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Anthropogenic Climate Change, Deforestation and Renewable Energy

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Abstract

Since the Industrial Revolution, greenhouse gas (GHG) emission, especially global CO_2 emission (GCE) has greatly increased with the growth of global human population (GHP), which has caused climate change. Both GCE and GHP are positively related with the rise of global mean surface temperature (GMST). Our empirical research shows that the impact from GCE on GMST is 7.72 times of that from TSI, and the impact from GHP on GMST is 7.9 times of that from TSI. The growth rate of global surface temperature was slower from 1998 to 2012, which was mainly caused by the decadal cooling of the tropical Pacific Ocean-La Niña. Deforestation and vegetation degradation affect climate change, feedback radiation between the atmosphere and the biosphere account for 30% of the variation in global surface radiation and precipitation. The share of renewable energy remains small in primary energy consumption due to their disadvantages.

Keywords

Climate Change, Deforestation, Fossil Fuel, Renewable Energy

1. Introduction

There is observational evidence that global mean surface temperature (GMST) has been rising since 1950, such as global temperature records since 1880, rising sea levels, shrinking glaciers in the polar regions [1]. GMST was −0.16˚C in 1880, and it was 1.02˚C in 2020, thus an increase of 1.18˚C [2]. GMST in 2020 was the year with the second highest temperature, second only to 2016. GMST in August 2021 was the 6th highest on record since 1880. The growth rate of GMST was 0.08˚C per decade from 1880 to 1980, and it was 0.18˚C per decade from 1981 to 2020 [3]. The annual growth rate of GMST was 0.13˚C from 1880 to

1900, −0.05˚C from 1901 to 1950, 0.18˚C from 1951 to 2000, and 0.04˚C from 2000 to 2018 [4]. Overall, GMST is on the rise.

The top seven hot years in Europe occurred between 2014 and 2020, 2020 was the hottest year on record, and summer of 2021 was the 4th hottest season on record. The top 10 hot years in Asia have all occurred since 2002, 2020 was the hottest year in the 111-year record, and June-August 2021 was the hottest period on record [2]. In North America, 2020 was the 10th hottest year on record, summer of 2021 was the second hottest on record after 2012. Mexico had a new national August maximum temperature record in 2021, which surpassed the record in 2020.

World glacier monitoring data of the past few decades shows that the loss of glaciers has increased fivefold. In 2021, the Arctic Sea ice in August was 20.1% lower than the 1981-2010 average. Ice loss from the Greenland Ice Sheet was 34 billion tons per year from 1992 to 2001, and it was 247 billion tons per year from 2012 to 2016, thus an increase of 6 times. Ice loss from Antarctic was 51 billion tons per year from 1992 to 2001, and it was 199 billion tons per year from 2012 to 2016, thus an increase of 2.9 times [5].

There were 30 storms and 13 hurricanes during Atlantic Hurricane Season in 2020, which surpassed the record set in 2005 [6]. Hurricane Ida, a dangerous Category 4 hurricane, made landfall in Louisiana on August 29, 2021. Cyclone Gati, with a maximum wind speed of 185 km/hr, was the strongest cyclone and made landfall in Somalia from November 21 to 24, 2020. Typhoon Goni, with a maximum wind speed of 315 km/hr, was one of the most powerful typhoons on record and made landfall in Philippines from October 26 to November 6, 2020 [7].

Part 2 is methodology by which we conduct our research. Part 3 is the result of empirical research. Part 4 is discussion, in which more details of fossil fuel consumption and GCE are presented, deforestation and global warming hiatus are discussed. Part 5 is conclusion. The novelty of the paper is that our research is based on data, conclusion is based on quantifiable correlation between variables.

2. Methodology

First, our data are publicly downloaded from related professional and expert websites. The data of GMST is from the NASA [2], the name of the data sheet is "Annual mean Land-Ocean Temperature Index in 0.01 degrees Celsius". The time is from 1880 to 2020, outliers have been eliminated from the data, and adjusted for homogeneity, the base period is 1951-1980. The data of global CO^2 emissions (GCE) are from Ritchie [8], the name of the data sheet is "owid-co2-data", the units of GCE are million tons. The time is from 1750 to 2020, we only take the data from 1880 to 2020. The data of total solar irradiance (TSI) is from Kopp [9]. The units of the data are "watts per square meter" (w/m^2). The data are based on "community-consensus TSI composite" and SATIRE-T model

[10]. The time of the TSI is from 1610 to 2018, we take the data from 1880 to 2018. The data of global human population (GHP) are from Roser *et al.* [11] and PopulationStat [12]. The time of data from Roser *et al.* [11] are from 1000 B.C. to 2015 A.D., we only take the data from 1880 to 2015; data for 2016, 2017, 2018, 2019, 2020 are from PopulationStat [12].

