Time Series Analysis on Climate Variables

SC475 PROJECT Presentation

202103017 - Dhruv Shah
202103022 - Vatsal Shah
202103053 - Vraj Thakkar

May 10, 2024

Mentor - Prof. Mukesh Tiwari

Table of contents

Motivation

- **Climate Change Impact:** Climate change is one of the most pressing issues of our time, with significant impacts on ecosystems, agriculture, human health, and economies worldwide.

Motivation

- **Climate Change Impact:** Climate change is one of the most pressing issues of our time, with significant impacts on ecosystems, agriculture, human health, and economies worldwide.
- **Temperature Trends:** Recent decades have seen noticeable shifts in temperature patterns across the world.

Motivation

- **Climate Change Impact:** Climate change is one of the most pressing issues of our time, with significant impacts on ecosystems, agriculture, human health, and economies worldwide.
- **Temperature Trends:** Recent decades have seen noticeable shifts in temperature patterns across the world.
- **Need for Analysis:** Understanding the trends and patterns in temperature data through time series analysis is crucial for policymakers and researchers to develop effective strategies.

Motivation

- **Climate Change Impact:** Climate change is one of the most pressing issues of our time, with significant impacts on ecosystems, agriculture, human health, and economies worldwide.
- **Temperature Trends:** Recent decades have seen noticeable shifts in temperature patterns across the world.
- **Need for Analysis:** Understanding the trends and patterns in temperature data through time series analysis is crucial for policymakers and researchers to develop effective strategies.
- In this project, we have attempted to analyze the monthly temperature data of the Indian Sub-continent over the time period of 1901-2021 and aimed to derive some meaningful inferences from our analysis.

The Dataset

The Dataset

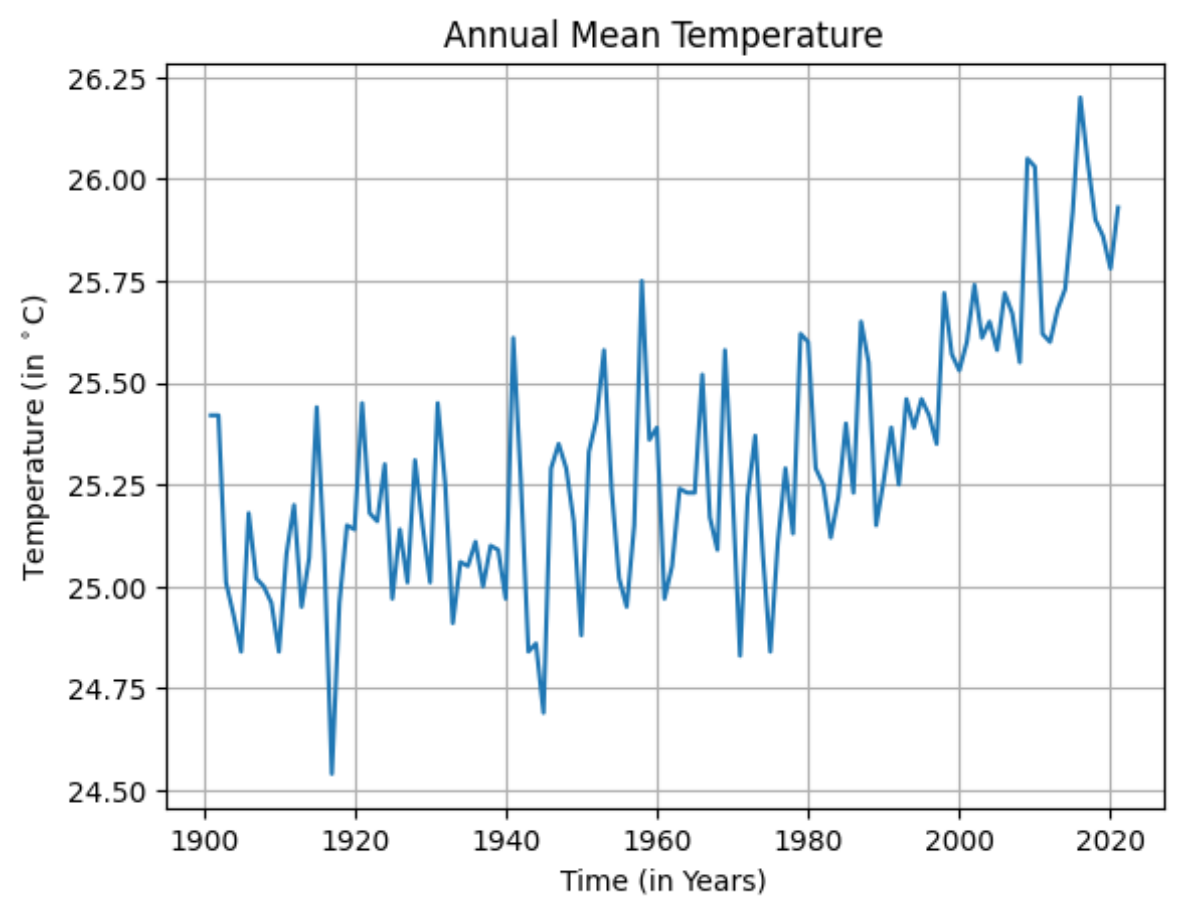
The dataset used is publicly available on the official website of the **Indian Meteorological Department (IMD).**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2	1901	19.32	20.89	24.95	28.22	29.76	29.85	28.24	27.33	27.23	26.33	22.92	20.05	25.42
3	1902	20.17	21.58	25.73	28.15	30	29.47	27.99	27.71	26.76	25.33	22.43	19.77	25.42
4	1903	19.28	20.71	23.92	27.67	29.47	29.53	28.32	27.16	27	25.69	22.01	19.3	25.01
5	1904	19.19	20.32	24.41	28.11	29.17	28.8	27.36	27.26	26.84	25.67	22.16	19.86	24.93
6	1905	18.34	18.37	23.15	26.26	29.73	29.87	28.13	27.65	27.16	26.35	23.24	19.79	24.84
7	1906	19.05	20.45	23.59	28.04	30.55	29.01	27.95	27.19	26.99	25.81	23.04	20.47	25.18
8	1907	20.28	20.75	23.53	27.1	28.95	28.91	28.1	26.89	27.06	26	23.16	19.48	25.02
9	1908	19.2	21.03	24.32	28.72	29.54	29.58	27.45	26.86	26.7	25.43	22.07	19.12	25
10	1909	19.38	20.79	25.08	26.95	29.4	28.45	27.12	26.87	26.83	25.64	23.1	19.96	24.96
11	1910	19.3	21.17	24.5	27.66	29.71	28.59	27.42	27.03	26.72	25.21	21.81	19.01	24.84

