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Fossil Fuel, Greenhouse Gas and Global Warming

By Chunji Liu & Tao Liu
Wuzhou University

Abstract- Since the Industrial Revolution, fossil fuel consumption and greenhouse gas emission have increased substantially, causing the rise of greenhouse gas concentration (GHGC) and in turn the rise of global mean surface temperature (GMST). We analyze the years of the rises and the falls of global temperature fluctuation, and find that the natural time interval between the rise and the fall of the temperature fluctuation has decreased from 31.5 years to 23 years, the impact from human activities has increased from 2.5 years to 9 years. We analyze the shares of total solar irradiance (TSI), greenhouse gas concentration (GHGC), and water vapor for the rise of GMST, we find that: TSI accounts for 23.4% for greenhouse effect from 1880 to 1964, and 12.4% from 1965 to 2022; GHGC accounts for 80.9% for greenhouse effect from 1880 to 1964,and 86.6% from 1965 to 2022; water vapor is negatively related with GMST from 1880 to 1964, accounting for -4.3% for greenhouse effect, and positively related with GMST from 1965 to 2022, accounting for 1% for greenhouse effect. Global warming hiatus from 1998 to 2012 is a shortened fall of global temperature fluctuation.

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FOSSILFUELGREENHOUSEGASANDGLOBALWARMING

Strictly as per the compliance and regulations of:

Fossil Fuel, Greenhouse Gas and Global Warming

Chunji Liu [α] & Tao Liu [σ]

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Keywords: fossil fuel, greenhouse gas, total solar irradiance, global warming.

I. Introduction

Since the 1950s, there are observed changes that global mean surface temperature (GMST) of the Earth is rising, such as rising atmospheric temperatures, rising sea levels and shrinking glaciers in the polar regions (US EPA, 2017). Researches indicated that ice depth in all regions of the Arctic Ocean decreased by approximately 40% over the late 40 years in the 20th century (Leggett, 2005). Global mean land-ocean surface temperature (GMST) was -0.16°C in 1880, and it was 0.89°C in 2022, thus an increase of 1.05°C (NASA, 2023a). The growth rate of the Earth's surface temperature was 0.08°C per decade from 1880 to 1980, and it was 0.18°C per decade from 1981 to 2020, an increase of 0.1°C (Lindsey and Dahlman, 2021). The hottest year was 2020 with an average surface temperature of 1.02°C, followed by 2016 at 1.01°C (NASA, 2023a). The average surface temperature in 2021 and 2022 was a little lower than that in 2020.

Since the 1960s, the surface air temperature in Northern China has significantly increased in winter, which leads to a drop in wind speed of the East Asia Monsoon. For example, the average annual wind speed decreased by 28%, and days with wind speeds exceeding 5m/s decreased by 58% (Xu et al, 2006). The Arctic is covered by millions of square miles of sea ice most of the year. But the extent of sea ice in the Arctic has been declining since 1970s, and the amount of sea ice has decreased by two-thirds. The growth rate of the Arctic temperatures is 3 times of that in the other places on Earth (Berardelli, 2020).

But at the beginning of the 21st century, there is no record of continued significant temperature rise, challenging the viewpoint of global warming. The growth rate of GMST was 0.09 ± 0.01°C per decade from 1900 to 1950, 0.1 ± 0.01°C per decade from 1950 to 2000. But the growth rate dropped to 0.04 ± 0.05°C per decade at the beginning of the 21st century (Lean, 2018). From 1998 to 2012, there was a slowdown or hiatus in global surface temperatures (Medhaug et al., 2017; Fyfe et al, 2013 and 2016). Ma et al. (2022) indicated that there was a winter warming slowdown in northwest cold regions and north cold regions across China from 1998 to 2018. Researches of both global and regional surface temperature indicated that there was not significant temperature rises from 1998 to 2012 (Johnson et al., 2018; Winslow et al., 2018; Garfinkel et al., 2017; Shen et al., 2018).