Second, we conduct regressions with GMST as dependent variable, with GCE, TSI and GHP as independent variables. We conducted 3 kinds of regressions: first, with one of TSI, GCE, and GHP as independent variable to test its impact on GMST respectively; second, with two of them as independent variable in the same equation; and third, with the three of them as independent variable in the same equation.

Finally, we review some literatures that affect GMST, such as deforestation, equatorial Pacific surface cooling. Thus, we have further evidence to know their effect on the GMST and which factor is more of significance.

3. Results

We conducted regression between GMST and TSI, the output shows that they are positively correlated, as shown in Table 1. F-statistic and t-Statistics are significant at 5% confidence level. The R-squared is 0.11, which shows that TSI accounts for 11.24% of the rise of GMST. We conducted regression between GMST and GCE, the output shows they are positively correlated, as shown in Table 2. F-statistic and t-Statistics are significant at 5% confidence level. The R-squared is 0.85, which means that the impact from GCE accounts for 85% of the rise of GMST. Therefore, the impact from GCE on GMST is bigger than that from TSI. We conducted regression between GMST and GHP, the output shows they are positively correlated, as shown in Table 3. F-statistic and t-Statistics are significant at 5% confidence level. The R-squared is 0.87, which means that the impact from GHP accounts for 87% of the rise of GMST. The impact from GHP is bigger than that from both TSI and GCE, thus, the impact from GHP is the biggest.

Table 1. Regression output between GMST and TSI.

Variables:	Coefficient:	t-Statistic:	R-squared: 0.11
C	−43206.16	−4.17	F-statistic: 17.35
TSI	31.74	4.165	D-W statistic: 0.17

Note: here *C* is the intercept.

Table 2. Regression output between GMST and GCE.

Variables:	Coefficient:	t-Statistic:	R-squared: 0.85
C	−30.23	−17.56	F-statistic: 788.58
TSI	2.97E−09	28.08	D-W statistic: 0.72

Note: here *C* is the intercept.

Table 3. Regression output between GMST and GHP.

Variables:	Coefficient:	t-Statistic:	R-squared: 0.87
C	−54.17	−24.50	F-statistic: 946.99
TSI	1.73E−08	30.77	D-W statistic: 0.82

Note: here *C* is the intercept.

We conducted regression with GMST as dependent variable, TSI, GCE and GHP as independent variables in the same equation. The output shows that both TSI and GHP are positively related with GMST, but GCE is negatively related with GMST; TSI is not statistically significant at 5% confidence level, both GCE and GHP are statistically significant at 5% confidence level, only that GHP is more significant than GCE at 5% confidence level. We conducted regression with GMST as dependent variable, GCE and GHP as independent variables in the same equation. The output shows that GCE is also negatively related with GMST, and GHP is positively related with GMST. Therefore, we know that GCE is linearly correlated with GHP.

We conducted Granger causality test with GMST and TSI, GCE, and GHP, the output is shown in **Table 4**. We can see that the impact from both GCE and GHP on GMST is statistically significant, but the impact from TSI is not statistically significant.

We have **Figure 1** of the time trend chart of GMST, TSI, GCE and GHP, it gives us a clearer insight of the relationship between the variables. In **Figure 1**, the horizontal axis is time in years, the units on the vertical axis are different for different variables. GMST are in 0.01 degrees Celsius, TSI in 1000 w/m^2, GCE in billion tons, GHP in billion people.

4. Discussion

TSI is roughly constant, it changes about 0.1% in an 11-year sunspot activity, about 2 W/m^2 between the most and the least active parts in the 11-year solar cycle. It was 1365.4 ± 1.3 W/m^2 in 1990s, and 1360.8 ± 0.5 W/m^2 during the 2008 solar minimum [13]. The Sun may experience large changes in TSI over a long time period and causes climate change. For example, the Maunder Minimum, a 70-year period of lower TSI, is thought to be connected with the Little Ice Age in Europe.