https://data.gov.in/resource/seasonal-and-annual-mean-temperature-series-period-1901-2021

The Temperature Dataset Analysis

The Annual Mean Temperature



- Clear upward trend over the past few decades.

Figure 1: The Annual Mean Temperature

The Monthly Average Temperature

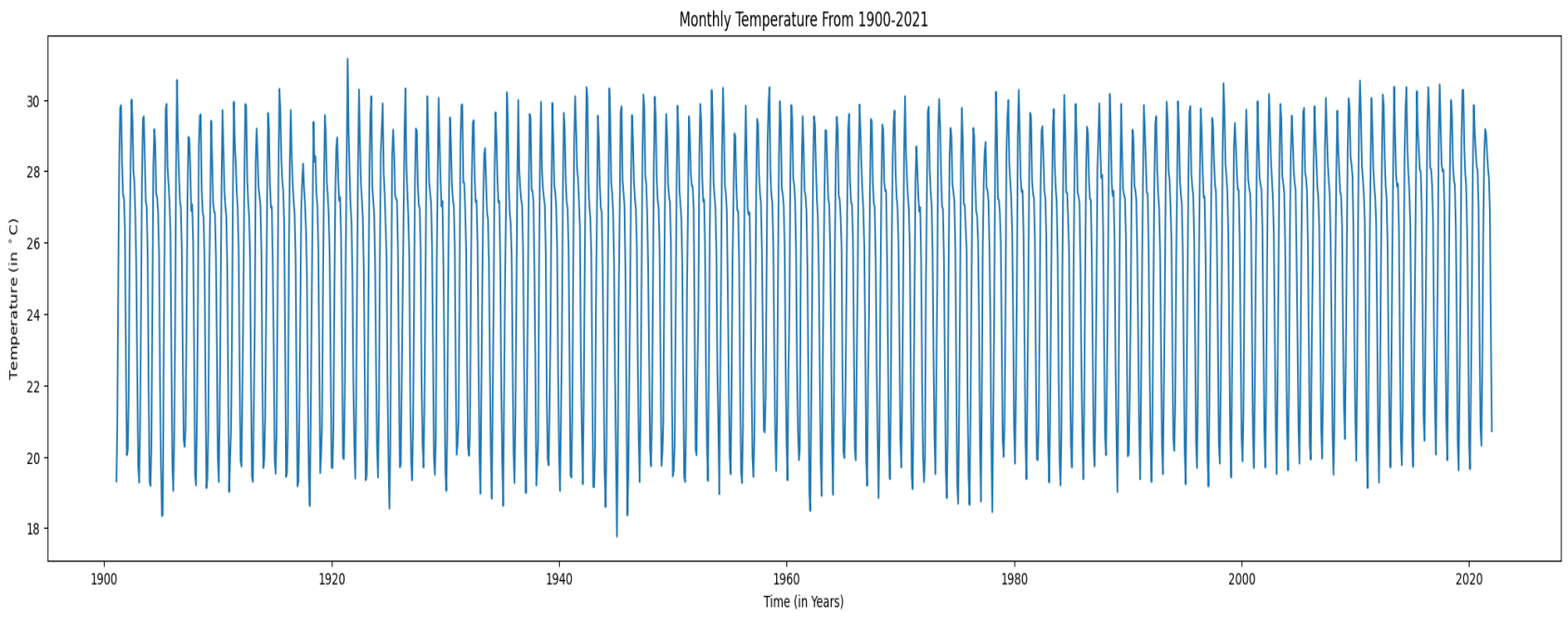
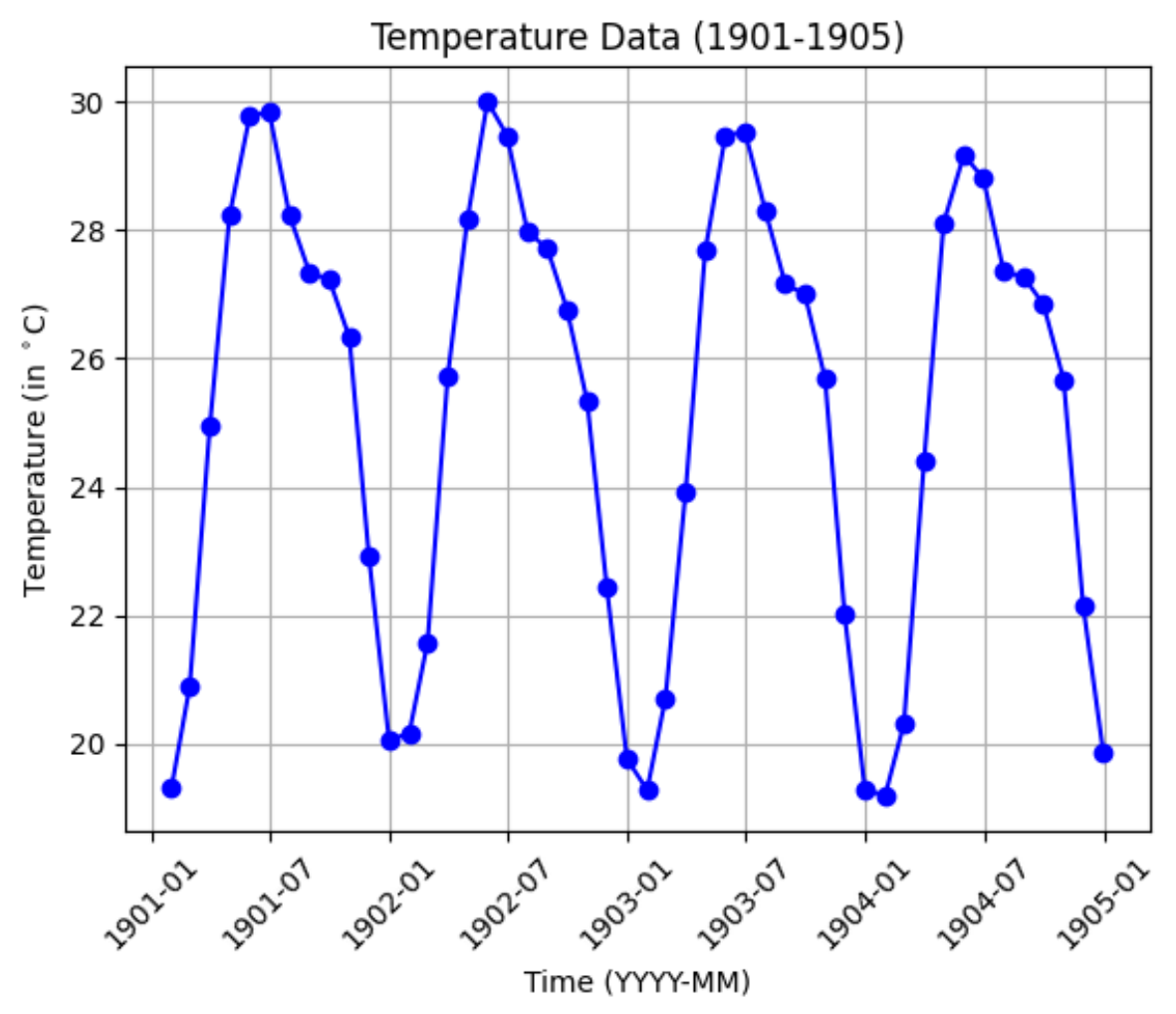


