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Effects of Anthropogenic CO_2 and Thermally-Induced CO_2 on Global Warming

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Abstract

Changes in CO_2 and temperature are correlated, but it is difficult to observe which is the cause and which is the effect. The release of CO_2 dissolved in the ocean into the atmosphere depends on the atmospheric temperature. However, examining the relationship between changes in CO_2 caused by other phenomena and temperature is difficult. Studies of soil respiration (*Rs*) since the late 20th century have shown that CO_2 emissions from soil respiration (*Rs*) are overwhelmingly greater than CO_2 emissions from fossil fuel combustion. This is also noted in the IPCC carbon budget assessment. In this paper, the dependences of *Rs* on temperature, time, latitude, precipitation, seasons, etc., were investigated using the latest NASA database. The changes in temperature and *Rs* correlated well. There is also a good correlation between *Rs* and CO_2 generation. Therefore, an increase in temperature results in an increase in CO_2. On the other hand, there is no evidence other than model calculations that an increase in anthropogenic CO_2 is mainly linked to a rise in temperature. The idea that global warming is caused by anthropogenic CO_2 production is still a hypothesis. For these reasons, the relationship between global warming and anthropogenic CO_2 should be reconsidered based on physical evidence without preconceptions.

Keywords

Global Warming, Anthropogenic CO_2, Thermally-Induced CO_2, Soil Respiration, Carbon Cycles

1. Introduction

The concept of global warming due to anthropogenic CO_2 has been proposed by the Intergovernmental Panel on Climate Change (IPCC) [1]. However, there is no direct evidence proving that anthropogenic CO_2 has induced global warming. Current global warming may be caused by a natural cycle and a portion of the "*Modern Warm Period*", as shown in our recent papers [2]-[4].

The observation of the Earth's temperature using satellites began in 1979. Two groups, the University of Alabama in Huntsville (UAH) [5] and Remote Sensing Systems (RSS) [6], have conducted the observation and analysis. The temperature in the lower troposphere measured by the UAH rises very slowly, increasing and decreasing repeatedly. The average temperature increase is 0.14˚C/decade [5]. We found a good correlation between the change rate of CO_2 concentration and satellite-based global temperature data during 1979-2022. Since the CO_2 concentration is currently increasing annually, the change rate of the CO_2 concentration can be called the "*CO_2 growth rate*" (ppm/year). Equation (1) can be reasonably derived as follows:

$$\mathrm{d}rco_2/\mathrm{d}t \fallingdotseq \gamma\Delta T \tag{1}$$

(rco_2: CO_2 concentration, γ: constant, ΔT: temperature change).

The constant γ changes depending on the biome distribution on Earth [3]. It was confirmed that the CO_2 growth rate (hereinafter referred to as $\mathrm{d}rco_2/\mathrm{d}t$) changes approximately several months after the temperature changes (hereinafter referred to as ΔT), which may be called "*thermally induced CO_2*". Other research has shown that ΔT and thermally-induced CO_2 are correlated, but the temperature changes first, and the change in thermally-induced CO_2 follows ΔT with a time lag of 0.5 - 1 year [7]-[10]:

$$\Delta T \rightarrow (0.5\text{-}1\ \text{year}) \rightarrow \Delta rco_2 \tag{2}$$

(Δrco_2: a change in CO_2 concentration).

Therefore, the essential Equations (1) and (2) cast doubts that anthropogenic CO_2 is the main cause of global warming [4] [11].

Our previous papers [2]-[4] suggested that ΔT affects plant decomposition and soil respiration (*Rs*), followed by a change in CO_2 generation. The higher the temperature is, the more CO_2 is generated. The effects of plant decomposition and *Rs* on CO_2 in the atmosphere are further clarified for global ΔT by reviewing related aspects and available datasets [4]. The aspects and datasets investigated included the following:

1) The carbon cycle budget shows that anthropogenic CO_2 accounts for only 4% of the total, and the residence time of CO_2 is approximately 4 years.

2) There is no correlation between CO_2 exhausted from fossil fuel combustion and $\mathrm{d}rco_2/\mathrm{d}t$.

3) CO_2 is only 4% of greenhouse gas, and the remaining 96% is H_2O.

4) Fifteen percent of solar energy is reflected from the ground as IR and is absorbed by IR active substances in the atmosphere. Nearly the entire amount of reflected IR is absorbed by H_2O molecules.