Different meteorological data sets and models can lead to different and even contradictory conclusions, it is apparent that the slowdown in surface temperature has led to doubt about the anthropogenic global warming in the public. We want to know the share of the greenhouse gas, total solar irradiance (TSI), and water vapor for the rise of GMST, and conduct empirical research to examine their impact. The following part of this article is arranged in this way: Part 2 is total solar irradiance, greenhouse gas and water vapor, we analyze their effect on GMST; Part 3 is fossil fuel and increased greenhouse gas emissions, we present the data of the use of fossil fuel and greenhouse emissions; Part 4 is global warming hiatus, a period of shortened fall in temperature fluctuation, the causes that lead to global

Author α: PHD. Business School, Wuzhou University. No. 82, Fumin Third Road, Wuzhou City. Guangxi Province, People's Republic of China. e-mail: liucjkf@126.com
Author σ: Associate Professor. Economic School, Henan University. People's Republic of China. e-mail: 2865519937@qq.com

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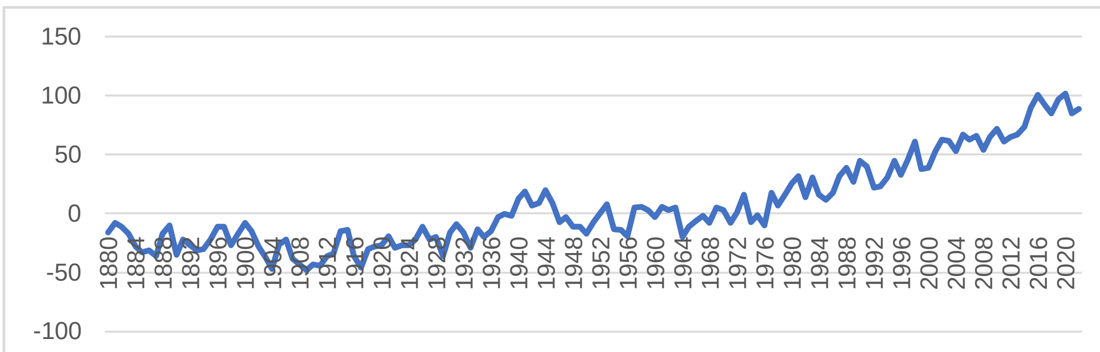
warming hiatus are reported; Part 5 is discussion; and Part 6 is conclusion

II. Total Solar Irradiance (TSI), Greenhouse Gas and Water Vapor

Before 1.2 million years, global temperature was warmer than today, and it gradually cooled down, the cooling came to a halt at 1.2 million years ago, and the situation continued to the present (Snyder, 2016). Research of Milutin Milankovitch indicated that global temperature warms and cools on roughly 41,000-year cycles. Since the last ice age, about 24,000 years ago, the rise of atmospheric concentration of greenhouse gases has been causing the rise of global surface temperature. But global surface temperature has risen much faster over the past 150 years than it did 24,000 years ago (Kelley, 2021).

Figure 1 is the annual data of GMST from 1880 to 2022 (NASA, 2023a). We divide GMST into 4 periods: (1) from 1880 to1909, 29 years, GMST slowed down gradually; (2) from 1910 to1944, 34 years, GMST rose gradually; (3) from 1945 to1964, 19 years, GMST slowed down gradually; and (4) from 1965 to 2022, 57 years, GMST rose gradually. During the first 3 periods of 1880-1964, GMST alternated in rise and fall at an average time interval of 27 years. After 1965, the pattern of temperature fluctuations changed, the temperature was on the rise with little decline.



Credit: NASA (2023a), GISS Surface Temperature Analysis (GISTEMP v4)

Figure 1: Annual Data of GMST from 1880 to 2022 (in 0.01 Degrees Celsius)

According to the 27-year time interval during the first 3 periods of 1880-1964, there should have been one year in 1990s when the temperature entered the period of decline. However, there was a global warming hiatus from 1998 to 2012, and global warming continued in 2013.