Figure 2: Monthly Avg. Temperature

The Monthly Average Temperature (Zoomed in)



- Evidential seasonal behavior with a period of 12 months.

Figure 3: The Monthly Average Temperature

Model fitting on the Annual Mean Temperature Data

Detrended Annual Mean Temp.

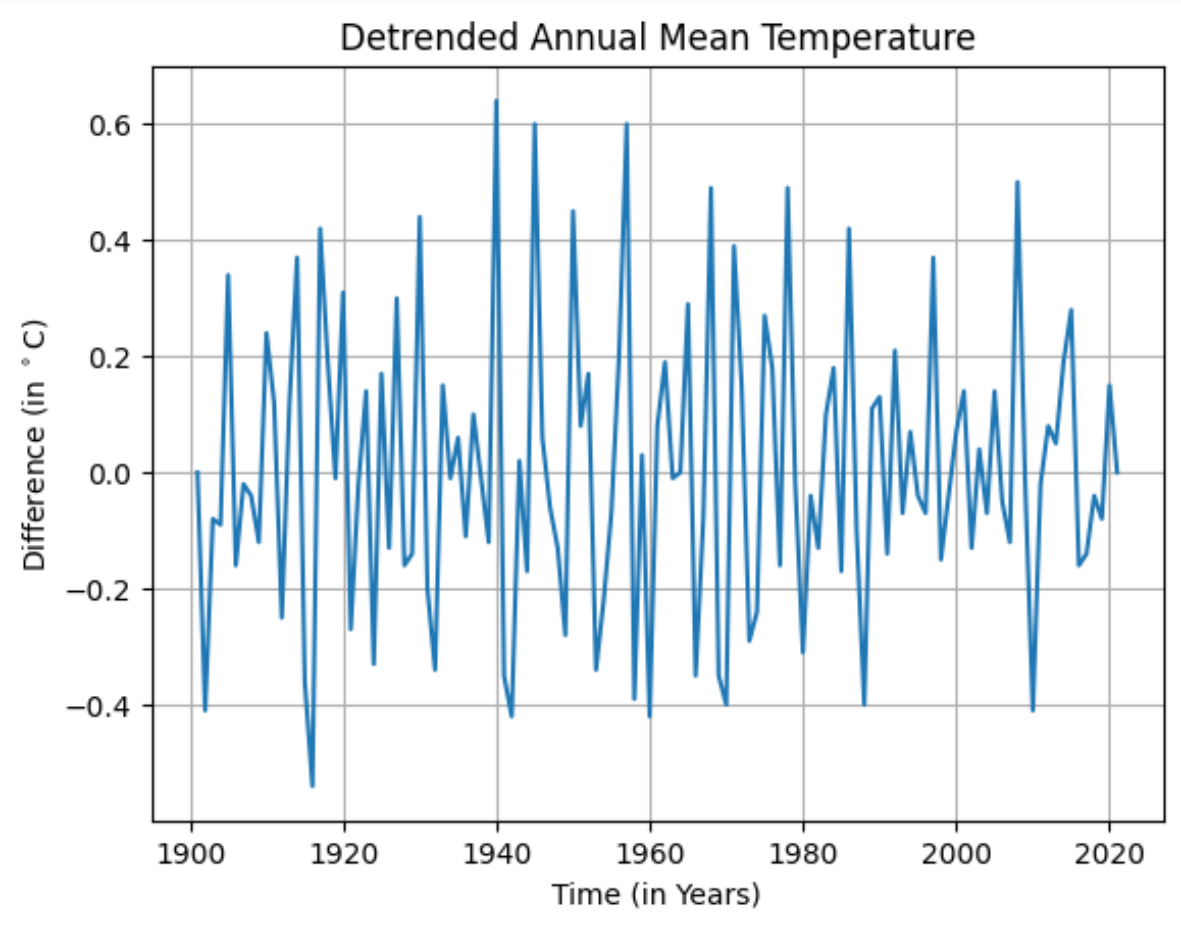


Figure 4: Detrended Annual Mean Temp.

- We are left with the residual data.

Detrended Annual Mean Temp.

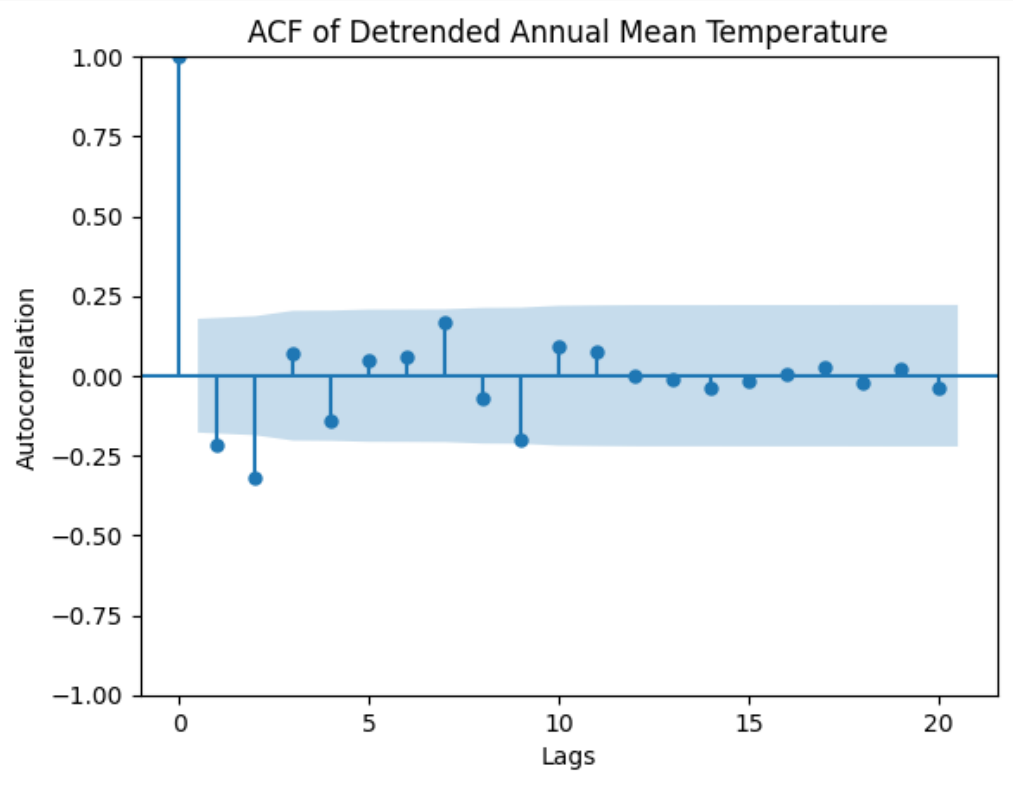


Figure 5: ACF of the Detrended and Deseasonalised Monthly Data

- $AR(2)$ model:

$$x_t - \phi_1 x_{t-1} - \phi_2 x_{t-2} = \epsilon_t$$

- The parameter values are, $\phi_1 = -0.30$ and $\phi_2 = -0.39$. Now the characteristic equation would be:

$$(1 + 0.30L + 0.39L^2)x_t = \epsilon_t$$

Detrended Annual Mean Temp.

