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Research on Global Warming Based on ARIMA and LSTM Neural Networks

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Abstract

In recent years, alarming temperature reports have underscored the reality of global warming. This research utilizes ARIMA and LSTM models to analyze historical global temperatures, predict future trends, and identify key influencing factors. Data collected up to 2021, supplemented by interpolation, facilitated the analysis of the temperature anomaly in March 2022. Predictions using ARIMA and LSTM models suggest that the global average temperature will reach 20 degrees Celsius by 2046 and 2065, respectively, with LSTM demonstrating higher accuracy based on RMSE analysis. The study also investigates the impacts of volcanic eruptions, forest fires, and COVID-19 on temperature. Finally, we compiled the research findings and recommendations into relevant suggestions, offering some strategies to address global warming based on the comprehensive analysis.

Keywords: Global Warming, ARIMA Model, LSTM Neural Network, Temperature Prediction, Impact Analysis

1. Introduction

Greenhouse gases are gases in the atmosphere that absorb solar radiation reflected from the ground and re-emit radiation, such as water vapor, carbon dioxide, and most refrigerants. Their effect is to make the Earth's surface warmer. This effect of greenhouse gases that make the Earth warmer is called the greenhouse effect. Since the Industrial Revolution, due to the rapid growth of human demand for energy and food, the emission of greenhouse gases led by CO2 has increased significantly. Carbon dioxide is heavier than air, so it sits at the bottom of the atmosphere like a big glass dome around the earth, trapping heat into the Earth but unable to release it, causing the greenhouse effect, or global warming.

The problem of rising temperatures that we have experienced so far has already caused changes in many of the Earth's ecosystems that are irreversible on time scales of hundreds to thousands of years. Therefore, it is urgent to explore the factors affecting global temperature change, explore and predict the future global temperature level, realize the accumulating influence of various human activities on nature, and take effective measures to save and slow down the harm caused by global warming.

Recent research underscores the multifaceted nature of global warming and its impacts on various systems. Bodour et al. [1] review the thermophysical properties of natural deep eutectic solvents, highlighting their potential in gas capture applications, which could mitigate greenhouse gas emissions. Biakhmetov et al. [2] analyze the carbon-saving potentials of municipal plastic waste pyrolysis, considering different system scales and end products, and its implications for waste management and emissions reduction. Cho et al. [3] assess the life cycle of renewable hydrogen transport using liquid organic hydrogen carriers, revealing significant sustainability benefits. Kovacs et al. [4] explore the impact of climate warming on ringed seal breeding habitats in Svalbard, demonstrating how warming affects Arctic ecosystems. Zhang et al. [5] investigate the evolutionary history and population dynamics of the endangered plant Bergenia scopulosa, offering insights into its ecological niche and conservation needs. Li et al. [6] examine the influence of γ-PGA on greenhouse gas emissions and grain yield from paddy rice, providing evidence of agricultural practices' effects on emissions and productivity. Xia et al. [7] study condensation heat transfer in refrigerant mixtures, which has implications for cooling technologies. Hong et al. [8] discuss reactive ion etching with low global warming potential gases, reflecting efforts to reduce industrial emissions. Oishi [9] highlights the combined effects of warming and nitrogen deposition on Sphagnum biomass production, while Suraj and Kan [10] investigate plant responses to increased temperatures and necrotrophs. Tomihara et al. [11] provide a genome assembly for the fruit fly Drosophila madeirensis, which can aid in understanding species adaptation. Fang et al. [12] analyze source-sink relationships in wheat under varying conditions, impacting crop management strategies. Maduforo et al. [13] discuss climate mobility and migrant health in West Africa, emphasizing socio-environmental impacts. Guo et al. [14] project the degradation of Quercus habitats in Southern China under future warming scenarios, and Zhang et al. [15] examine cross-border dust transport from Mongolia in the context of global warming.

2. Abnormal temperature rise in March 2022

The data used in this section are the monthly mean temperature data from 1743 to 2013 of some places in the world in the attached table. However, the mean temperature of some places is missing, so the interpolation fitting method is firstly.