Suppose the natural time interval between the rise and the fall of the temperature fluctuation is "x", and the human impact on the temperature is "y". Human activities have caused the rise of global surface temperature, therefore, we suppose the real time interval of the rise of surface temperature is "x+y", and the fall "x-y", from period (1) and period (2), we have equation system (1):

$$\begin{cases} x - y = 29 \\ x + y = 34 \end{cases} \quad (1)$$

We get: x=31.5, y=2.5, which means the natural time interval between the rise and the fall of temperature fluctuation is 31.5 years from 1880 to 1944, and the impact from human activities is 2.5 years.

We can divide the period of 1965-2022 into three small periods: (1) from 1965 to 1997, 32 years, the temperature rose gradually; (2) from 1998 to 2012, 14 years, global temperature slowed down; and (3) from 2013 to 2022, 9 years, the temperature rose again, this period is not over yet. During the first 2 small periods of 1965-2012, we can see that the average time interval is 23 years. The small period of 1998-2012 is most likely a shortened period of the fall of temperature fluctuation, which has been disturbed and shortened by human activities. From small period (1) and small period (2), we have equation system (2):

$$\begin{cases} x + y = 32 \\ x - y = 14 \end{cases} \quad (2)$$

We get: x=23, y=9, which means the natural time interval between the rise and the fall of temperature fluctuation is 23 years from 1965 to 2012, and the impact of human activities is 9 years. From equation system (1) and equation system (2), we know that the natural time interval between the rise and the fall of the temperature fluctuation has decreased from 31.5 years to 23 years, and the impact from human activities has increased from 2.5 years to 9 years.

We want to examine the relationship between GMST and TSI, greenhouse gas concentration (GHGC) and water vapor, calculate the share of TSI, GHGC and water vapor for global warming, and figure out the order of these factors in which they have contributed to global warming.

There are many factors that affect greenhouse effect, here we only focus on TSI, GHGC, and water vapor. Here, GHGC consists of carbon dioxide (CO2), methane

(CH4) and nitrous oxide (N2O), we list water vapor as an independent factor that affects GMST. The reasons are as follows: although water vapor is a greenhouse gas, its behavior is different from other greenhouse gases. First, increased concentration of carbon dioxide leads to the rise of surface temperature, which is mainly brought about by the use of fossil fuel. Second, higher surface temperature causes surface water to evaporate and more water to enter the atmosphere. Third, the increasing concentration of water vapor in the air leads to a further increase in surface temperature. The concentration of water vapor varies according to temperature. At 30°C, a volume of air contains up to 4% water vapor. At -40°C, it can hold 0.2% water vapor (Britannica, 2023a). Atmospheric water vapor reflects and absorbs solar radiation, it transports heat from the tropics to the cold regions and plays a leading role in the hydrological cycle (Jacob, 2001). Water vapor is a regulator of the atmospheric temperature. The overall concentration of water vapor in the air is stable, and its change in the air is small. Therefore, we list water vapor as the third factor after TSI and GHGC.

We conduct regressions with GMST as dependent variable, and TSI, GHGC and water vapor as independent variables respectively. The data set of GMST is from NASA (2023a), the time is from 1880 to 2022, the base period is 1951-1980. Outliers have been eliminated from the data set and adjusted for homogeneity, the unit of the datais 0.01 degrees Celsius. The data set of TSI is from Kopp (2023), the data consist of two parts, one part is "Historical TSI Reconstruction", it is from 1610 to 2018, we only take the data from 1880 to 2018. The other part is from the data set of "community-consensus TSI composite" (Kopp, 2023), we only take the data of 2019, 2020, 2021, and 2022. The units of the data are watts per square meter (w/m^2). The data set of greenhouse gas concentration (GHGC) is from Ritchie and Roser (2023a). The time of the data is from1880 to 2022. The data of annual GHGC are the sum of annual carbon dioxide concentration, methane concentration, and nitrous oxide concentration, the units are ppm. We can't find the data of atmospheric concentration of water vapor, but we have the data of global mean precipitation (GMP). Water vapor concentration is closely related with GMP, so we use GMP as the proxy variable for water vapor concentration. The data set of GMP is from the website of the Environmental Protection Agency of the United States (EPA, 2022a), the time is from 1901 to 2021, the units are inches.