The 0.1% variations in TSI with the eleven-year solar cycle cannot explain the intensity and speed of global warming on Earth, and there's no convincing evidence that suggests TSI has risen upward enough to lead global warming over the last century [14]. According to the data from Kopp [9], the mean value of TSI in 1610 was 1360.19 W/m^2, and it was 1361.26 W/m^2 in 2018, thus an increase of 1.07 W/m^2. TSI has increased, but the increase is only 1.07 W/m^2 [10]. The impact from changes of TSI on the surface temperature could be neglected from 1885 to 2013 [15].

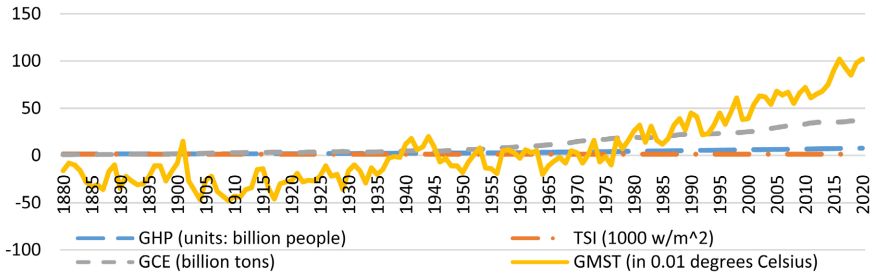

Figure 1. The time trend chart of GMST, TSI, GCE and GHP.

Table 4. Granger causality test between GMST and TSI, GCE, and GHP.

Null Hypothesis	Observations	F-statistic	Probability
TSI does not Granger cause GMST	137	0.64	0.53
GMST does not Granger cause TSI	137	3.75	0.03
GCE does not Granger cause GMST	139	12.98	7.E−06
GMST does not Granger cause GCE	139	0.22	0.80
GHP does not Granger cause GMST	139	18.56	8.E−08
GMST does not Granger cause GHP	139	0.45	0.64

GMST rises with greenhouse gas (GHG) emission, for example, GMST rises with the rise of global CO_2 emission (GCE). GCE was 853.71 million tons in 1880, and it was 34807.26 million tons in 2020, thus an increase of 39.77 times [16]. Global fossil fuel consumption was 2575TWh in 1880, and it was 136,761 TWh in 2019, thus an increase of 52.11 times [17]. Increased consumption of fossil fuel is a major driver for global climate change. Carbon dioxide concentration in the air was 280 ppm in 1750, and it was 412.45 ppm in 2020, thus an increase of 0.47 times [18]. Approximately 337 billion metric tons of carbon has been emitted into the atmosphere due to the use of fossil fuel and cement production since 1751, half of which was after the mid-1970s [19]. Fossil fuels are still the main primary energy and the share of renewable energy is small. GCE in the non-OECD countries has been increasing and has been more than that in the developed country since 2004, this trend continues, no sign of decline [20].

GMST has been increasing with GHP and GCE. The world population was 1474.53 million in 1880 [11], and it was 7794.8 million in 2020 [21], thus an increase of 4.29 times. From 1950 to 1990, the growth rate of GHP is the fastest since the Industry Revolution, with an annual rate of 1.88% [11]. China is the most populous country in the world, with a population of 1407 million in 2021. India is the second, with a population of 1393 million. The United States is the third, with a population of 332 million. Asia is the first populous continent, with a population of 4608 million in 2021. Africa is the second populous continent, with a population of 1351 million. Europe is the third populous continent, with a population of 740 million [12].

The growth rate of global surface temperature was slower from 1998 to 2012, which was mainly caused by the decadal cooling of the tropical Pacific Ocean-La Niña. Decadal cooling of the tropical Pacific affects temperate regions in the Northern Hemisphere winter, enhances cooling in northwestern North America, weakens Aleutian low [22], and leads to global warming hiatus. It is evident that ocean is a very important factor to stabilize surface temperature. Global warming is primarily a human effect. If humans consume more energy and emit more GHG, global warming would continue, and the global warming hiatus may happen again. But it will not change the long-term trend of global warming.

