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# Time Lag in Changes in Global Temperature and $CO_2$ Concentration Following Changes in the Oceanic Niño Index

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## Abstract

Satellite measurements of global temperature began in 1979. According to the results of these measurements, the correlation between the global temperature and ocean temperature is very good, with a correlation coefficient of 0.99. The global temperature is controlled by the ocean temperature. The ocean temperature is not always constant but changes periodically, with high and low temperatures occurring repeatedly. This phenomenon is known as the El Niño or La Niña phenomenon. El Niño and La Niña phenomena are monitored by temperature changes in a specific area of the equator in the Pacific Ocean and are called the Oceanic Niño Index (ONI). When the ONI fluctuates significantly, El Niño and La Niña phenomena occur. A comparison of the ONI data from the National Oceanic and Atmospheric Administration (NOAA) and the global temperature data reveals that the temperature change throughout the entire Earth occurred approximately five months after the ONI change. At the western end of the Pacific Ocean, the direction of the warm current changes, and a warm current flows northward via the coast of the Japanese Islands. Even in such a unique location, the temperature change during the El Niño phenomenon changed five months later than did the change in the ONI value. Measurements of atmospheric $CO_2$ concentrations at the Mauna Loa Observatory in Hawaii began in 1958. We compared these $CO_2$ concentration changes with the above global temperature changes via NOAA data. As a result, we found that changes in global $CO_2$ concentrations appeared approximately four months after global temperature changes. The $CO_2$ concentration increases with increasing temperature. El Niño and La Niña phenomena are observed as small fluctuations in atmospheric $CO_2$ concentrations. This is mainly due to increased plant respiration and accelerated decomposition of organic matter in soils due to rising temperatures. $CO_2$ emissions from the ocean are also thought to have a significant impact, but quantitative investigations are a future task. On the other hand, compared with the global $CO_2$ balance, $CO_2$ emissions from anthropogenic activities are low. Our recent research results revealed that temperature and $CO_2$ changes are correlated, but $CO_2$ changes are the result of temperature changes, and we have not found that $CO_2$ changes cause temperature changes.

## Keywords

Global Warming, Anthropogenic $CO_2$, Thermally Induced $CO_2$, Soil Respiration, Cross-Correlation, Time Lag, El Niño, Oceanic Niño Index

## 1. Introduction

Analyses of Antarctic ice cores revealed that temperature changes preceded changes in $CO_2$ concentrations by hundreds to thousands of years in past glacial and interglacial cycles [1]. However, the Intergovernmental Panel on Climate Change (IPCC) states that modern warming differs from past natural climate changes in that it is the result of a rapid increase in atmospheric $CO_2$ concentrations caused by human activity, which has intensified the greenhouse effect and caused the Earth's temperature to rise [2]. This means that the increase in $CO_2$ may precede the increase in Earth's temperature, and the Earth's temperature may continue to rise.

Humlum *et al.* [3] examined the relationship between changes in $CO_2$ concentration and land-sea surface temperature over the period from January 1980 to December 2011 and reported that changes in $CO_2$ always lag changes in temperature by 10 - 12 months. Wang *et al.* [4] analyzed the relationships between the Mauna Loa atmospheric $CO_2$ growth rate and tropical land climatic elements. They reported that the Mauna Loa $CO_2$ growth rate lags precipitation by 4 months, leads temperature by 1 month, and correlates with soil moisture with a zero.

On the basis of our recent analysis [5], the temperature change and rate of $CO_2$ change are correlated with a temperature-leading time lag. The correlation was investigated by calculating a correlation coefficient $r$ of these changes for selected ENSO events in the study. Annual periodical increases and decreases in the $CO_2$ concentration were considered, with a regular pattern of minimum values in August and maximum values in May each year. An increased deviation in $CO_2$ and temperature was found in response to the occurrence of El Niño, but the increase in $CO_2$ lagged behind the change in temperature by 5 months. This pattern was not observed for La Niña events. An increase in global $CO_2$ emissions and a subsequent increase in global temperature proposed by the IPCC were not observed, but an increase in global temperature, an increase in soil respiration, and a subsequent increase in global $CO_2$ emissions were noticed. This natural process can be clearly detected during periods of increasing temperature, specifically during El Niño events. The results cast strong doubts that anthropogenic $CO_2$ is the cause of global warming.