Table 1: Regression Output between GMST and TSI from 1880 to 1964

Independent Variables	coefficient	t-Statistic	R-Squared: 0.11
C	-18628.32	-3.13	F-statistic: 9.79
TSI	13.67	3.13	D-W statistic: 0.53

Note: here C is the intercept

Table 2: Regression Output between GMST and GHGC from 1880 to 1964

Independent Variables	Coefficient	t-Statistic	R-Squared: 0.38
C	-128.4	-8.21	F-statistic: 51.0
GHGC	0.07	7.14	D-W statistic: 0.72

Note: here C is the intercept

Table 3: Regression Output between GMST and GMP from 1901 to 1964

Independent Variables	Coefficient	t-Statistic	R-Squared: 0.02
C	-16.04	-7.39	F-statistic: 0.99
GMP	-5.51	-0.99	D-W statistic: 0.37

Note: here C is the intercept

Due to the obvious changes in patterns and trends after 1965, we divided the data of GMST into two periods for empirical analysis, the first period is 1880-1964, and the second period is 1965-2022. Table 1 presents the regression output between GMST and TSI from 1880 to 1964, the output indicates that there is a positive relationship between GMST and TSI, t-statistics and F-statistic are significant at 5% confidence level. The R-squared is 0.11, which means that the rise in TSI accounts for 11% of the rise in GMST. Table 2 presents the regression output between GMST and GHGC from 1880 to 1964, the output indicates that there is also a positive relationship between GMST and GHGC, t-statistics and F-statistic are significant. The R-squared is 0.38, which means the rise in GHGC accounts for 38% of the rise in GMST.

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Table 3 presents the regression output between GMST and GMP from 1901 to 1964. The output indicates that there is a negative relationship between GMST and GMP, the R-squared is 0.02, which means that the rise in GMP accounts for 2% of the decline in GMST. However, the t-Statistic of GMP is not significant at 5% confidence level, the F-statistic is a little smaller than the critical value, which means that there is no significant correlation between GMST and GMP. We also conduct Granger causality test between GMST and GMP, the output indicates that there is not a statistically significant Granger causality between them.

We get the quantified effect of TSI, GHGC and GMP on GMST, they are 0.11, 0.38 and 0.02 respectively. So we have the sum of the effects of them, which is 0.47 (0.11+0.38-0.02). We get the share of 23.4 % of TSI for the rise of GMST as shown in equation (1). Similarly, we get the share of 80.9% of GHGC for the rise of GMST, and -4.3% of GMP (water vapor).

Share of TSI for the greenhouse effect 1880-1964:

$$\frac{the\ effect\ \ of\ TSI}{sum\ \ of\ the\ effects\ \ of\ TSI,GHGC\ and\ water\ \ vapor}=\frac{0.11}{0.11+0.38-0.02}=0.234 \qquad (1)$$

We continue to conduct regressions between GMST and TSI, GHGC and GMP with data from 1965 to 2022. The output in table 4 indicates that there is a positive relationship between GMST and TSI from 1965 to 2022, t-statistics and F-statistic are significant at 5% confidence level. The increase in TSI account for 12% of the rise in GMST. The output in table 5 indicates that there is also a positive relationship between GMST and GHGC, the t-statistics and F-statistic are significant, the rise in GHGC account for 84% of the rise in GMST. We also conduct regression with GMST as dependent variable, with TSI and GHGC as independent variables in the same equation from 1965 to 2022, the output indicates that GHGC is statistically significant at 5% confidence level, however, TSI is not statistically significant.

