The Impacts of the International Climate Policies on Global Temperature

Descriptive Statistics Report

Kevin Wu and Matthew Chen

University of Chicago

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1 Research Design Summary

Climate change has been at the forefront of global issues for several decades. Research institutions, corporations, and governments worldwide are constantly working to reduce human-induced climate change, which has caused increasingly extreme weather patterns and has the potential to cause catastrophic damages across the globe. The first globally significant policy enacted to combat climate change was the Kyoto Protocol, which was signed in 1997 and officially enacted in 2005 (the second being the Paris Agreement of 2015). Our study aims to determine the effectiveness of international climate policies, which began with the Kyoto Protocol, on slowing the rate of global temperature increase.

In general, for any climate-based research, the dependent variable would be temperature and the independent variable would be time. The job of the researcher then is to model temperature as a function of time, find the rate of increase, and use this to predict future temperature. The causal mechanism, rather than being a continuous action, rather is a discrete classifier. We classify the time points by pre- and post-Kyoto Protocol, attempting to test whether the Kyoto Protocol caused a decrease in the rate of warming. To test our theory, we will first build a model that determines the overall rate of climate change using monthly averages of global land surface temperature data from 1850 to 1997 (the inception of the Kyoto Protocol). We will then use this model to predict global temperature from 1998 to 2021. We will then create a separate model, using only data from 1998 to 2021, to look at the actual rate of climate change. This process will be done with two separate datasets: first, a dataset measuring global average surface temperature, and second, a dataset measuring the average surface temperature specifically inside the contiguous United States.

2 Data and Descriptive Statistics

To analyze rates of global temperature change over time, we require data that captures global average land surface temperatures accurately and consistently. Ideally, the global average land surface temperature would be computed by taking the average of air temperature measurements recorded by a infinite amount of equivalent weather stations at every location. However, since this situation does not exist, finding the ideal average is impossible, and estimation is required.

We found a data set collected and maintained by Berkeley Earth, an independent U.S. non-profit organization affiliated with the Lawrence Berkeley National Laboratory. According to Berkeley Earth, their current archive contains data from over 39,000 unique weather stations, combining 1.6 billion temperature reports from 16 preexisting archives. They estimate global average land surface temperature by using available data to take a land-area weighted average, as opposed to a station average (Rohde et al., 2013).

The data found on the Berkeley Earth website reports temperatures as anomalies, in Celsius, relative to the January 1951 to December 1980 temperature averages, which is 8.60°C for global and 11.36°C for the contiguous United States. We will add these averages to the anomaly values in the original global and U.S. data, respectively, to obtain the absolute temperature values. We will include both original data in text format and our modified data in CSV format in our supplementary materials. Additionally, for each month, Berkeley Earth reports the one-year, five-year, ten-year, and twenty-year moving averages centered about that month, rounding down if the center is in between months. For example, the annual average from January to December 1950 is reported at

June 1950. We will use the following variables in our study:

1. Year: starts in 1750, but only require 1850 - 2020
2. Month: 1 (January) - 12 (December)
3. Global_Avg_1: global one-year average land temperature in Celsius
4. Global_Avg_Unc_1: the 95% confidence interval around the average, accounting for statistical and spatial under-sampling effects
5. Global_Avg_10: global ten-year average land temperature in Celsius
6. Global_Avg_Unc_10: the 95% confidence interval around the ten-year average, accounting for statistical and spatial under-sampling effects

The contiguous U.S. versions of items 3 - 6 will also be used.

Period	1850-1997	1997-2020	1850-2020
Global	8.42 (0.35)	9.61 (0.23)	8.56 (0.53)
Contiguous U.S.	11.16 (0.48)	12.23 (0.48)	11.30 (0.60)

Table 1: Average temperatures (°C); standard deviations in parentheses

We will begin exploring the data by providing some basic statistics, using the one-year moving average columns. Across our period of interest (1850 - 2020), the average global temperature was 8.56°C and the average U.S. temperature was 11.30°C. Pre-Kyoto (1850 - 1997), the average global temperature was 8.42°C and the average U.S. temperature was 11.16°C. Meanwhile, post-Kyoto (1998 - 2020), the average global temperature was 9.61°C and the average U.S. temperature was 12.23°C. There has been a drastic increase in average temperatures, marked by a 1.19°C increase in average global temperature and 1.07°C increase in average U.S. temperature. Averages and standard deviations are summarized in Table 1.