5) $\Delta^{13}C$ and CO_2 show anti-correlation, but the interpretation of the Suess effect cannot be applicable for this anti-correlation if the result is considered to-

gether with the global carbon budget.

6) The extent of the correlation between $\mathrm{d}rco_2/\mathrm{d}t$ and ΔT differs depending on the latitude and between the land and sea.

7) During El Niño, $\mathrm{d}rco_2/\mathrm{d}t$ follows ΔT with a time lag of several months, and CO_2 emission and absorption at the Earth's surface respond to ΔT.

8) The concentrations of CO_2, CH_4, and N_2O gases increase annually, but seasonal changes are observed. These concentrations decrease from spring to summer and increase from fall to winter.

9) *Rs* is interpreted to activate in spring because of increasing temperatures and to generate CO_2, CH_4, and N_2O in fall due to biological processes after a time lag.

10) Temperature patterns have changed over the last 2000 years, as shown by the ice age and warm periods. Therefore, CO_2 has evolved to breathe slowly in response to ΔT.

Based on these results, we concluded that changes in plant decomposition and *Rs* due to global temperature primarily control global CO_2 cycles. The impact of CO_2 emissions from fossil fuel combustion on global warming is low. In this paper, the effect of selected global conditions on soil respiration (*Rs*) was further investigated based on the National Aeronautics and Space Administration (NASA) database.

2. Global Data

All the datasets analyzed here are available from NASA on the Oak Ridge National Laboratory (ORNL) website [12]. The annual carbon flux (g·C·m^{-2}) from soil respiration (*Rs*) (y-axis or values) was analyzed with selected parameters (x-axis or values) in the database. When multiple *Rs* values with the same x values are reported in the database, the *Rs* values are averaged for the same x values. This "global database of soil respiration data" was first reported in 2010 [13] and has been updated. The current database is version 5.

3. Results and Discussion

3.1. Effect of Selected Global Conditions on Soil Respiration (*Rs*)

The release of CO_2 from soil respiration (*Rs*) is the largest terrestrial C flux to the atmosphere, but data-driven estimates are still lacking [14] [15]. Raich and Schlesinger [16] reviewed the measured rates of *Rs* to identify uncertainties in global flux estimates and investigated the influences of temperature, precipitation, and vegetation on *Rs* rates in 1991. The annual global CO_2 flux from soils was estimated to average 68 ± 4 (Pg·C·yr^{-1}) based on extrapolations from biome land areas. On a global scale, *Rs* rates were positively correlated with mean annual air temperature and mean annual precipitation.

The effect of selected global conditions on *Rs* was further investigated based on the latest NASA database. **Figure 1** shows the change in annual C flux (g·C·m^{-2}) from *Rs* with the mean annual temperature (˚C) between 1961 and

2017. *Rs* has an approximately linear relation with temperature. The regression line is $y = 23.3x + 582.0$, which is comparable with the $y = 25.6x + 300$ line reported by Raich and Schlesinger [16]. Equations (1) and (2) above indicate that the CO_2 growth rate ($\mathrm{d}rco_2/\mathrm{d}t$) changes with the temperature change (ΔT) after a time lag [2]-[4]. Our results suggested that ΔT affects plant decomposition and soil respiration (*Rs*), followed by a change in CO_2 generation. The positive relationship between *Rs* and temperature confirms the previous proposition.