When El Niño events occur, an increase in the global temperature is usually observed several months later [6] [7]. El Niño is a climate phenomenon characterized by the warming of sea surface temperatures in the central and eastern Pacific Oceans. While the exact causes of El Niño events are complex, several key factors that contribute to El Niño occurrence may be summarized as follows [8]-[10]. El Niño events are driven primarily by a weakening of Pacific trade winds, which disrupts normal ocean-atmosphere interactions. This weakening allows warmer water from the western Pacific to spread eastward, leading to positive sea surface temperature anomalies in the central and eastern equatorial Pacific. These warmer surface waters then deepen the thermocline, further reinforcing warming and atmospheric changes. While influenced by natural climate cycles, the critical factors are the initial weakening of trade winds, the subsequent ocean-atmosphere feedback, and the resulting changes in sea surface temperatures and thermocline depth.

The Oceanic Niño Index (ONI) is an index that reflects fluctuations in sea surface temperatures in the equatorial Pacific Ocean. The National Oceanic and Atmospheric Administration (NOAA) considers El Niño conditions to be present in the ocean when the ONI in that area, known as the Niño-3.4 region (see **Figure 1**) [11], is +0.5 or higher, meaning that surface waters in the east-central tropical Pacific are 0.5˚C warmer than average. Oceanic La Niña conditions exist when the ONI is −0.5 or lower, indicating that the region is 0.5˚C or greater, which is cooler than average. The Niño-3.4 region is the east-central equatorial Pacific between 5N-5S, 170W-120W, which is approximately $6.179 \times 10^6$ km$^2$ and 1.2% of the Earth's surface area, approximately $510.1 \times 10^6$ km$^2$.

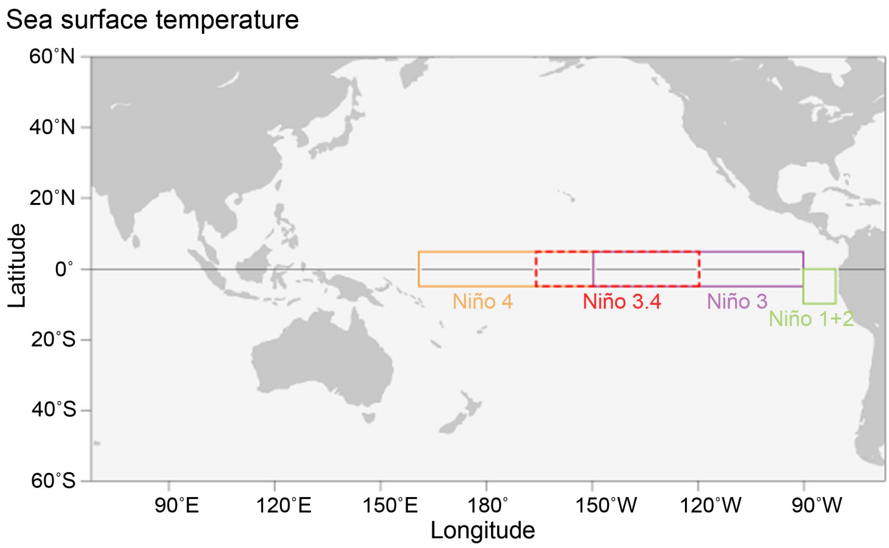


**Figure 1.** Locations of the parts (the Niño 3.4 region) of the tropical Pacific used for monitoring sea surface temperature to determine NOAA's official Oceanic Niño Index [11].

Our recent research [5] [12]-[16] has shown that global temperature changes precede changes in $CO_2$ concentrations by 5 months. Therefore, rising temperatures may induce increased $CO_2$ emissions. This phenomenon is due mainly to the promotion of soil respiration. Large amounts of "thermally induced $CO_2$" are emitted, especially from midlatitude forests. "Thermally induced $CO_2$" is more temperature dependent than the amount emitted from tropical rainforests. Moreover, its amount significantly exceeds anthropogenic emissions. This process can be organized as shown in **Figure 2** [16]. This differs from the view of the IPCC.

The IPCC proposed that anthropogenic $CO_2$ is causing global warming through the greenhouse effect. The observed temperature-leading process suggests a natural phenomenon via soil respiration, casting doubt on the theory that anthropogenic $CO_2$ is the only cause. Considering the important role of temperature-dependent soil respiration, it is necessary to consider whether the current efforts to reduce anthropogenic $CO_2$ emissions are effective in lowering global $CO_2$ concentrations [16]. The purpose of this paper is to further clarify and confirm the process summarized in **Figure 2**. To do so, we focus on the ONI, which is an index of the ENSO process. We then consider the time-dependent changes in the ONI, global temperature, and $CO_2$ concentration and the processes by which they change.