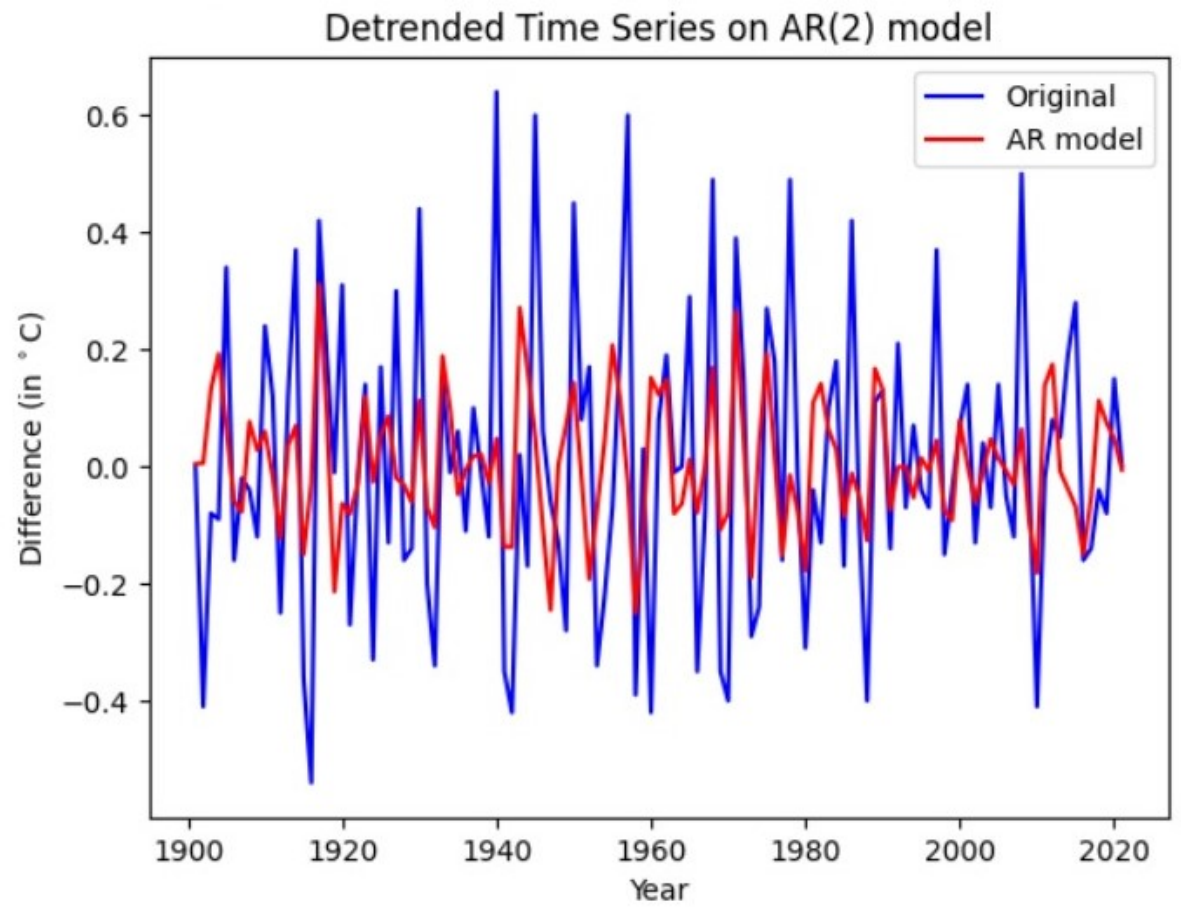
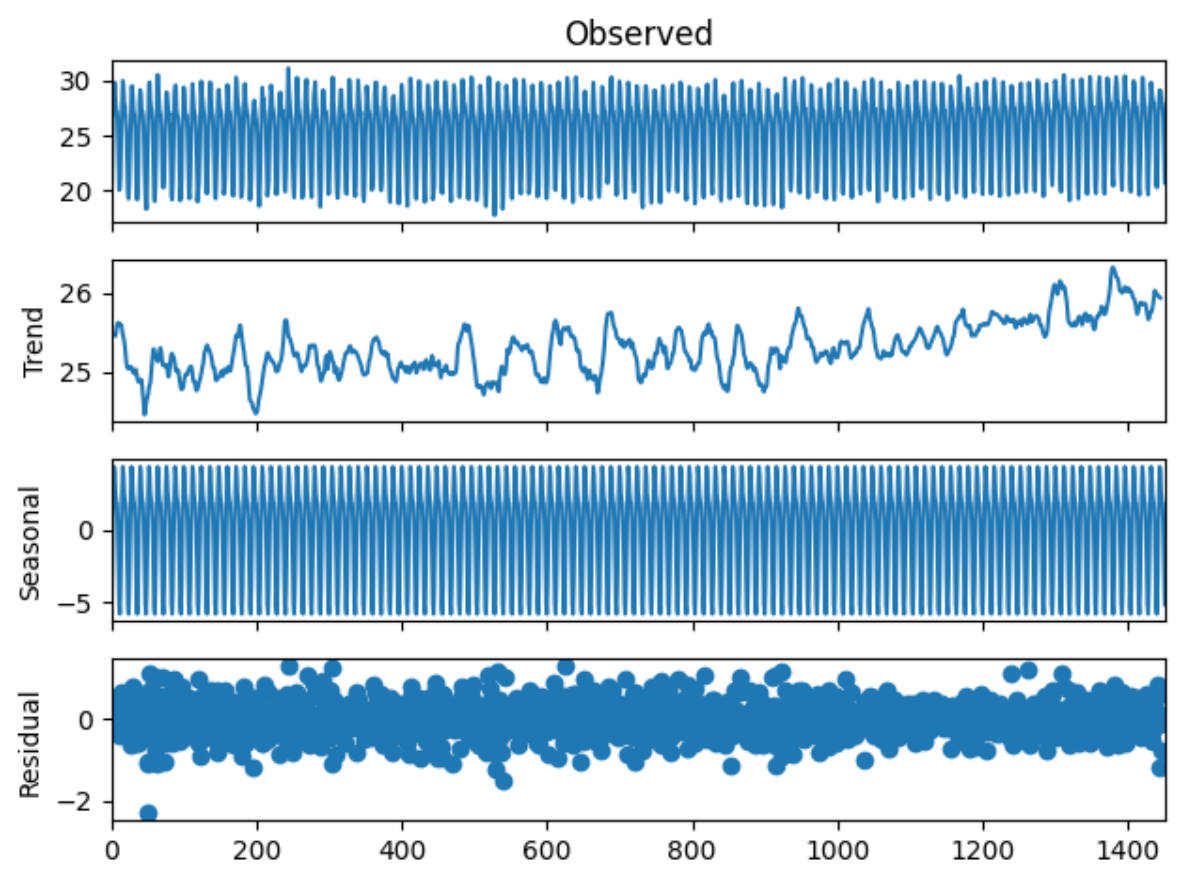


Figure 6: Fitting the AR(2) Model on the Detrended Time Series

- Checking for the Causality conditions for an $AR(2)$ process, we get $\phi_1 + \phi_2 < 1$, $\phi_2 - \phi_1 < 1$ and $|\phi_2| < 1$. Therefore the process is **Causal**.