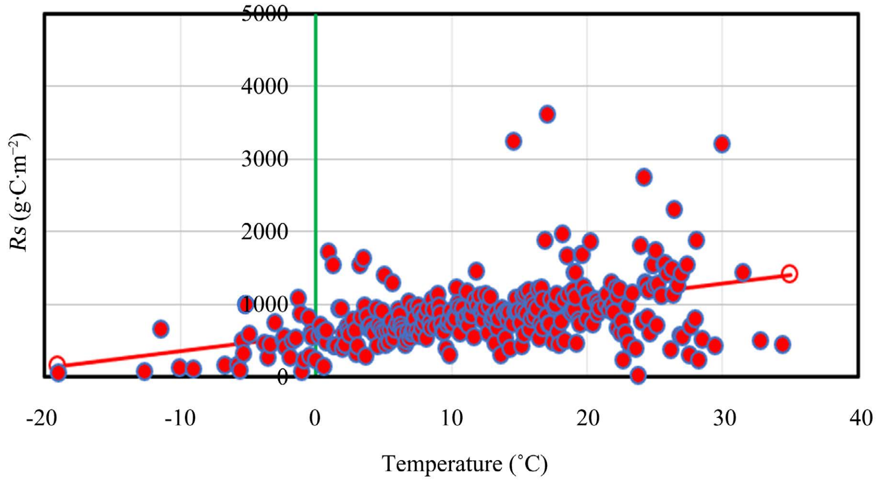

Figure 1. Change in annual *C* flux (g·C·m^{-2}) from soil respiration (*Rs*) versus mean annual temperature (˚C) between 1961 and 2017 (the coefficient of determination (r^2): 0.172). The regression red line is $y = 23.3x + 582.0$.

Since the average satellite-based global temperature measured by the UAH changes by 0.14˚C/decade [5], *Rs* is expected to increase annually. Figure 2 shows the temporal changes in the annual *C* flux (g·C·m^{-2}) from *Rs* between 1979 and 2018. The UAH satellite-based global temperatures are also shown in the figure. The temporal increase in *Rs* again confirms the previous proposition that ΔT affects plant decomposition and soil respiration (*Rs*), followed by a change in CO_2 generation.

The extent of the correlation between $\mathrm{d}rco_2/\mathrm{d}t$ and ΔT differs depending on the latitude and between the land and sea, as discussed in our previous paper [3]. Figure 3 shows the change in the annual *C* flux (g·C·m^{-2}) from *Rs* with latitude between 1961 and 2017. There was no correlation between *Rs* and latitude. As it was suggested that the constant γ in Equation (1) changes depending on the biome distribution on Earth [3], vegetation and other factors may change *Rs* in addition to being major factors influencing temperature with latitude.

Raich and Schlesinger [16] showed the correlation between mean rates of *Rs* and mean productivity rates in different vegetation biomes. Figure 4 shows the change in annual *C* flux (g·C·m^{-2}) from *Rs* with annual gross primary production at sites (g·C·m^{-2}) between 1961 and 2017. A positive relationship between *Rs* and plant productivity was observed.