We collected the changes of the average temperature from 2011 to 2021 relative to the average temperature from 1951 to 1980, and processed the initial data set according to various standards to obtain the changes of the average temperature from 1981 to 2021 relative to the average temperature from 1951 to 1980.

The figure below shows the change of annual average temperature relative to the average temperature of 1951-1980. The red five pointed star shows the temperature change in March 2022. The value here is no longer the annual average temperature, but directly reflects its rise.

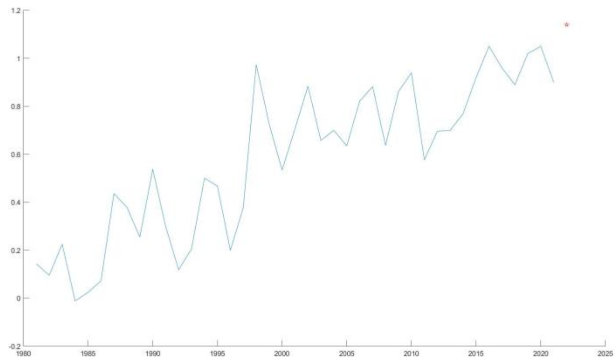

Figure 1: Comparison between the temperature in March 2022 and the previous temperature

According to Figure 1, the temperature in March 2022 is higher than that in any decade from 1980-2021. Therefore, we can conclude that the rise in global temperature in March 2022 is greater than the increase observed in any decade in the past.

3. Prediction of future global temperature level by ARIMA model

3.1 Brief introduction of ARIMA model algorithm

The full name of ARIMA model is differential autoregressive moving average model, which is a common time series prediction and analysis method. It is a combination of differential model, autoregressive model and moving average model, in the form of ARIMA(p, d, q). Where, p is the number of autoregressive terms, q is the number of sliding average terms, and d represents the difference order.

Its essential idea is to reveal the change rule of the phenomenon represented by the time series data over time, and to predict and analyze the future of the phenomenon by extending the rule to a certain time period in the future.

3.2 ARIMA specific steps

Step1: Judge the data stability. Stability test of time series data. This time series is non-stationary. The annual global temperature data can be made into the following

line chart, and it can be observed that the temperature has an upward trend.

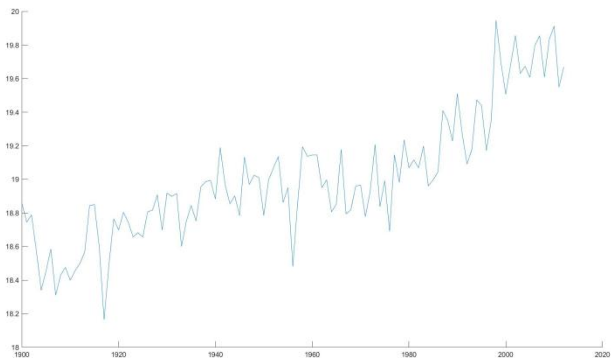

Figure 2 Broken line chart of global annual average temperature (before differential treatment)

Step2: Data stabilization processing: We can take logarithm of the data or carry out differential processing. In this paper, the difference method is adopted until the stationary sequence is obtained by difference.

After a differential processing of the global average annual temperature data, the results are as follows. Through observation, we can see that the data is relatively stable. It can be concluded that the middle order d of ARIMA(p,d,q) in this model is 1.