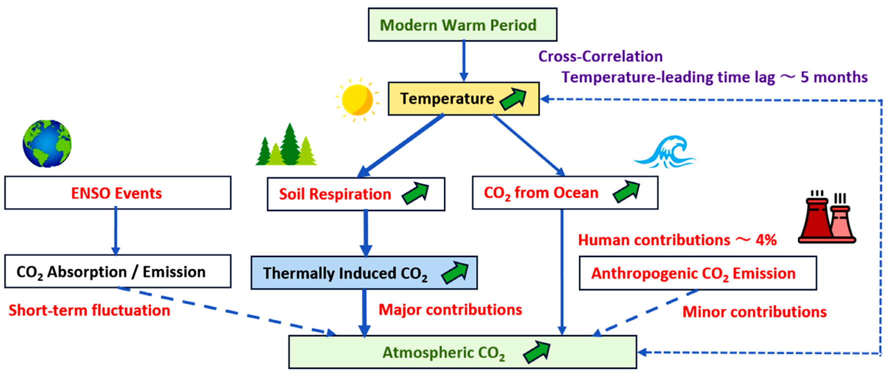


**Figure 2.** Processes of increases in atmospheric $CO_2$ during the modern warm period [16].

## 2. Global Data

The ONI data are reported by the National Oceanic and Atmospheric Administration (NOAA), and all the original data were downloaded [11]. The three-month average ONI values were used.

Since 1979, the University of Alabama in Huntsville (UAH) has updated global temperature datasets that represent the piecing together of temperature data from a total of fifteen instruments flying on different satellites. Further details are available [17]. Temperatures here were obtained from the datasets, and the 13-month average of lower troposphere anomaly values was used, where the temperatures were averaged over the 6 months before and after each specific month.

In general, the correlation coefficient $r$ between variables $x$ and $y$ can be defined as follows:

$$r = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

For convenience, *r* can be easily calculated via built-in functions in Microsoft Excel®. This calculated *r* is used to show correlations between two variables throughout this paper.

The annual mean growth rate of $CO_2$ in a given year is the difference in concentration between the end of December and the start of January of that year reported by NOAA. Further details are available on their website [18]. Because of the seasonal changes in $CO_2$ concentrations, the annual means and the monthly data are compared.

Monthly average temperature data in Japan were obtained from 15 locations selected from meteorological observation stations that have been conducting observations since 1898 by the Japan Meteorological Agency, with little impact from urbanization and without bias toward specific regions. For each location, the deviation of the monthly average temperature (observed monthly average temperature minus the 30-year average from 1991to 2020) is calculated [19].

## 3. Results and Discussion

The 13-month average global and ocean temperatures based on satellite observations are available from the UAH database [17]. **Figure 3** compares these results between 1979 and 2023. Both results are well correlated, with a correlation coefficient of 0.993. This means that the global temperature is almost completely controlled by the ocean temperature.

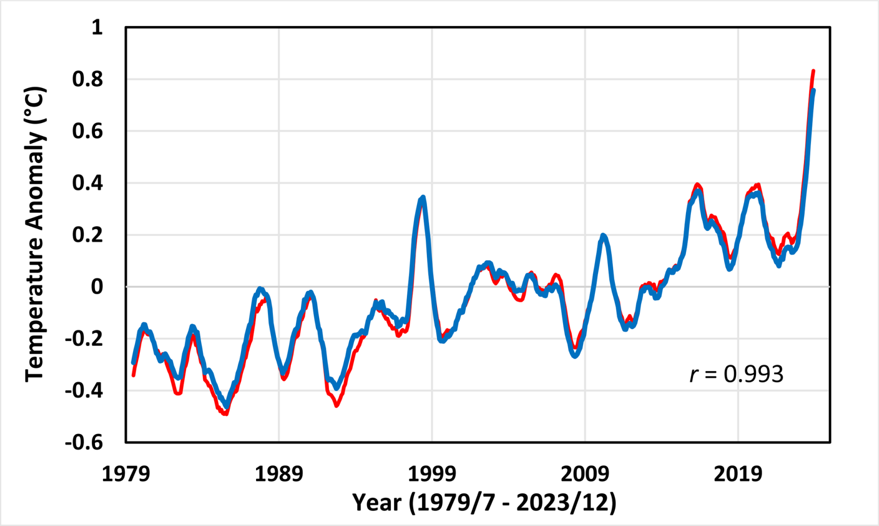


**Figure 3.** Correlation between the global temperature anomaly (red line, ˚C) and ocean temperature (blue line, ˚C) between 1979 and 2023.