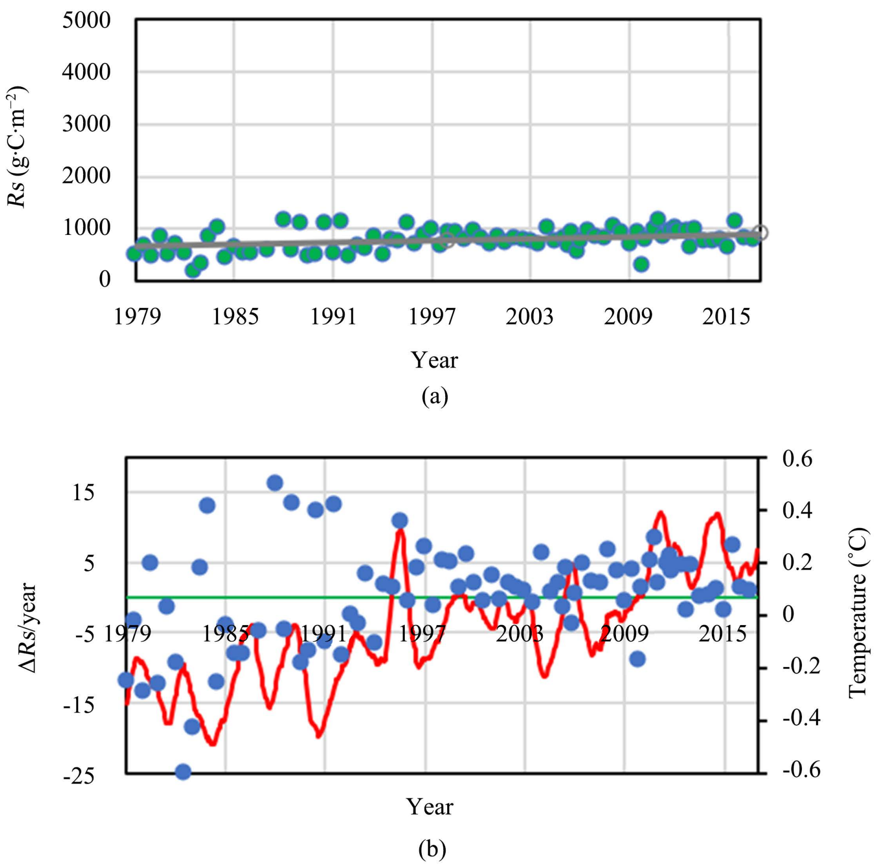

Figure 2. (a) Temporal change in annual *C* flux (green dots; scale: left axis; unit: g·C·m^{-2}) from soil respiration (*Rs*) between 1979 and 2017 (the coefficient of determination (r^2): 0.165). The regression gray line is $y = 6.5x - 12236.8$. (b) Temporal change in the growth rate of the ΔRs (the average value of each year minus the anomaly value) between 1979 and 2017. The red curve shows satellite-based temperatures (scale: right axis, unit: ˚C) during the same period: 13-month average lower troposphere anomaly values by the UAH.

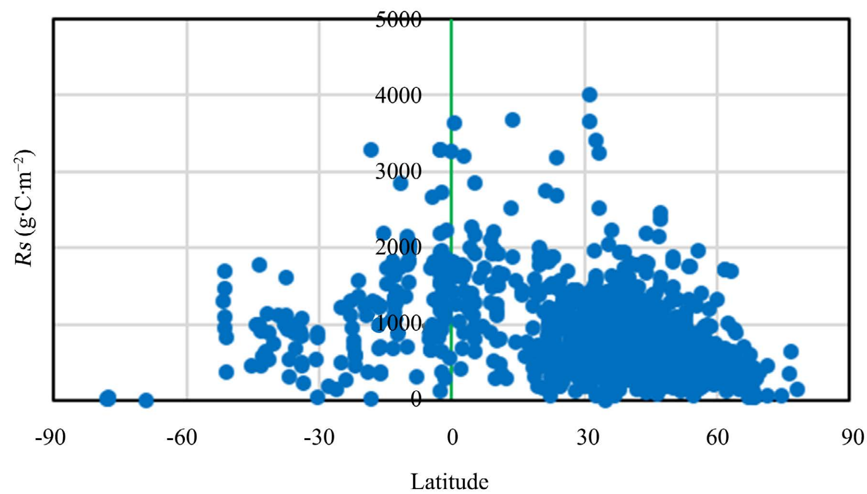

Figure 3. Change in annual *C* flux (g·C·m^{-2}) from soil respiration (*Rs*) versus latitude between 1961 and 2017.

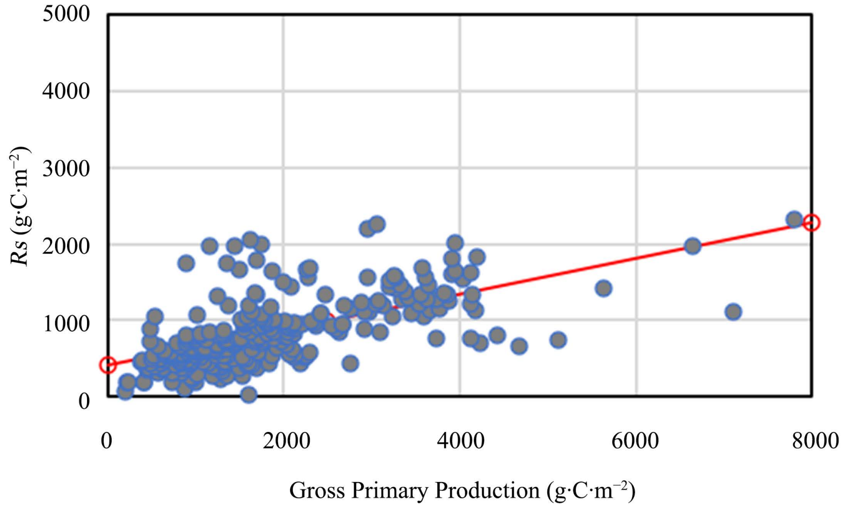

Figure 4. Change in annual *C* flux (g·C·m^{-2}) from soil respiration (*Rs*) versus annual gross primary production at the site (g·C·m^{-2}) between 1961 and 2017 (the coefficient of determination (r^2): 0.399). The regression red line is $y = 0.2x + 409.8$.