Deforestation and vegetation degradation. There is a strong biosphere radioactive feedback in moderately humid regions, where appropriate precipitation and radiation promote vegetation growth. Vegetation growth enhances heat transfer and increases the height of the Earth's tropospheric boundary, which in turn affects the thickness, height and surface radiation of the atmosphere. Feedback radiation between the atmosphere and the biosphere is ubiquitous on a global scale and account for 30% of the variation in surface radiation and precipitation [23].

The balance of feedback radiation between the atmosphere and the biosphere affects CO_2 concentration in the air. Vegetation, especially forests, reduces CO_2 concentration in the air, expands the thickness of the troposphere and increases its height. In this way, the troposphere is better able to buffer the extremes of super-cooling or overheating, making surface temperatures suitable for human survival.

However, large-scale man-made deforestation and other vegetation destruction still exist. 16 million hectares of forest were reduced every year in 1990s, and 10 million hectares of forest were reduced every year from 2015 to 2020. Since 1990s, more than 80 million hectares of primary forest across the world has been cut down, and 420 million hectares of forest are converted to other land use [24]. Agriculture expansion is the major driver for deforestation, and overgrazing and grassland development lead to grassland degradation. Global deforestation continues due to population growth and urbanization, which leads to the rise of CO_2 concentration in the air and reinforces the greenhouse effect.

Renewable energy. Renewable energy is intermittent, it is unreliable due to weather changes or other natural changes. High upfront cost makes renewable energy expensive. The global fossil fuel consumption was 192.17 Exajoules in 1970, 339.53 Exajoules in 2000, 492.36 Exajoules in 2019, accounting for 93.74%, 86.07%, and 84.32% of global primary energy consumption in that year respectively. The global renewable energy consumption was 12.05 Exajoules in 1970, 29.16 Exajoules in 2000, 66.62 Exajoules in 2019, accounting for 5.88%, 7.39%, and 11.41% of global primary energy consumption in that year respectively. The growth rate of fossil fuel consumption was 1.64% from 2008 to 2018, and it was 0.7% from 2018 to 2019. The growth rate of renewable energy consumption was 7.3% from 2008 to 2018, and it was 5.5% from 2018 to 2019 [20]. We can see that the share of global fossil fuel consumption in primary energy consumption is far

greater than that of global renewable energy, only that the growth rate of renewable energy is much bigger than that of fossil fuel.

5. Conclusions

The world is cooperating to reduce GHG emission, but the effort to stabilize the world's climate faces enormous challenges due to the increase of GHG emission in developing countries. Global CO_2 emission from 2000 to 2019 accounted for 30.7% of global cumulative emissions, this is the fastest period of CO_2 emission in human history [25]. In 2019, the increase of GHG emission in developing countries was much more than the reduction of GHG emission in developed and economically sluggish countries. The reduction of GHG emission in developed and economically sluggish countries offset only 15.7% of the increase of GHG emission in developing countries. In 2019, CO_2 emission in the non-OECD countries was 22,157 million tons, accounting for 64.8% of the world's total. The annual growth rate of CO_2 emission in these countries was 2.5% from 2008 to 2018, 2.4% from 2018 to 2019 [25]. Therefore, reducing fossil fuel consumption in developing countries has been the key to addressing global warming and climate change.

There are 173,000 terawatts per second of solar energy reaching Earth, which is more than 10,000 times of the world's total energy consumption [26]. It is the most abundant renewable energy resource, but the huge cost of upfront infrastructure investment makes it unaffordable for ordinary households. As prices continue to fall, solar energy is becoming an economical energy source for residents and businesses. Nuclear fusion power generation is a relatively clean energy, it can solve the problem of energy shortage in large energy-consuming countries such as China and India, but the technology is not yet mature. The research and development of clean energy is not only the way to addressing global warming, but also the way to meeting the energy demand of the world.

In 2020, more than 37,400 species of animals and plants were on the verge of extinction, which accounted for 28% of all assessed species [27]. It is high time that nation countries should establish national parks and ecological reserves to conserve plants and the environment. Conserving plants, co-existing with them is the only way to sustainable development. Deforestation and urbanization are driven by the growth of GHP, which have driven global warming and climate change. Therefore, preserving the environment and slowing down the population growth are important to address the problem of global warming and climate change.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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