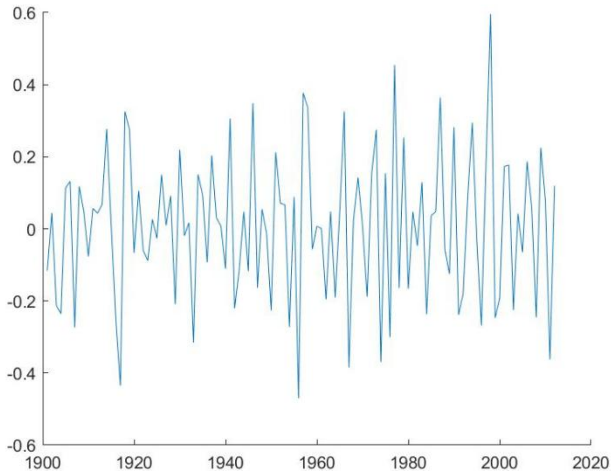

Figure 3 Line Chart of Global Annual Average Temperature (Before Differential Treatment)

Step3: Calculate the autocorrelation and partial correlation functions, and calculate the values of p and q according to the properties of autocorrelation and partial correlation functions.

The expression of the autocorrelation function (ACF) is as follows:

$$\mathrm{ACK}(k) = \rho_k = \frac{\mathrm{Cov}(y_t, y_{t-k})}{\mathrm{Var}(y_t)}$$

Partial autocorrelation function (PACF) describes the linear correlation between the expected past observations of the time series observations given the intermediate observations. Compared with the autocorrelation coefficient, PACF eliminates the interference of intermediate k-1 random variables and strictly represents the correlation between the two variables.

Step4: Perform autocorrelation and partial autocorrelation analysis on global annual temperature data to find the best estimated values of p and q of the series. The results of ACF and PACF are shown below. p=2 and q=2 can be identified.

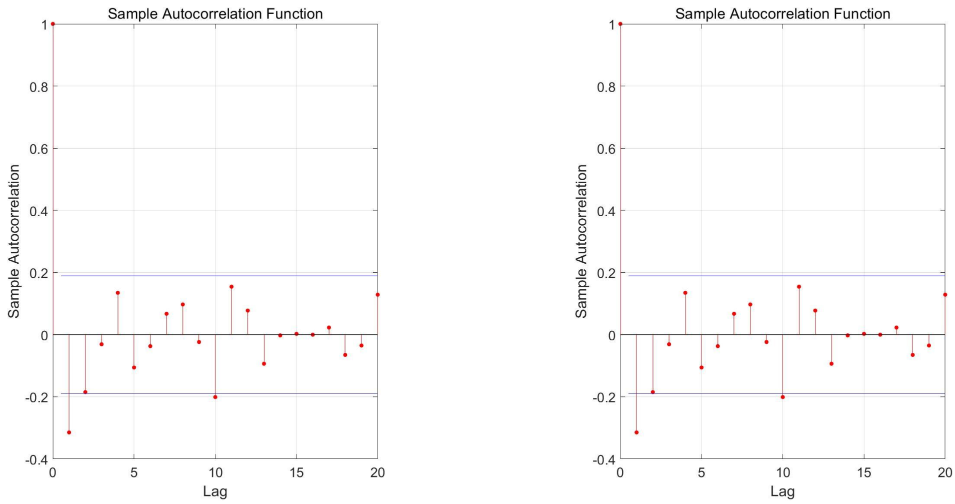

Figure 4 Best estimates for autocorrelation and partial autocorrelation analysis

3.3 ARIMA model results

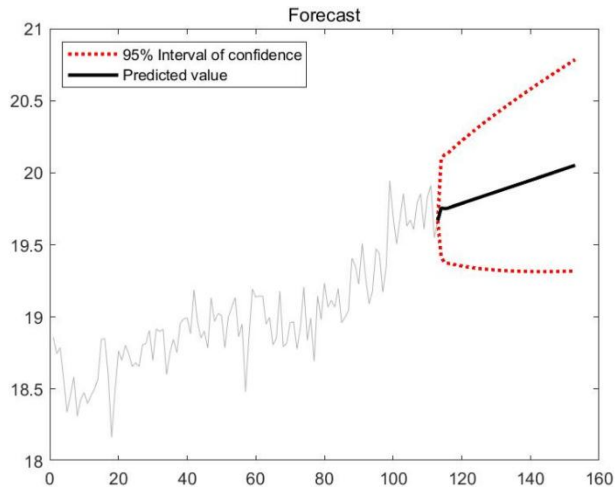

Figure 5 ARIMA model results

In the figure 5, the black lines represent the predictions and the red areas represent the 95% confidence intervals.