Temperature is the most important factor for determining the *Rs* rate, but precipitation or moisture may be the second most important factor affecting the *Rs* rate [10] [16]. **Figure 5** shows the change in annual *C* flux (g·C·m^{-2}) from *Rs* with mean annual precipitation (mm) between 1961 and 2017. There is a weak but positive relationship between the two variables. The results confirm that precipitation or moisture may be other factors that determine the *Rs* rate.

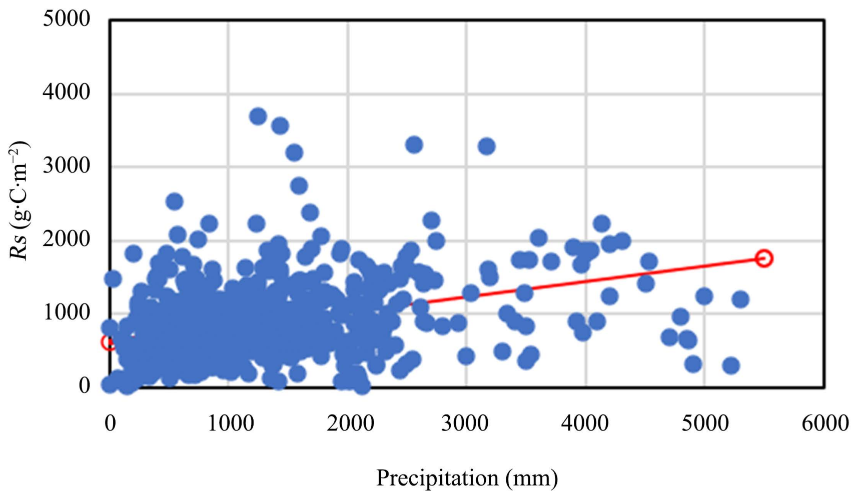

Figure 5. Change in annual C flux (g·C·m^{-2}) from soil respiration (*Rs*) versus mean annual precipitation (mm) between 1961 and 2017 (the coefficient of determination (r^2): 0.129). The regression red line is $y = 0.21x + 610.1$.

The concentrations of CO_2, CH_4, and N_2O gases increase annually, but seasonal changes have been observed in previous papers [4]. These concentrations decrease from spring to summer and increase from fall to winter. *Rs* is interpreted to activate in spring because of increasing temperatures and to generate

CO_2, CH_4, and N_2O in autumn due to biological processes after a time lag [4]. **Figure 6** shows the mean seasonal *Rs* flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) in spring, summer, autumn, or winter at the US sites listed in **Table 1**. The vertical (y-axis) values are the ΔRs (=*Rs* flux − average *Rs* flux) at each site. These results confirm the previous interpretation that *Rs* is activated in spring, maximizes in summer, and decreases in winter, but the concentrations of these gases in the "atmosphere" exhibit a time lag.

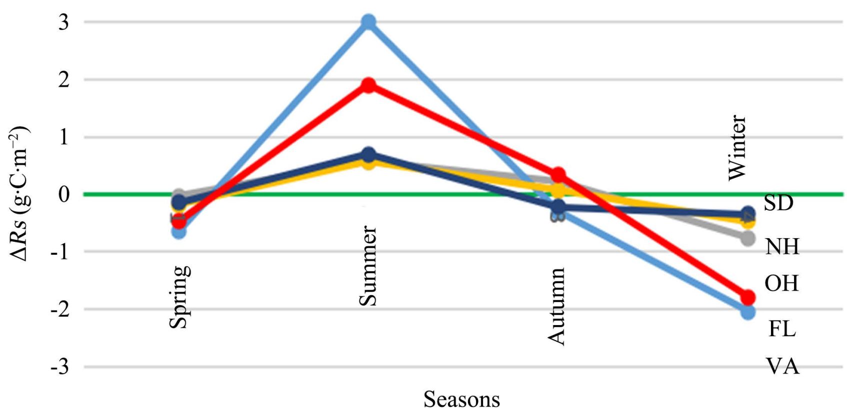

Figure 6. Mean seasonal *Rs* flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) in spring, summer, autumn, or winter in the U.S. **Table 1** shows the location and data used. The vertical values are the ΔRs (=*Rs* flux − averaged *Rs* flux) at each site.