Model fitting on the Monthly Mean Temperature Data

Seasonal Decomposition of the Monthly Average Temp.



- Presence of trend as well as seasonality.

Figure 7: Seasonal Decomposition of the Monthly Average Temp.

The Monthly Average Temperature Data

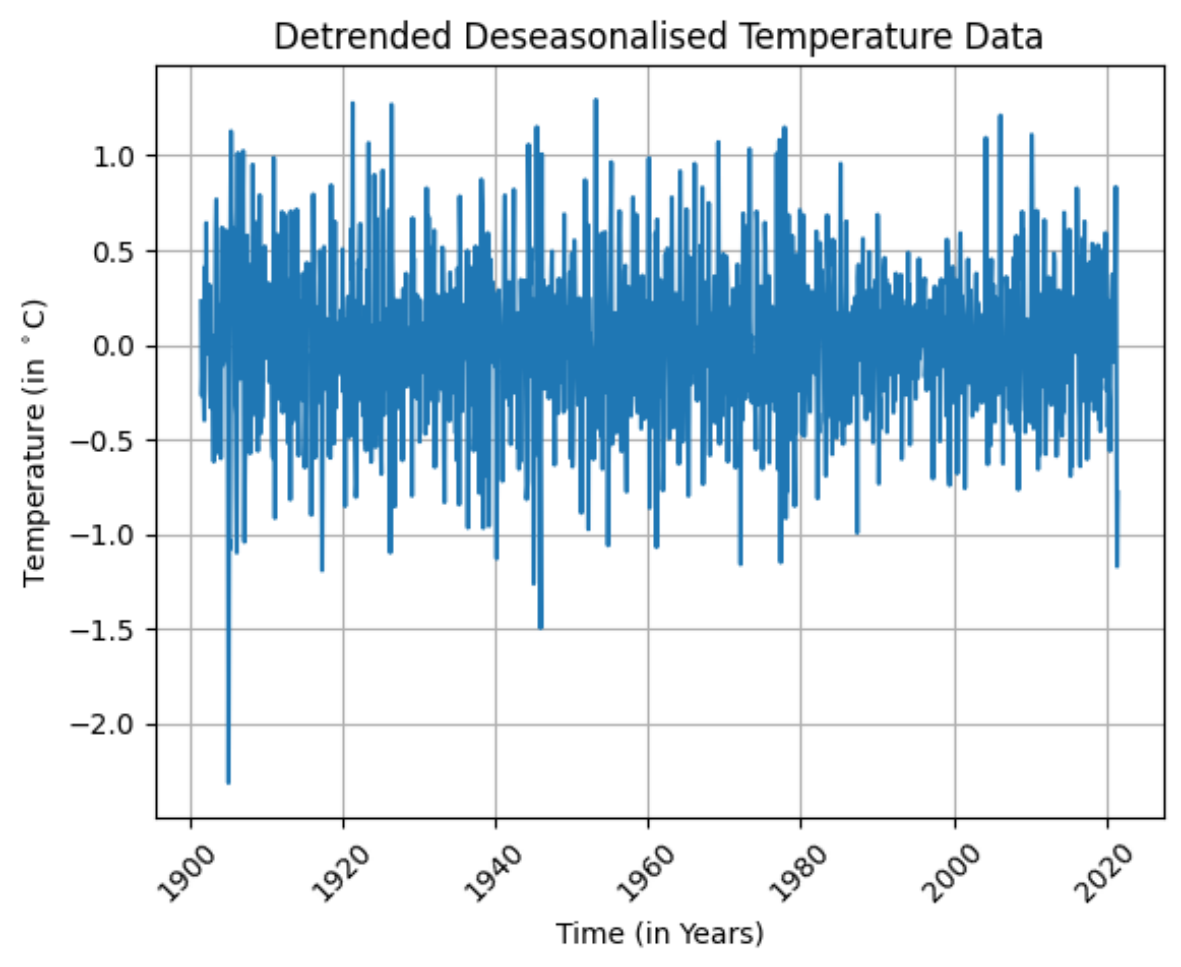


Figure 8: Detrended Deseasonlised Monthly Temperature Timeseries

The Monthly Average Temperature Data

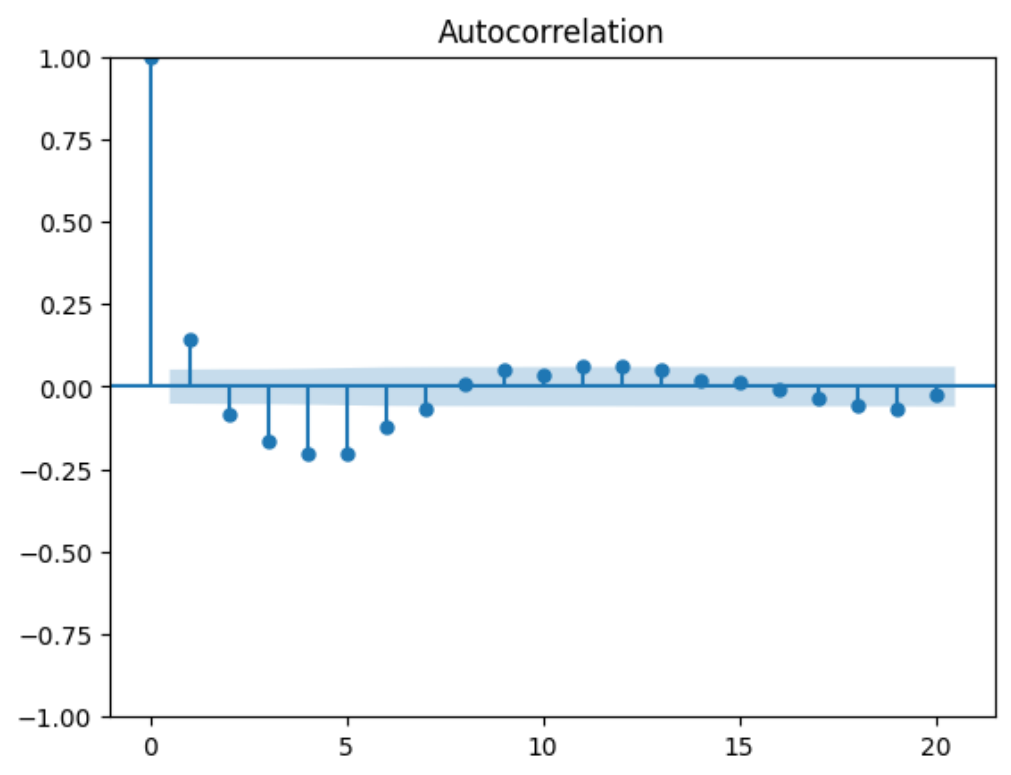


Figure 9: ACF of the Detrended and Deseasonalised Monthly Data

- Significant autocorrelation up to Lag 7.