We conduct regression between GMST and GMP from 1965 to 2021 as shown in table 6. The output in table 6 indicates that there is a positive relationship between GMST and GMP from 1965 to 2021, the rise in GMP accounts for 1% of the rise in GMST. However, t-Statistic of GMP is not significant at 5% confidence level, F-statistic is not significant too. Granger Causality test between them indicates that: “GMST does not Granger Cause GMP”; “GMP does Granger Cause GMST”.

Table 4: Regression Output between GMST and TSI from 1965 to 2022

Independent Variables	Coefficient	t-Statistic	R-Squared: 0.12
C	-45325.03	-2.72	F-statistic: 7.42
TSI	33.32	2.72	D-W statistic: 0.19

Note: here C is the intercept

Table 5: Regression Output between GMST and GHGC from 1965 to 2022

Independent Variables	Coefficient	t-Statistic	R-Squared: 0.84
C	-288.17	-15.14	F-statistic: 299.30
GHGC	0.14	17.30	D-W statistic: 0.85

Note: here C is the intercept

Table 6: Regression Output between GMST and GMP from 1965 to 2021

Independent Variables	Coefficient	t-Statistic	R-Squared: 0.01
C	38.17	8.75	F-statistic: 0.54
GMP	5.09	0.73	D-W statistic: 0.16

Note: here C is the intercept

We get the quantified effects of TSI, GHGC and GMP on GMST from 1965 to 2022, they are 0.12, 0.84and 0.01 respectively. We get the sum of the effects of TSI, GHGC and water vapor on GMST, which is 0.97 (0.12+0.84+0.01). We get the share of 12.4% of TSI for the rise of GMST as shown in equation (2). Similarly, we get the share of 86.6% of GHGC for the rise of GMST, and 1% of GMP (water vapor).

Share of TSI for the greenhouse effect 1965-2022:

$$\frac{the\ effect\ of\ TSI}{sum\ of\ the\ effects\ of\ TSI,GHGC\ and\ water\ vapor}=\frac{0.12}{0.12+0.84+0.01}=0.124 \quad (2)$$

The share of TSI for the greenhouse effect was 23.4 % from 1880 to 1964, and it was 12.4% from 1965 to 2022, thus, an decrease of 11%. The share of GHGC for the greenhouse effect was 80.9% from 1880 to 1964, and it was 86.6% from 1965 to 2022, thus an increase of 5.7%. The share of GMP (water vapor) for the greenhouse effect was -4.3% from 1880 to 1964, and it was 1% from 1965 to 2022, thus an increase of 5.3%.

III. Fossil Fuel and Increased Greenhouse Gas Emission

In the Northern Hemisphere, temperature differences between July (summer) and January (winter) have been decreasing, the average surface temperature in July has been lower than that in January since 2013 (NASA, 2023a). In the Southern Hemisphere, temperature differences between January (summer) and July (winter) have been also decreasing, the average temperature in January has been lower than that in July since 2017 except 2020 (NASA, 2023a). The increase in average surface temperature in the Northern Hemisphere is higher than in the Southern Hemisphere, this is brought about by more greenhouse gas emissions and more fossil fuel use in the Northern Hemisphere.

Increased use of fossil fuels have led to rapid rise in atmospheric GHGC since 1750. Atmospheric GHGC was 1,413.45 ppm in 1880, and it was 2,663.61 ppm in 2022, thus an increase of 88.45%(Ritchie and Roser, 2023a). Changes in the Earth's energy budget demonstrated that greenhouse gas emission was the main cause for global climate change (Xie et al., 2015).Anthropogenic greenhouse gas emissions have increased greatly and caused the rise of global surface temperature since the mid of the 20th century (IPCC, 2013; Fleming, 2007).