Table 1. Mean seasonal *Rs* flux ($\mu mol \cdot m^{-2} \cdot s^{-1}$) in spring, summer, autumn, or winter at US sites. (ΔRs = *Rs* flux − averaged *Rs* flux).

State	Location	Year		Spring	Summer	Autumn	Winter
OH	Morgan County	2005	*Rs*	1.09	1.69	1.34	0.36
			ΔRs	−0.03	0.57	0.22	−0.76
VA	Blady Experimental Farm	2004	*Rs*	2.31	5.94	2.64	0.91
			ΔRs	−0.64	2.99	−0.31	−2.04
NH	White Mountain National Forest	1998	*Rs*	0.49	1.25	0.74	0.21
			ΔRs	−0.19	0.58	0.07	−0.46
SD	Northern Great Plains	2011	*Rs*	0.33	1.17	0.25	0.12
			ΔRs	−0.14	0.70	0.22	−0.34
FL	Tall Timbers Research Station	2010	*Rs*	2.56	4.93	3.36	1.24
			ΔRs	−0.46	1.91	0.34	−1.78

3.2. What Are the Necessary and Sufficient Conditions to Determine the Cause of Global Warming?

Equation (1) was originally proposed by Salby. Unfortunately, no scientific details were published when he was alive, but some of his achievements can be seen in the remaining videos [9] [10]. We found a good correlation between $drco_2/dt$

and ΔT, which is equivalent to his proposal [2]. This relationship can be readily observed during ENSO events because ΔT significantly deviates from the average value during these events. The process for El Niño events is summarized in Figure 7 [2]. Global temperatures increase followed by global CO_2 emissions after a 0.5 - 1-year time lag. These results lead to essential Equations (1) and (2) that contradict the necessary conditions for the anthropogenic CO_2 hypothesis for global warming.

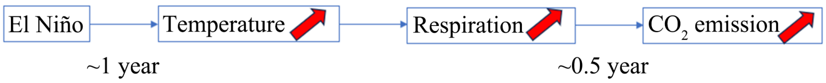

Figure 7. Proposed process for strong El Niño events: an increase in global temperature (ca. 0.5˚C), an increase in soil respiration (*Rs*), and subsequent global CO_2 emissions (ca. 4 Gt·C) [2].

Since this hypothesis contradicts Equations (1) and (2), global warming may be induced by causes other than anthropogenic CO_2. We further investigated necessary and sufficient conditions (or requirements) to support evidence of global warming induced by natural cycles [3] [4]. The following conditions were investigated: 1) no correlation between CO_2 exhausted from fossil fuel combustion and $\mathrm{d}rco_2/\mathrm{d}t$; 2) anti-correlation between $\Delta^{13}C$ and CO_2 considered together with the global carbon budget; 3) seasonal changes in CO_2, CH_4, and N_2O concentrations with a time lag; and 4) different $\mathrm{d}rco_2/\mathrm{d}t$ variations with latitude. These results were interpreted as changes in ΔT followed by changes in CO_2 via soil respiration (*Rs*), as illustrated in Figure 8. ΔT and ΔCO_2 are connected by two major processes in ecological systems, photosynthesis and *Rs*. Therefore, it is critical to investigate how *Rs* is affected by global conditions, and some of these results were investigated in this paper. These correlations may provide sufficient conditions to support evidence of global warming induced by natural cycles.

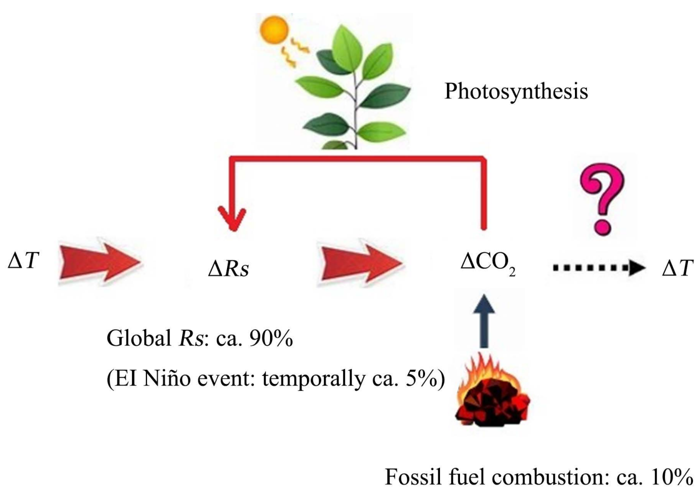

Figure 8. Changes in the carbon cycle (ΔCO_2) due to soil respiration (ΔRs) and global temperature (ΔT).