Since	1850	1900	1950	1997
Global	1.09	1.26	1.82	2.84
Contiguous U.S.	0.98	1.23	1.42	2.56

Table 2: Mean rates of change (°C/Century)

Next, we will consider mean rates of temperature change using the ten-year moving average columns. Mean rates of temperature change have increased exponentially both worldwide and in the U.S., as seen in 2. Since the Kyoto Protocol was signed in 1997, the mean rate of temperature change has more than doubled compared to mean rate of temperature change since 1850, from 1.09°C/Century to 2.84°C/Century worldwide and from 0.98°C/Century to 2.56°C/Century in the United States.

While it is clear that there has been an increase in both mean temperature and mean rate of temperature change pre- and post- Kyoto Protocol, we cannot conclude the Kyoto Protocol has expedited global warming because these statistics offer no evidence of what would have happened in the absence of the Kyoto Protocol. Furthermore, we cannot rely only on mean rates of temperature change in determining the effectiveness of international climate policies because each data point is reliant on previous data points. Instead, we need to apply time-series techniques, which we will do through an ARIMA time-series model and compare predicted vs. actual rates of change as described in Section 1.

3 Descriptive Figures

Figure 1 and Figure 2 show the trend in global and U.S. average land surface temperatures between 1850 and 2020. Each data point represents one month, at which both one-year and ten year moving averages centered at that month are plotted (hence why the ten-year average line ends earlier than the one-year average line). The 95% confidence intervals around the means are also plotted. Due to more prominent statistical and spatial under-sampling effects, the confidence intervals are wider in earlier years than more recent years.

Looking at the smoother ten-year average lines, there appears to be a consistent increase in average temperature. The mean rates of temperature change appear to be higher in Figure 1 than Figure 2, an observation supported by the values in Table 2. Both graphs appear to be increasing at an increasing rate, which is also supported by Table 2.