In 2019, fossil fuels accounted for 84% of global primary energy consumption, renewable energy accounted for only 11%, and nuclear energy accounted for 4% (Ritchie and Roser, 2021). Fossil fuels accounted for more than 80% of primary energy consumption in China, the United States and India, this pattern of energy consumption is also common in most developing countries (BP data, 2020).

Atmospheric CO2 concentration in 2009 increased by 38% compared with that in 1750, and the methane concentration increased by 1.48 times (Riebeek, 2010). Global CO2 emission was 3,954.43 million metric tons (including land use change) in 1880, 41,062.90 million metric tons in 2021, thus an increase of 9.38 times (Ritchie and Roser, 2020a). Global CO2 emission has been increasing since the Industrial Revolution. The use of global fossil fuels were 2,575TWh in 1880, and it were 136,761TWh in 2019, thus an increase of 52.11 times (Ritchie and Roser, 2020b). Approximately 337 billion metric tons of carbon have been emitted into the atmosphere due to the use of fossil fuels and cement production since 1751, half of which was after the mid-1970s (Boden et al., 2017).

In 2004, CO2 emissions from OECD counties were 13,450.8 million tons, and it were 13,626.7 million tons from Non-OECD countries (BP data, 2021). For the first time in history, Non-OECD countries are emitting more CO2 than OECD countries. In 2020, CO2 emissions in OECD countries were 10,778.1 million tons, and it were 21,540.5 million tons in Non-OECD (BP data, 2021). Thus, CO2 emissions from Non-OECD countries have been 2 times of that from OECD countries. From 2000 to 2019, developed countries experienced a decline in CO2 emission. On the contrary, CO2 emissions in most developing countries are gradually increasing including China and India (BP data, 2021).

The average growth rate of CO2 emissions in OECD countries was -0.4% per year from 2009 to 2019, and it was 2.5% per year in Non-OECD countries (BP data, 2021). The total increase of CO2 emissions from developing countries are farmore than the total reduction from developed countries, and the total reduction from developed countries offsets only 15.7% of the total increase from developing countries (Zhou, 2021). Therefore, reducing CO2 emissions in developing countries have been the key to mitigating global warming.

IV. Global Warming Hiatus, a Period of Shortened Fall in Temperature Fluctuation

Atmospheric circulation between ocean basins affects global surface temperatures, research of Kosaka and Xie (2013) indicated that the cooling in the eastern equatorial Pacific led to the slowdown in surface temperature from 1998 to 2012. In 2014, the abnormal warming of the sea surface temperature in the tropics of the west Pacific Ocean drove the atmospheric circulation, leading to the cold winter in central North America (Hartmann, 2015). The cooling in sea surface temperature in the tropical eastern Pacific caused the global warming hiatus from 1998 to 2013, such as La Niña, and it is connected with the warming in both Indian Ocean and Atlantic Ocean (Zhao, 2018).

The slowdown of global surface temperature is part of natural climate variability, it is known as La-Niña decadal cooling. The cooling surface temperature of the tropical Pacific and sea-ice loss of the Arctic brought about an atmospheric teleconenction between the two regions during the phase of La Niña-decay years, and brought about the cold winter over Eurasian continent during the past two decades (Matsumura and Kosaka, 2019). The decline in global surface temperature was connected to the natural decadal cycle in the Pacific Ocean and is exacerbated by the warming of the Atlantic Ocean (Ma et al., 2020).

The synchronized tropical eastern Pacific variability led to the slowdown of the global surface temperature in early 2000s, the atmospheric pattern of cold ocean-warm land also led to the hiatus of global warming in the early 2000s and the acceleration in the 2010s (Yang et al., 2020). Owing to the phase variations in the Atlantic Multi Decadal Oscillation and the Arctic Oscillation, there was a significant slowdown in the surface temperature in the cold regions over China, and the Tibetan Plateau determines the characteristics of extreme temperatures across these cold regions (Ma et al., 2022).

