effect of station location and elevation on temperature of different areas.

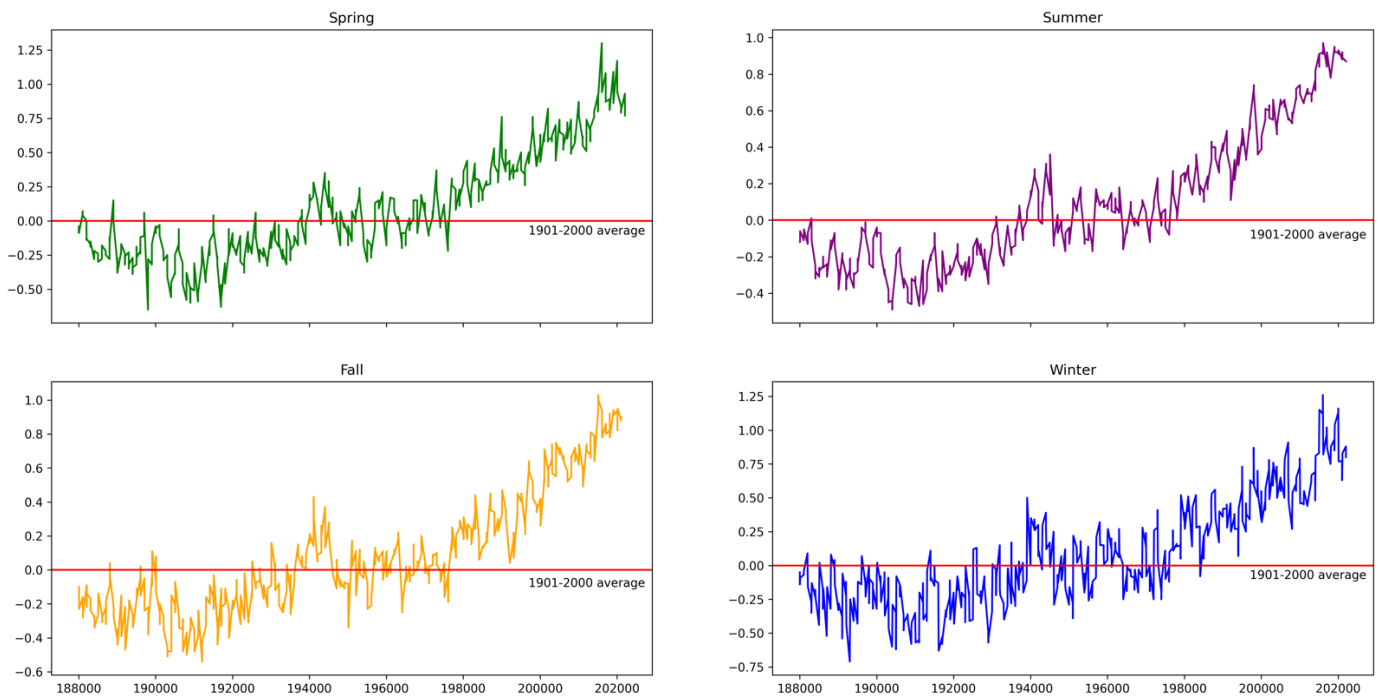
¹ NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published July 2022, retrieved on July 24, 2022 from <https://www.ncei.noaa.gov/cag/>

Graph 1: Monthly Global Land and Ocean Temperature Anomaly from 1880 to 2022



The line graph 1 suggests a general increase in global temperature over time. From 1880 to 1940, the temperature anomaly initially fluctuated at low mean with predominantly negative values. This means the observed temperature was lower than baseline temperature over the period 1901-2000. From 1940 to 1980, the temperature anomaly started to fluctuate at higher mean value. There were consistently positive values and displayed increasing trend from about 1985, indicating that observed temperatures are also increasing. The temperature anomaly peaked the highest of 1.3 degrees Celsius in around 2015. Graph 1 overall shows positive relationship between temperature and time and provides evidence to support the presence of global warming.