4. Prediction of future global temperature level by LSTM model

4.1 Introduction to LSTM Model

As an effective model for time series prediction and analysis, LSTM is an improved circulating neural network, which can effectively alleviate the defect of gradient explosion or phased gradient disappearance existing in circulating neural network.

4.2 LSTM model results

The predicted results are shown in the figure below:

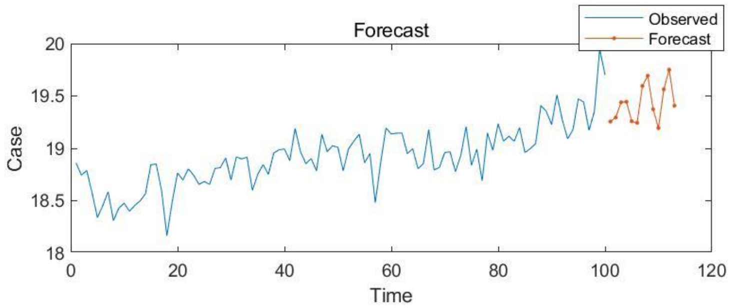

Figure 6 Schematic diagram of LSTM model results

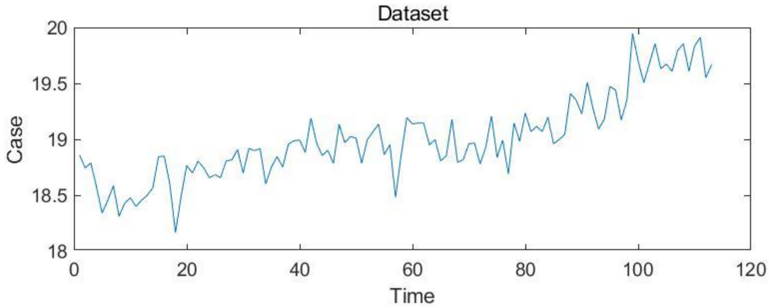

Figure 7 Actual temperature measurements from 1900 to 2012

By comparing Figure 6 and Figure 7, we can find that the results predicted by LSTM model are relatively close to the actual observed temperature, both of which show fluctuation rising.

Next, this paper brings the sorted global mean temperature data of global observation points from 1900 to 2012 into the LSTM model to predict the average temperature of global observation points from 2013 to 2115.

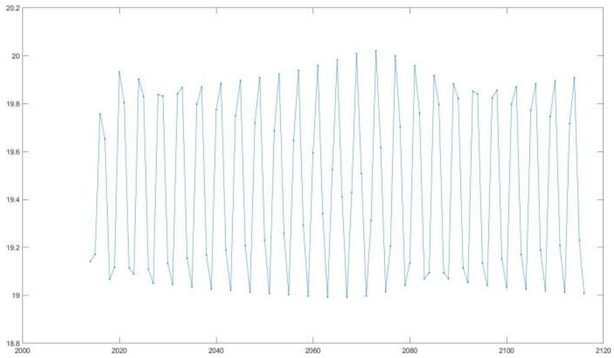

Figure 8 Projected mean temperature at global observation sites during 2013-2115

5. Predict when the global average temperature will reach 20 degrees Celsius

5.1 Predict global temperatures using the ARIMA model

Part of the data are sorted into the following table:

Table 1 Global Mean Temperature predicted by ARIMA Model (Part)

year	temperature	year	temperature
2043	19.9798	2047	20.01178
2044	19.9878	2048	20.01977

2045	19.99579	2049	20.02777
2046	20.00378	2050	20.03576

It can be seen that the global average temperature will reach 20 degrees Celsius before 2050, that is 2046, under the prediction of this model.