The multidecadal variability in the Southern Ocean is linked to the internal variability in the tropical oceans through atmospheric teleconnection, especially to the internal variability in the Pacific Ocean (Chung et al., 2022). There are atmospheric interactions between the regime of the Atlantic Ocean and the regime of the Pacific Ocean. Before 1980s, the El Niño-Southern Oscillation in the tropical Pacific in winter caused the anomaly in the tropical Atlantic in the next spring. But the impact declined after 1980s. The impact from the North Tropical Atlantic on the El Niño-Southern Oscillation has become significant since mid-1980s (Park et al., 2023).

Trade wind drives the warm surface water in tropical oceans to flow from east to west, which causes warm water pools along the west coast of continents. Thus the surface temperature in the west Pacific is 8°C warmer than in the east Pacific, which contributes to the precipitation in Indonesia, Australia, and parts of Africa (Stevens, 2011).93.4% of the energy that led to global warming was absorbed by the ocean, 2.3% by the atmosphere, 2.1% by continents, 0.9% by glaciers/ice caps, 0.8% by the Arctic Sea ice, 0.2% by the Greenland ice sheet, 0.2% by the Antarctic ice sheet (Mooney, 2013). Therefore, oceans absorb heat and balance the heat of Earth surface, playing a key role in regulating the surface temperature.

Earth's obliquity is the angle between the plane of Earth's orbit and that of Earth's equator, it varies between 24.5° and 22.1°. It causes the change of the incident angle of solar radiation and affects the amount of sunlight, leading to the change of seasons. It is currently 23.4° and falling, halfway between 24.5° and 22.1°. This change has brought about milder seasons, making winter a little warmer and summer a little cooler. As Earth changes its position relative to the Sun, the climate is coming into an ice age (Buis, 2020). Therefore, changes in the Earth's obliquity have been leading to the change of the climate, it is one of the factors that brought the the slowdown in global surface temperature from 1998 to 2012.

In fact, the above mentioned factors that contribute to global warming hiatus are also factors that contribute to the cyclical patterns and the characteristic of global surface temperature fluctuation. Therefore, global warming hiatus of 1998-2012 is also a period of shortened fall in temperature fluctuation.

V. Discussion

TSI was 1362.31w/m^2 in 2022, and 1360.76w/m^2 in 1880, an increase of 1.55w/m^2. Although TSI has increased, its share for the greenhouse effect has declined, which was mainly caused by the rise in GHGC. Water vapor was negatively related with global surface temperature from 1880 to 1964, however, it became positively related with global surface temperature from 1965 to2022, which means water vapor prevented the rise of global surface temperature from 1880 to 1964, and the evaporation of water vapor increased with the rise of surface temperature from 1965 to 2022.

The Earth's rotation around the sun, especially the axial tilt dominates the glacial cycle in Milankovitch cycles. The axial tilt affect the incoming solar energy to the Earth, which affects the climate of Earth. According to the theory of Milankovitch cycles, the surface climate should be more cooling than it is now (Buis, 2020). Changes in Earth's obliquity can influence long-term climate trends, they are factors to operate on much longer timescales, such as tens of thousands of years, which play a role in the broader climate context. The impact from the use of fossil fuels on global surface temperature is of short-term, it may be decades of years. If we reduce the use of fossil fuels significantly, the growth rate of global warming will slow down in decades.

Human activities have made global surface temperature rise by 0.7°C in the 20thcentury by the use of fossil fuel and greenhouse gas emission. According to predictions, average surface temperature will rise 2-6°C by the end of the 21stcentury (Riebeek, 2010). The increased use of fossil fuel in cities has altered hydro-meteorological fluxes. During the phase of El Niño, the cities in the western parts of Pacific Ocean show a strong urban heat island effect, while during the phase of La Niña, the cities in the eastern parts of Pacific Ocean show a strong urban heat island effect (Fitria et al., 2019). The urban heat island effect has driven the temperature rise over the capital cities in east Africa, it raises the temperature of Dodoma by 1°C, Kampala by 4°C, and Khartoum by 8°C. It raised the regional temperature by 0.64°C during the daytime from 2000 to 2020, and 0.34°C during the nighttime (Garuma, 2023).