- A damped oscillatory ACF, indicating the presence of **periodicity and stationarity** in the monthly temperature data.

The Monthly Average Temperature Data

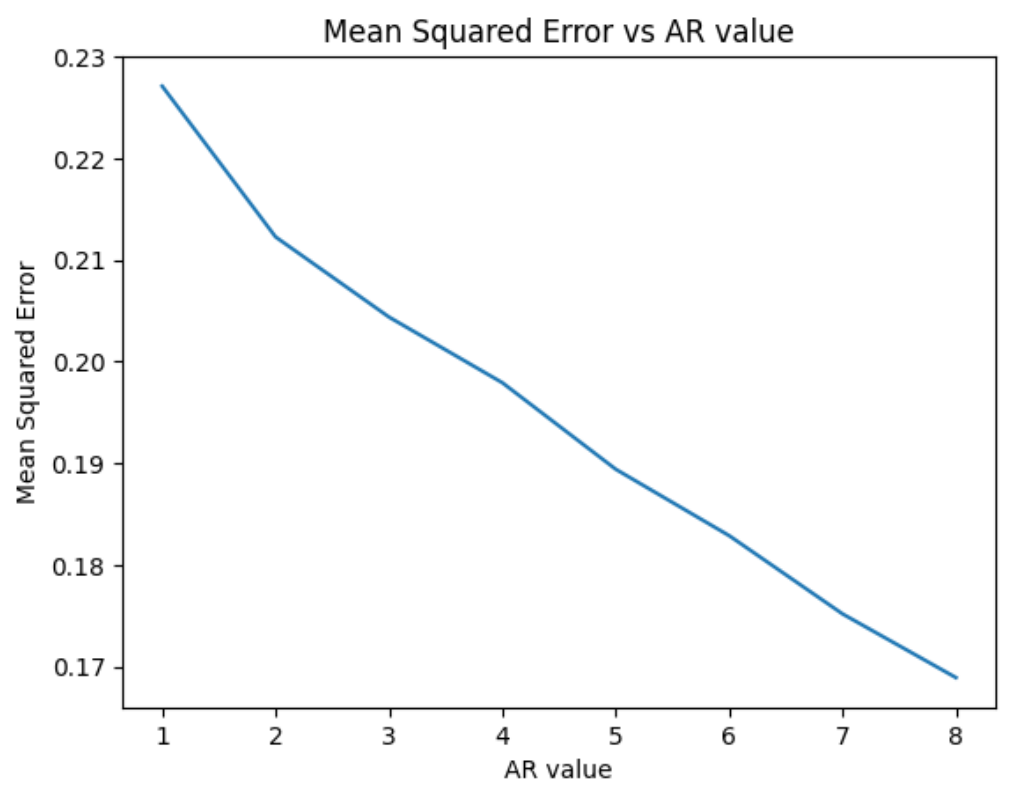


Figure 10: Mean Squared Error of each Order (p)

- Attempting to fit M A(q) models for $q = 1, 2, .., 6$ we obtain non-invertible MA models hence, we take **q = 0**.
- For AR(p) models, we obtain the mean squared error for $p = 1, 2, ..8$.
- Higher orders as they might overfit on our dataset
- Therefore, we choose **ARIMA(2,1,0).**