5.2 Predict global temperatures using the LSTM model

Part of the data are sorted into the following table:

Table 2 Global Mean Temperature predicted by LSTM Model (Part)

year	temperature	year	temperature
2062	19.50861	2066	19.6169
2063	18.99775	2067	19.01529
2064	19.31255	2068	19.20537
2065	20.01984	2068	19.9987

It can be seen that under the prediction of this model, the global average temperature will reach 20 degrees Celsius in 2065 after 2050 and before 2100.

5.3 Use RMSE to judge the accuracy of the model

RMSE is the root mean square error, which can effectively measure the deviation between the observed value and the true value. The smaller the value, the smaller the deviation between the observed value and the true value, and the higher the accuracy of the model. The calculation method is as follows:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{obsi} - x_{acti})^2}$$

The RMSE values of the above two models were calculated respectively, and the RMSE of the ARIMA model is 0.4807, and that of the LSTM model is 0.3378. It can be concluded that the model accuracy of LSTM is higher.

6. Analyze the influence of natural disaster factors on global temperature

6.1 Volcanic eruption

The Great Explosive eruption of Mount Tambora in the Philippines on 15 June 1991 was one of the largest volcanic eruptions in the world in the 20th century, spewing huge amounts of ash and pyroclastic flows. The eruption lowered the height of the mountain by about 300 meters. As a result, the Earth entered two years of volcanic winter. It can be seen that this volcanic eruption is representative among the historical volcanic eruptions. Therefore, this paper selects the 1991 eruption of Mount Tambora in the Philippines to analyze the disaster of the volcano.

Since the impact of the volcanic eruption on the climate lasted for about three years, we first selected the study from 1981 to 1994 to observe the annual mean temperature of the Philippines. It can be seen that the annual mean temperature of the Philippines showed a downward trend in 1991:

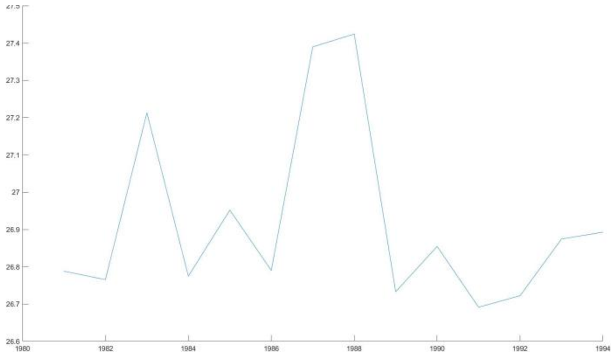

Figure 9 Annual mean temperature in the Philippines, 1981-1994

Now let's look at the average monthly temperature for 1989, 1990 and 1991.

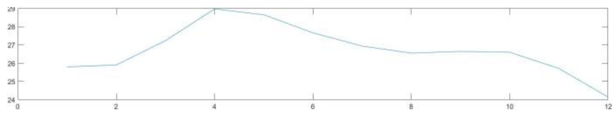

Figure 10 Annual mean temperature in the Philippines in 1989

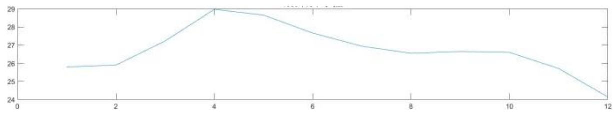

Figure 11 Annual mean temperature in the Philippines in 1990

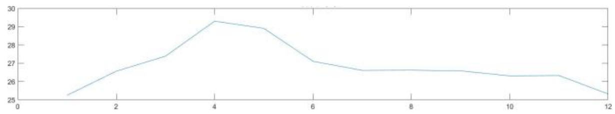

Figure 12 Annual mean temperature in the Philippines in 1991

In the month-specific data, we can find that normally, the temperature in the Philippines will start to drop gradually in June, which is a normal climate phenomenon in the Philippines. Therefore, we need to judge the impact brought by the volcanic eruption according to its decreasing amplitude. We still take the decreasing amplitude from June to August of the past three years for research, and the results of the cooling are respectively 1.111 degrees Celsius, 0.487 degrees Celsius and 1.898 degrees Celsius. It can be seen that the decreasing amplitude has significantly increased, which can confirm that the volcanic eruption does have a decreasing effect on the temperature.