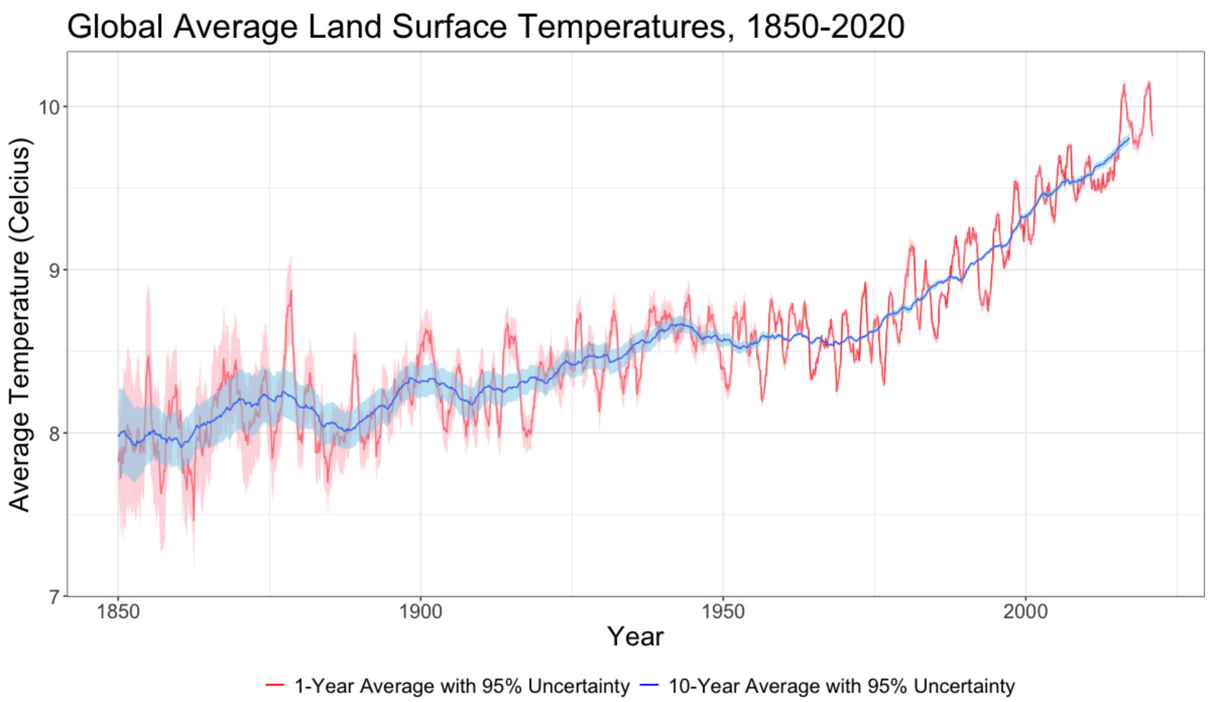

Figure 1: Global average land surface temperatures from 1850 - 2020. Note that the y-axis starts from 7°C in order to better see the trends.

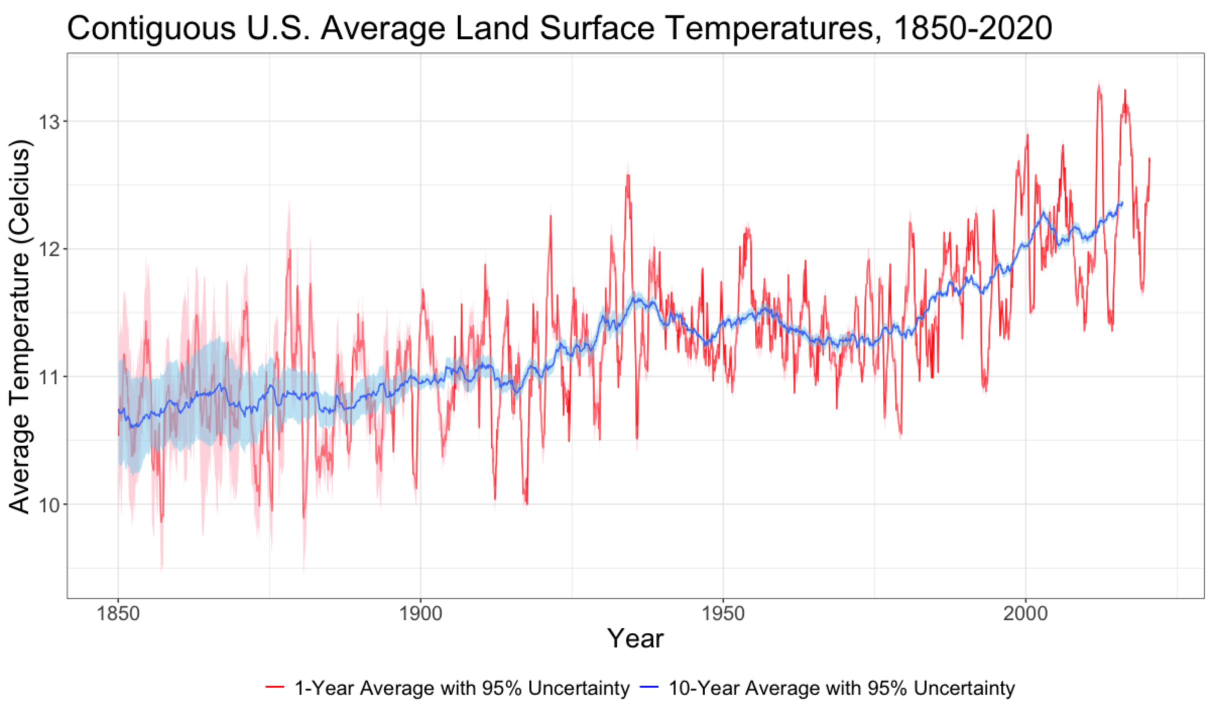

Figure 2: Contiguous U.S. average land surface temperatures from 1850 - 2020. Note that the y-axis starts from 9°C in order to better see the trends.

References

Rohde, R., Curry, J., Groom, D., Jacobsen, R., Muller, R. A., Perlmutter, S., … Wurtele, J. (2013). Berkeley Earth temperature averaging process. *Berkeley Earth*.