Graph 2: Seasonal Global Land and Ocean Temperature Anomaly from 1880-2022



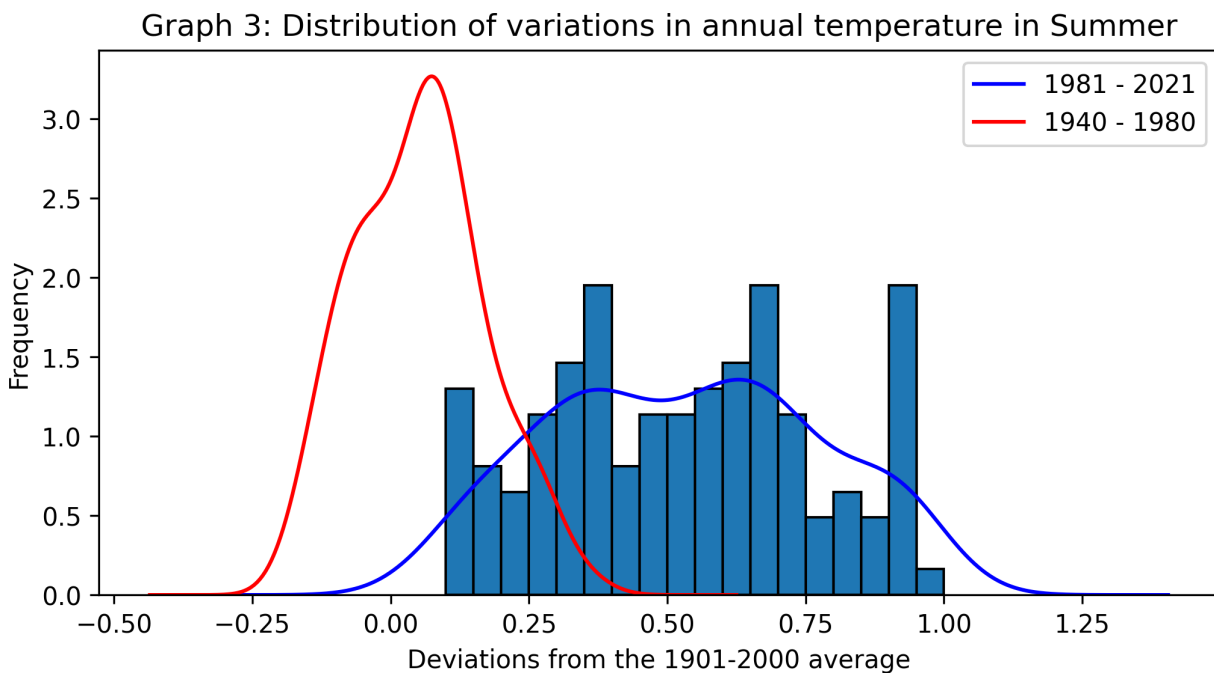
Although longer-term temperature anomaly (one year or a decade) is more effective for exposing the general trend of global warming, shorter-term temperature anomaly (such as seasons and months) can provide more information about the underlying process of global warming. The seasonal graph 2 can help us notice how patterns might be different from what we see in the monthly graph 1. As suggested by graph 2 above, there is no difference in pattern between seasonal and monthly data. Both fluctuated in similar progress: initially at low mean from 1880-1940, then at higher mean from 1940-1980 and finally at consistent increase rate after 1985. Among seasons, there are also similar patterns in the change of temperature anomaly from 1880 to 2022. The only difference is that the consistent increases in temperature anomaly were clearer in Spring, Summer and Fall since 1980 but for Winter it was just clear enough after 1985. This might indicate longer time taken to be able to see the increase in

temperature during Winter time. Also, Winter and Spring can peak at higher temperature anomaly compared to Summer and Fall ($\approx 1.25 > \approx 1.0$).

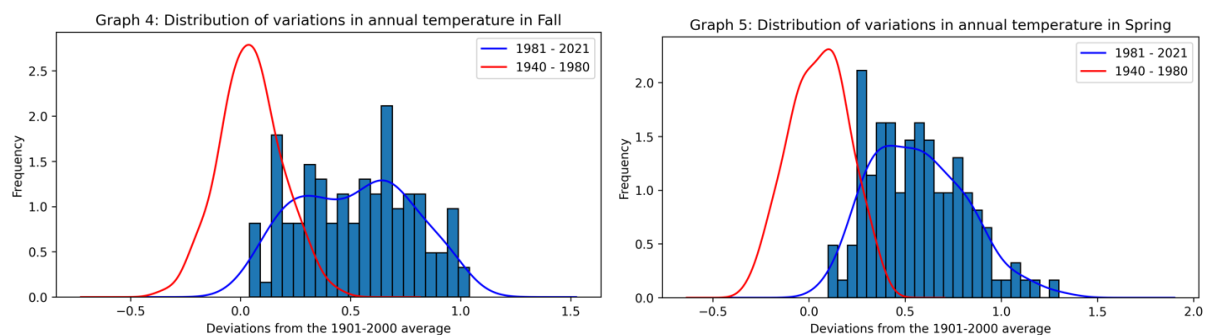
In general, both seasonal and monthly temperature visualizations are supporting the argument of global temperature is rising over time.