Then this paper tries to analyze it on a global scale:

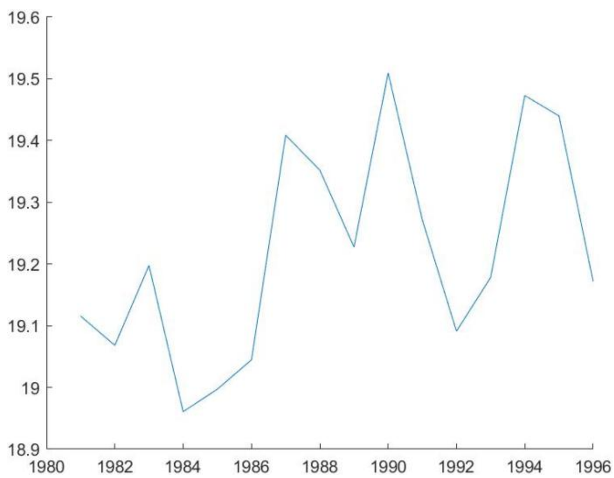

Figure 13 Global Annual Average Temperature from 1981 to 1996

It can be found that the global mean temperature showed a downward trend between 1991 and 1992, and the rate of decline was accelerated compared with the previous downward cycle. It can be seen that the volcanic eruption will have a certain impact on the global mean temperature. In order to explain the above change rule, the paper consulted the data and found the specific reasons as follows:

Volcanic eruptions spew sulfur dioxide into the stratosphere, which reduces the amount of sunlight reaching the Earth and reduces the heat that solar radiation brings to the ground and atmosphere. The eruption in the Philippines, for example, spewed nearly 20 million tons of sulfur dioxide into the stratosphere, which reduced the intensity of sunlight on Earth by 10 percent.

6.2 Forest fire

The 2003 Siberian forest fire was the largest and most destructive forest fire in recent years. The 2003 Siberian wildfires caused 47 million acres of land to go up in flames. The emissions from these fires are equivalent to the reductions the European Union has pledged under the Kyoto Protocol. Rising Siberian temperatures and thawing permafrost are the most likely causes of the increasing number and intensity of forest fires in Siberia. Satellite images of the fire showed Eurasia covered in smoke. The effects of these fires on ozone depletion are still visible in environmental studies today.

Below, we will select the period from 2000 to 2006 to study the impact of this forest fire on temperature change. By referring to the relevant data of the Siberian forest fire, this paper selects two places that are greatly affected by the Siberian fire: Moscow and Tokyo for analysis.

First, here are the temperature changes in both places and around the world:

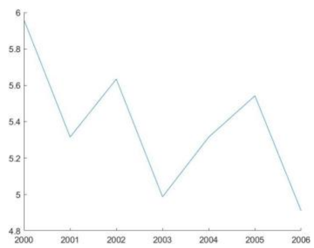

Figure 14. Annual mean temperature in Moscow, 2000-2006

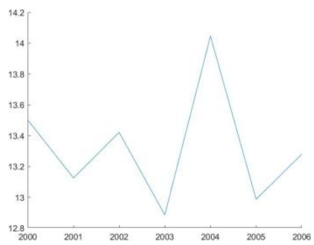

Figure 15. Average annual temperature in Tokyo, 2000-2006

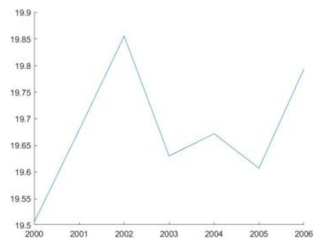

Figure 16. Global annual mean temperature, 2000-2006

By observing the data in the figure above, it can be found that both the observation points closest to the forest fires, both Moscow, Russia, and Tokyo, which is a certain distance from the forest fires, showed a rising state in 2003, and the rising rate was higher than that of the previous rising cycle. Therefore, we can infer that the volcanic eruption will accelerate the temperature rise.

