Team 109
Global Temperature Trends and Impact of CO_2 and Deforestation on Temperature Change

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Introduction

The Problem: Climate Change has been globally recognized as an issue since 1988; however, there is limited comprehensive research to predict country specific global temperature. We used ML based models for predictions.

Importance:
- Severe impact to Earth's ecosystem
- Lasting effects for future generations

Data

Global Temperatures: Monthly Temperature (°C) for mid 1700s to 2013 for major cities in 150+ countries
- Public download   Size: 532.83 MB
- Records: approximately 8+ mm   Temporal: Yes

CO_2 Emission: Yearly CO_2 emissions (metric tons per capita) by country from 1990 to 2019
- Public download   Size: 87.53 kB
- Records: 266   Temporal: Yes

Forest Area: Yearly forest area (hectares) by country from 1990 to 2020
- Public download   Size: 216 kB
- Records: 7500+   Temporal: Yes

Approach

Use-case 1: Predict temperature based on the historical country specific dataset.
Seasonal Autoregressive Integrated Moving Average eXogenous (SARIMAX) model
How it works: Combination of auto regression and moving averages with seasonality. Common method for analyzing time series datasets
Why it works: The global temperature is a seasonal time series dataset, and we predict the temperature based on historical time series temperature changes.

Use-case 2: Predict the impact of CO_2 emission and forest area on temperature change
Artificial Neural Networks (ANNs)
How it works: Uses multiple layers of neurons, adjusting the strength of connections between neurons to learn patterns and make predictions on new data using regression
Why it works: Can learn Non-Linear relations, CO_2 emission and forest area data are features for each country and country average temperature is dependent variable

Innovation (New Approach):
- Predict and show temperature change by country globally
- Predict and show impact of CO_2 emission and forest area data on temperature for most countries

Experiments

Time Series Temperature Prediction:
- Dropped all null temperature records and kept only cities with data available for all 12 months
- Identified great variance in temperature ranges for different countries (Figure 1)
- Calculated yearly mean temperature at country level to prepare the time series data
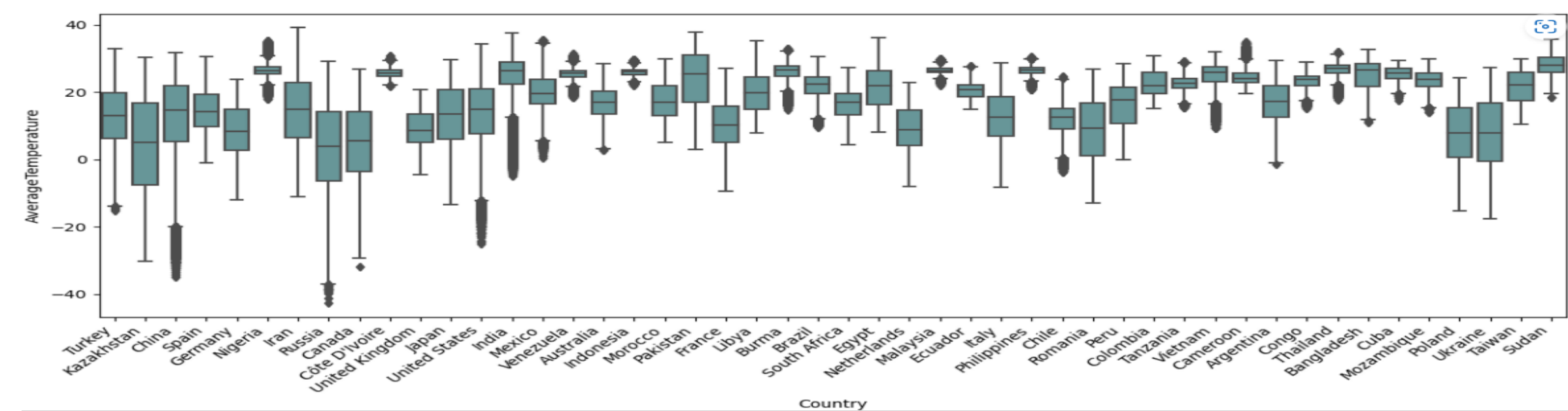
CO_2 and Forest Area Impact:
- Dropped all null values before merging all 3 datasets
- Major countries are decreasing CO_2 emissions except China, India, and Russia (Figure 2)
- Major countries are increasing forest area except Brazil and Canada (Figure 3)
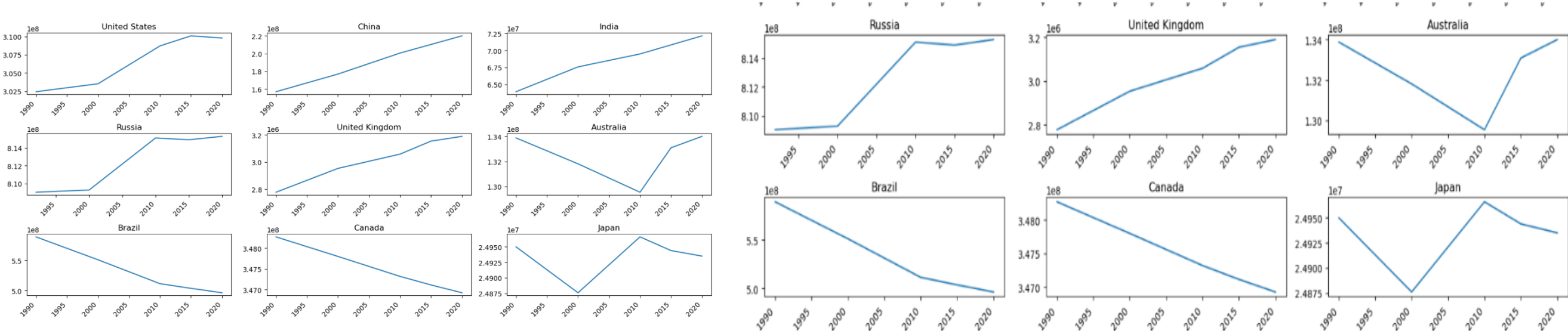