Since *Rs* is correlated with global warming via the CO_2 generated by *Rs*, Equation (1) can lead to Equation (3):

$$dRs/dt \doteqdot \gamma' \Delta T \tag{3}$$

(*Rs*: soil respiration, γ': constant, ΔT: temperature change).

Figure 2(b) shows the results of Equation (3), although global *Rs* estimates provide some errors, unlike global CO_2 measurements, because of the nature of *Rs* measurements.

3.3. Changes in the Carbon Cycle Balance Due to *Rs* and Other Inputs

The annual global CO_2 flux from soil respiration (*Rs*) is estimated to average 75 - 105 ($Pg \cdot C \cdot yr^{-1}$ or $Gt \cdot C \cdot yr^{-1}$) [14] [17] [18], while the annual global CO_2 flux from fossil fuel combustion is estimated to be approximately 8 ($Pg \cdot C \cdot yr^{-1}$) [18]. This means that fossil fuel combustion additionally inputs approximately 10% of the carbon cycles from the soil respiration system, and the effect of the global CO_2 flux from fossil fuel combustion is much smaller than that from *Rs*. Strong El Niño events, such as those in 1997-1999 and 2015-2016, further added approximately 5% to the carbon cycle, but the emitted CO_2 was absorbed in ecosystems when the temperature returned to the normal level [2]. The global temperature is increasing at a rate of 0.14˚C*/decade* based on satellite-based observations [5]. *Rs* also increases due to the increase in temperature, as shown in **Figure 1**. The rates of average increase in CO_2, including changes in *Rs*, are now 2 - 3 ($ppm \cdot yr^{-1}$), which is equivalent to 4 - 6 ($Pg \cdot C \cdot yr^{-1}$) [2]. Therefore, this increase in CO_2 annually contributes approximately 5% to the global carbon cycle. We currently have physical evidence that increases in temperature affect increases in CO_2, but do not yet have enough physical evidence that increases in anthropogenic CO_2 affect increases in temperature.

3.4. Concluding Remarks (See Figure 8)

Changes in temperature and CO_2 correlate well, but it is difficult to observe which is the cause and which is the effect. The release of CO_2 dissolved in the ocean into the atmosphere depends on the atmospheric temperature, but examining the relationship between changes in CO_2 caused by other phenomena and temperature is difficult. Studies of soil respiration (*Rs*) since the late 20th century have shown that CO_2 emissions from soil respiration (*Rs*) are overwhelmingly greater than CO_2 emissions from fossil fuel combustion, as shown by the IPCC carbon budget assessment [18].

Although CO_2 is an infrared active substance, the major contribution of CO_2 to global warming is hypothetical. Fifteen percent of the solar energy is reflected from the Earth's surface and absorbed by infrared active materials [3]. However, 96% of the infrared active substances in the atmosphere are H_2O. Additionally, compared to H_2O, CO_2 only absorbs in the narrow infrared region of 15 μm with low energy. We need solid evidence to confirm that CO_2 is making a significant contribution to global warming.

As shown in this paper, changes in temperature and *Rs* correlate well (**Figure 1** and **Figure 6**). There is also a good correlation between *Rs* and CO_2 generation (**Figure 4** and **Figure 7**). Therefore, an increase in temperature results in an increase in CO_2. There is no evidence other than model calculations that an increase in anthropogenic CO_2 is linked to a rise in temperature. The relationship between global warming and anthropogenic CO_2 should be reconsidered based on physical evidence.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Abbreviations

ENSO Index:	El Niño-Southern Oscillation Index
IPCC:	The Intergovernmental Panel on Climate Change (the United Nations body)
NASA:	The National Aeronautics and Space Administration
UAH:	The University of Alabama in Huntsville
$\mathrm{d}rco_2/\mathrm{d}t$:	The change rate of the CO_2 concentration or CO_2 growth rate
Rs:	Soil respiration
ΔT:	Temperature change
r^2:	Coefficient of determination