3. Distribution of temperatures and temperature variability over time

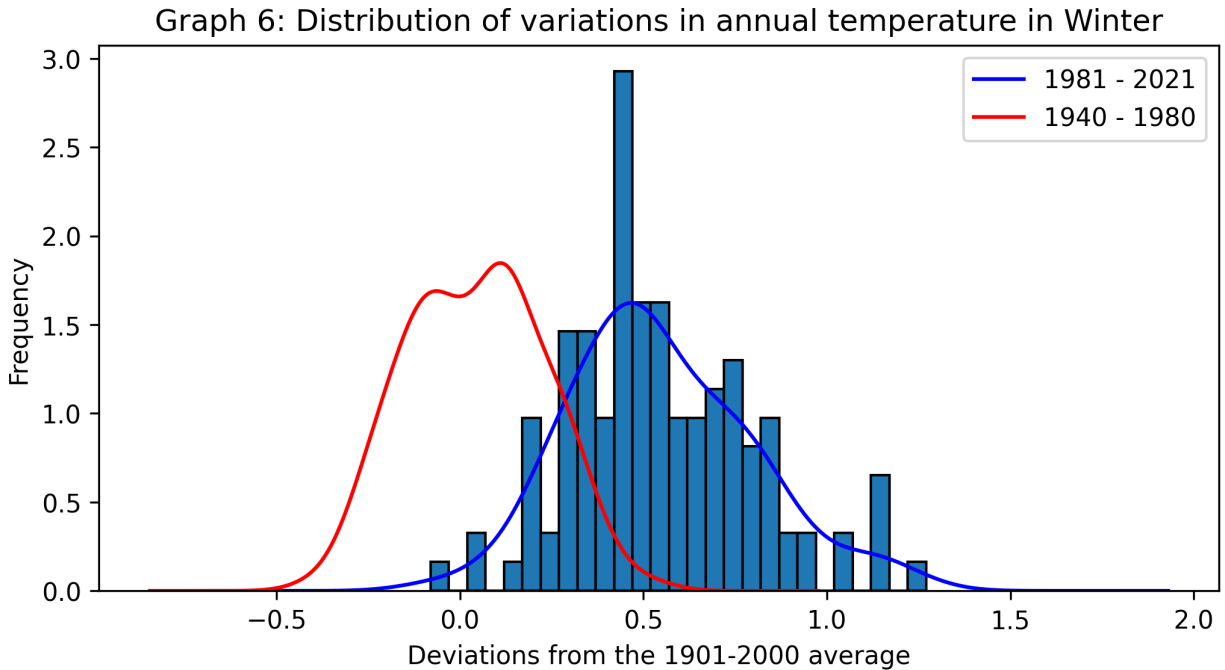
Beside the changes in global temperature anomaly, we are also concerned that climate change may make extreme weather events more common. In the past, some parts of the world suffered big storms and severe heat waves, both of which caused significant damage and disruption to economic activity. Will climate change make weather more extreme and variable? The analysis below is going to investigate the distribution and variability of temperature over time.



Graph 3 above shows how summer temperatures have shifted toward more extreme temperature in the past. There are 2 separated time periods with a range of 40 years for each represented in the graph. One is from 1940 to 1980 and the other is from 1981 to 2021. Red and blue lines represent the general shape of summer temperature anomaly distribution corresponding to each time period. For both time periods, the distribution of summer temperatures forms bell curve shape (also known as normal distribution). This bell curve shape suggests that the majority of temperature values are close to the average, generating a curve in the center. Extreme temperatures, which occur less frequently, fall in the wings, hotter to the right and colder to the left. As the peak of the curve shifts to the right over time, temperatures in more places fall into the hotter side and fewer fall into the cold side. The curve also flattens out, indicating greater temperature variability around the world. However, the temperature may not become more variable in reality; rather, the flattening out may be due to different parts of the world warming up at different speeds.



Graphs 4 and 5 are showing that there is similar shifting pattern in Fall and Spring seasons, except for Spring there is less spread out around the mean of temperature indicating smaller standard deviation compared to the Fall and Summer.



For the Winter, there is not much difference in temperature variability between the period 1940-1980 and period 1981-2021. But there is still a shift in distribution curve, indicating winter temperatures shift to higher levels and it further reinforces its effect to the process of ice growth and ice melting around the world as another indicator of climate change.

4. Conclusion

All in all, global temperature has been increasing over time and extreme weathers become more common. Evidence shown by change in behavior and distribution of temperature anomaly has proved that climate change is real. Although, temperature alone will not give us a complete picture of climate change, it does give us a glimpse of the changes that are happening and could seriously affect human life in the future.