Humans are also raising the surface temperature by deforestation. Trees convert CO2 in the air into oxygen through photosynthesis, they are natural regulators of CO2. An increase in tree cover leads to more oxygen in the atmosphere. Trees also raise atmospheric humidity by transpiration and in turn make precipitation to increase in the region. Therefore, trees can buffer the surface temperature from over-heating or cooling, making the surface temperature suitable for human life (Derouin, 2022).Carbon dioxides are released into the air when trees are cut or burned, deforestation is preventing trees from converting CO2 into oxygen. Deforestation has led to the rise of atmospheric GHGC and in turn intensified the greenhouse effect.

According to research of Food and Agriculture Organization of the United Nations, the first cause for climate change is the use of fossil fuels, the second is deforestation, which accounts for 20% of greenhouse gas emissions (Derouin, 2022). Most of the farmland around the world were once forests, agriculture has been the primary driver for deforestation. Beef, soybean, palm oil and wood products are responsible for the most tropical deforestation. Deforestation, agriculture, and other land-use changes are the second sources contributing to the rise of GHGC after the use of fossil fuels (EPA, 2022b).

4,000 years ago, most of China was covered in forests, but by the end of the 20thcentury, only 20% of the forests were left. From 1600s to 1870s, half of the forests in the eastern part of North America were cut down. 2,000 years ago, 80% of West Europe were covered by forests, but only 34% of forests were left by the early 2000s (National Geographic, 2022). 10 million square kilometers of forests have disappeared since the beginning of the 20th century, 10% tropical trees have been cut down since 2000, and in 2019 alone, 121,000 square kilometers of tropical trees were destroyed (Derouin, 2022). From 2000 to 2010, land use for cattle ranches, soybeans and oil palms accounted for 40% of tropical deforestation, local agriculture accounted for 33% of the subsistence deforestation (FAO, 2020).

VI. Conclusion

Over the 11-year solar cycle, the difference in TSI between the most active and least active states is 0.1%, about 2 watts per square meter (NASA, 2023b). According to the data from Kopp (2023), the mean value of TSI was 1360.19 w/m^2 in 1610, and 1361.26 w/m^2 in 2018, thus an increase of 1.07 w/m^2. The variation in TSI is minimal and negligible. The researches of Finsterle et al (2021) also indicated that there were no significant change in TSI during recent solar minima in 2008/09 and 2019/20. The impact from changes of TSI on global surface temperature is much smaller than that from the use of fossil fuel from 1885 to 2013 (Solanki et al., 2013).

Human activities are causing the natural time interval of the rise and fall of temperature fluctuation to shorten. Both the share of GHGC and water vapor for the greenhouse effect have increased, but the share of TSI for the greenhouse effect has decreased. The average solar radiation that strikes each square metre of Earth's surface is 342 watts, the net radiative forcing from humans has been 1.6 watts per square meter since the Industrial Revolution (Britannica, 2023b). Although anthropogenic activities are the main cause for global warming and climate change, the impact itself is much smaller compared to TSI. TSI is still the primary factor that makes the climate of Earth.

In the first half of the 21st century, low growth rate in the world's population can reduce greenhouse gas emissions to a level equivalent to eliminating all deforestation. Voluntary family planning can help women actively participate in economic activities, help to preserve local environment and contribute to the establishment of sustainable ecological environment (World watch Institute, 2016). In low-income countries, rapid population growth has reduced the average resources devoted to improving their health and education. Therefore, slowing down the high levels of fertility in low-income countries is essential for their sustainable development (UN DESA, 2022). Developing countries have exceeded developed countries in the use of fossil fuels and greenhouse gas emissions, they should reduce the use of fossil fuel and replace fossil fuel with clean energy just like the developed countries.

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