The Monthly Average Temperature Data

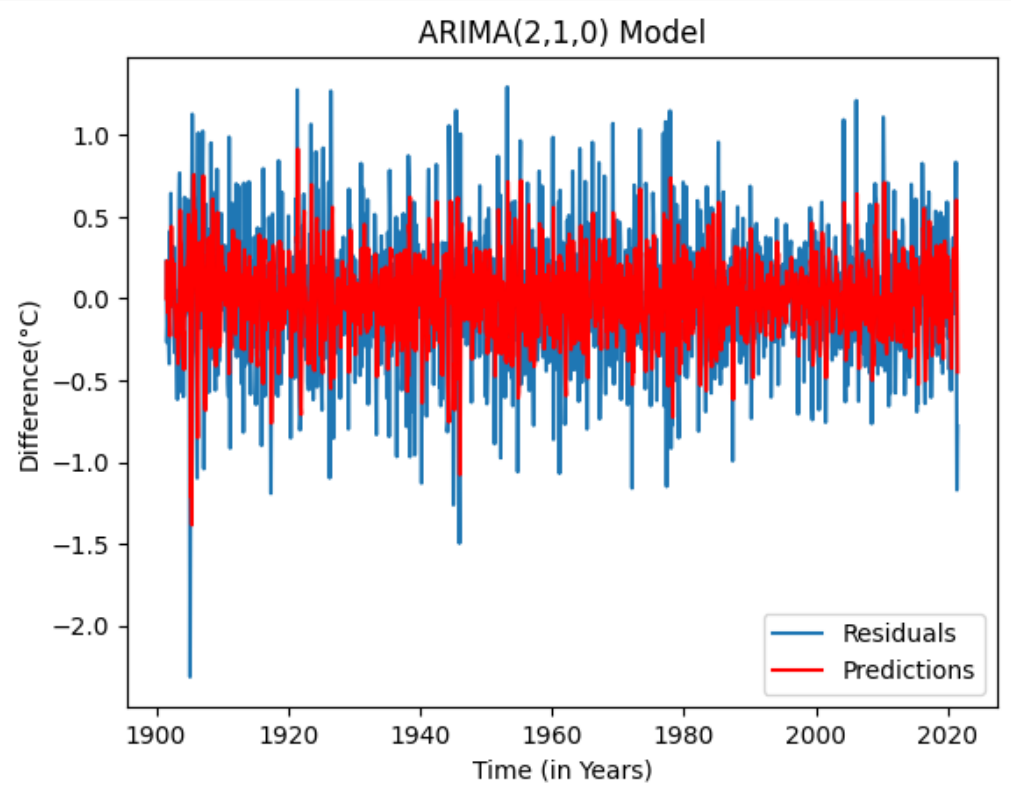


Figure 11: Fitting the ARIMA(2,1,0) Model on the Detrendend, Deseasonalised Time Series

- Equation of *ARIMA(2,1,0)* process:

$$(1 - \phi_1 L - \phi_2 L^2)(1 - L)x_t = \epsilon_t$$

- We get, $\phi_1 = -0.46$ and $\phi_2 = -0.25$.
- Causality conditions for an $AR(2)$ process, we get $\phi_1 + \phi_2 < 1$, $\phi_2 - \phi_1 < 1$ and $|\phi_2| < 1$. Therefore **the process is causal.**

The Monthly Average Temperature Data

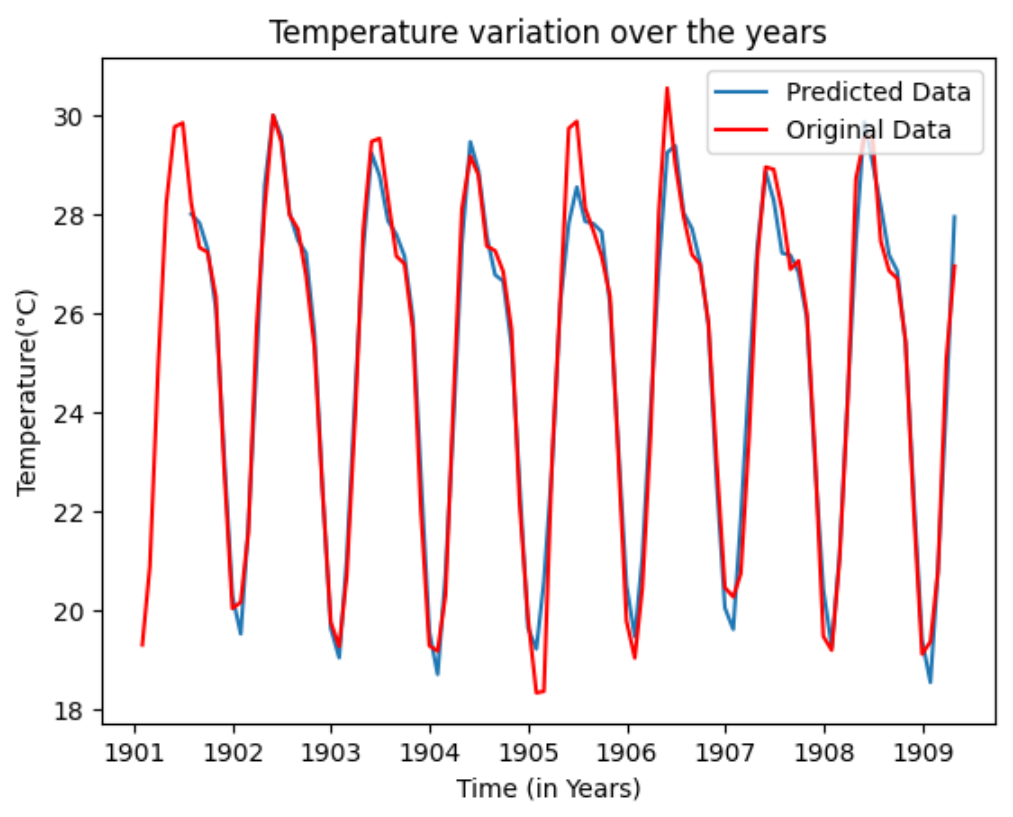


Figure 12: ARIMA(2,1,0) Model on a section of the entire data.

- Snapshot describing the fit of ARIMA(2,1,0) models on the first few years of the monthly data.

Is there a Seasonal Shift ?

- Investigated seasonal shifts in climate data over time by analyzing correlations between temperatures in consecutive months across different years.
- Despite rigorous analysis, observed no significant trends indicative of substantial seasonal shifts over time.
- Constrained by the monthly granularity of data, which limited the ability to detect subtle shifts in seasonal patterns.

Future Work

Future Scope of Work

- Introduce more rigorous concepts of **Spectral Analysis** to analyse the underlying seasonal nature in the dataset.
- We can analyse another climate variable such as **rainfall** and see if it is correlated to temperature.

THANK YOU!