Figure 1. Temperature Variance across Countries

Figure 2. CO_2 Emissions for Major Countries

Figure 3. Change in Forest Area for Major Countries

Results

SARIMAX. Trained ~159 SARIMAX models for temperature prediction (Figure 4)
- Table 1 shows Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) of top three countries

ANNs. Trained to predict impact of deforestation and CO_2 emission on climate change for ~140 countries (Figure 5)
- Model has two hidden layers each followed by dropout layer to avoid overfitting
  - First has 128 neurons
  - Second has 64 neurons
- Model learns 8,785 parameters
- Table 2 shows MSE and MAPE of top 3 countries

Visualization.
D3: Figure 6 shows snapshots of our global temperature changes
- Depicts temperature increase in different regions from 1890 to 2043
  - Figure 6a shows baseline temperatures when first temperature data is available for many regions
  - Figure 6b and Figure 6c show temperature changes by quarter degrees based on our baseline temperatures in 2014 and 2043

Tableau: Users can visualize different what-if scenarios
- Figure 7a and Figure 7b show temperature change between base case values for CO_2 emissions and forest area with:
  - 5% increase in CO_2
  - 1% decrease in forest area

Country \Metric	Train		Test	
	MSE	MAPE	MSE	MAPE
USA	3.700	0.096	0.200	0.023
China	2.573	0.095	0.157	0.023
India	5.012	0.020	0.236	0.016

Table 1: SARIMAX Model Error Summary

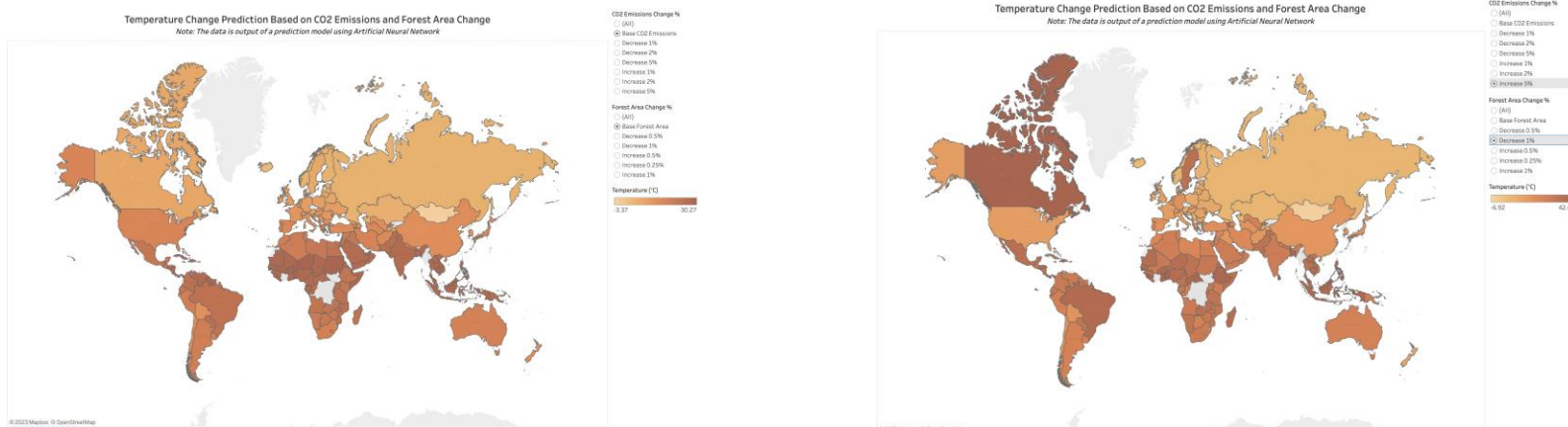| Country \Metric	Train		Test	
	MSE	MAPE	MSE	MAPE
USA	5.08	0.11	4.26	0.12
China	3.99	0.11	4.08	0.12
India	8.77	0.10	6.85	0.09