This paper tries to generalize this conclusion to the whole world. By looking at the data above, we can see that in 2003 and 2004, the temperature showed a rise, but the rate of increase is not nearly as fast as the previous rising cycle. Therefore, we conclude that forest fires have more effects on local temperature and climate than on global temperature.

6.3 COVID-19

This paper also first takes the city as an example and selects the temperature observation point of New York as a reference. By consulting the data, we can get the temperature data of New York from 2016 to 2021. We took December 20, 2019 as the time of the outbreak of COVID-19.

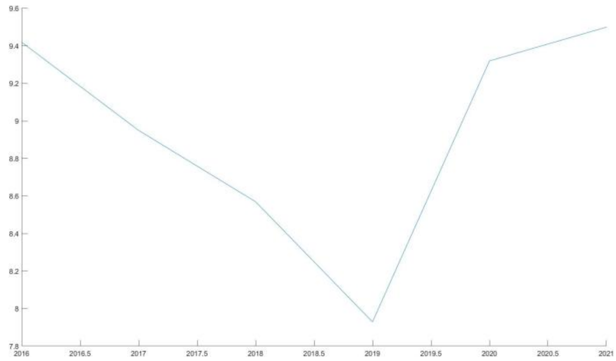

Figure 17. Annual Average Temperature of New York, USA, 2016-2021

The figure below shows the rise of local temperature based on the average temperature of 1850-1900.

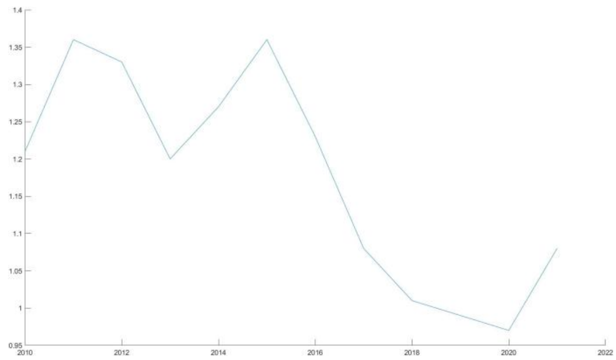

Figure 18. Global Annual Average Temperature from 2010 to 2021

It is found by comparison that, although the temperature in New York and the world will rise in 2020 after COVID-19, and the rate of rise will accelerate, it is difficult to judge the role of COVID-19 in the process because there are only two years of climate data and other uncertainties cannot be excluded.

7. Some suggestions

In recent years, global temperatures have been rising continuously, leading to more frequent extreme weather events, rising sea levels, and a decline in biodiversity, among other severe environmental and social issues. To better understand this phenomenon and predict future trends, this study employs ARIMA and LSTM models to analyze historical global temperature data, aiming to identify key factors influencing global temperature changes and propose effective mitigation strategies. This research not only provides new insights into global warming but also offers scientific evidence for policymakers to implement more effective measures for mitigation and adaptation on a global scale.

In terms of energy conservation and emission reduction in industrial industries, two emerging technologies are capturing carbon emissions from industrial sources or directly from the atmosphere. One is that the combustion of power plants is captured in chimneys and buried underground, thus being removed from the atmosphere. Second, the machine absorbs from the air through chemical reaction. The operations that can be performed for methane are: instrument air system or motor is used in industrial mining; Or arrange emission reduction or green completion, and transport the collected methane to the sales pipeline to reduce the combustion demand.

In the aspect of clean energy utilization, on the one hand, scientific and technological methods are used to reduce the use cost of clean energy and increase its popularization rate; On the other hand, strengthen the correct guidance of policies and encourage the development and innovation of science and technology in clean energy. For example, we now have all the technologies needed to decarbonize the economy, and those technologies that we still need to develop can be quickly developed under the right policies.

In cities, early implementation of water adaptation measures (including irrigation, rainwater collection, moisture conservation, etc.) and the formation of a network of parks and open spaces, wetlands and urban agriculture can reduce flood risk and heat island effect. Afforest other available land resources on the earth.

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