Table 2: ANN Model Error Summary
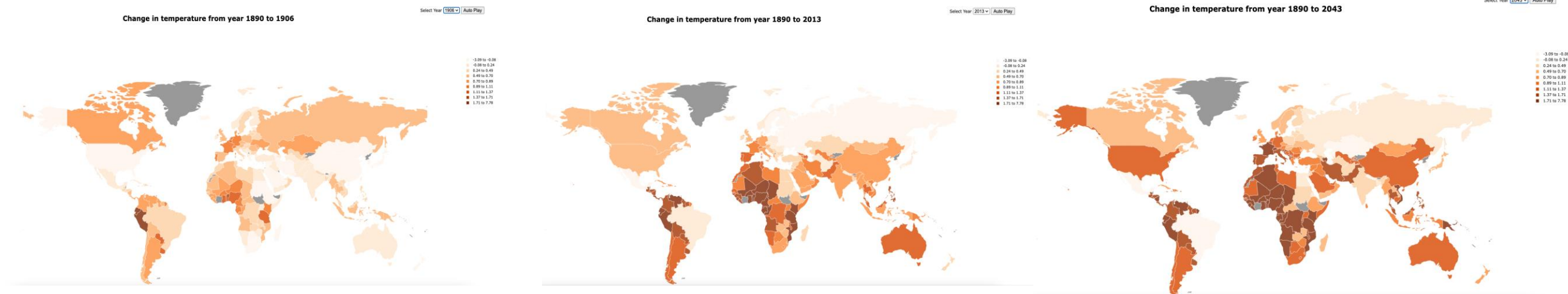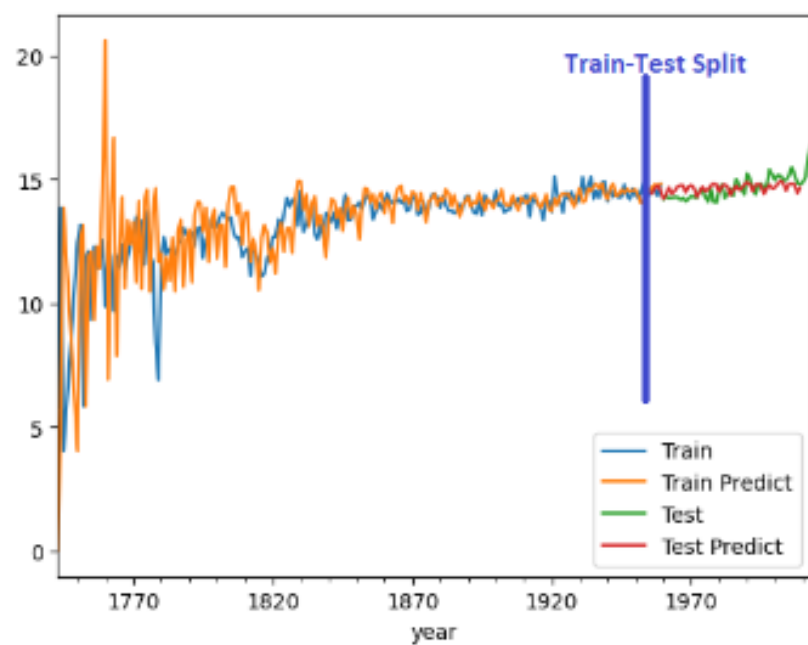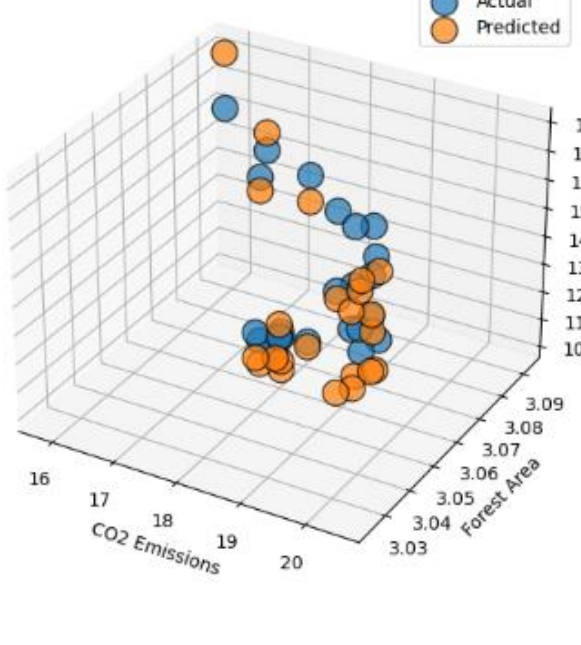

Figure 6. Global Temperature Changes

Figure 4. US Temperature Model Fit

Figure 5. Actual vs Predicted Plot

Figure 7. Temperature Prediction