**Figure 4(a)** compares the changes in the ONI values obtained from NOAA and satellite-based global temperatures between 1979 and 2023. The correlation coefficient between the two is 0.143. The global temperatures lag behind the ONI. Therefore, the correlation coefficient between the ONI and global temperature was investigated by changing the lag time (in months). Figure 4(b) shows the result. The value at which the correlation coefficient is maximized indicates that the global temperature changes with a lag of approximately five months compared with the ONI value.

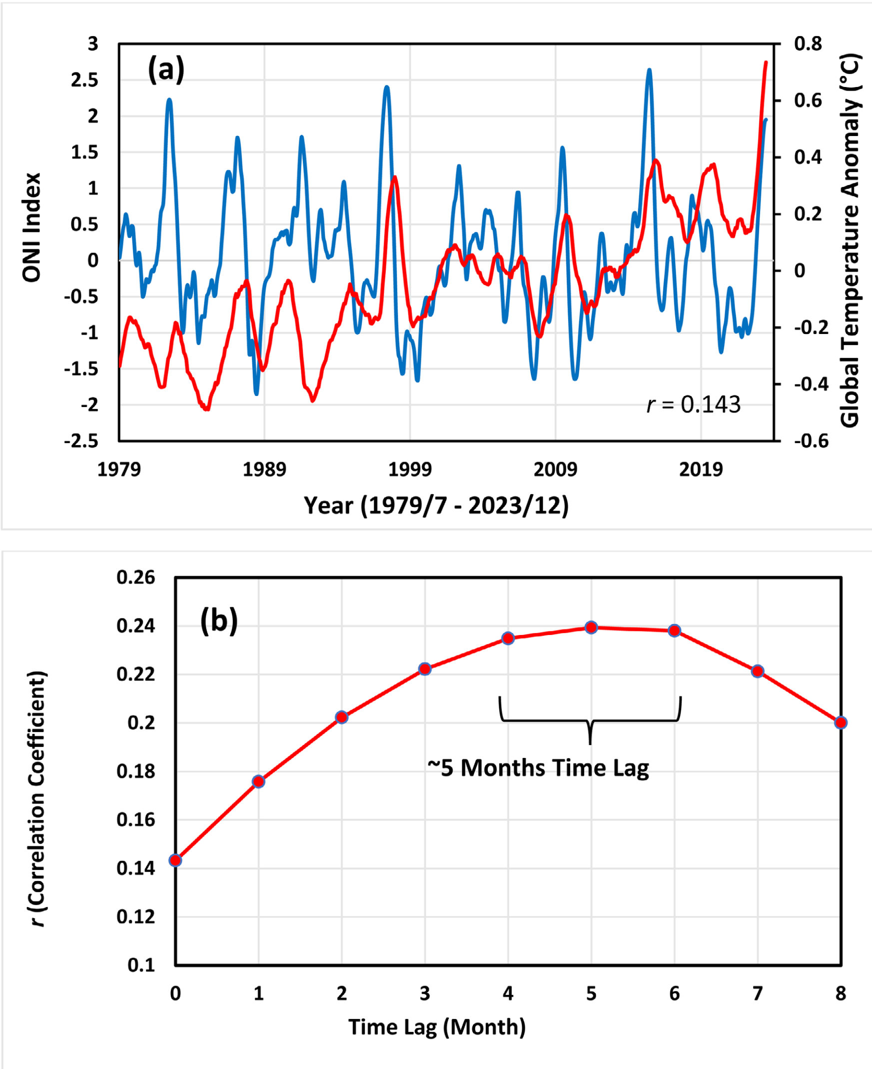


Figure 4. (a) Correlations between global temperature anomalies (red line, scale: right axis, ˚C) and the ONI (blue line, scale: left axis) and (b) Changes in correlation coefficients with time lag (in months).

Oceanic gyres are large systems of circular ocean currents [20] driven primarily by global wind patterns and the Coriolis effect, which deflect moving water. Oceanic gyres are broadly shown in Figure 5 [21]. While gyres are generally stable, their formation and characteristics can be significantly influenced by phenomena such as the El Niño-Southern Oscillation (ENSO).

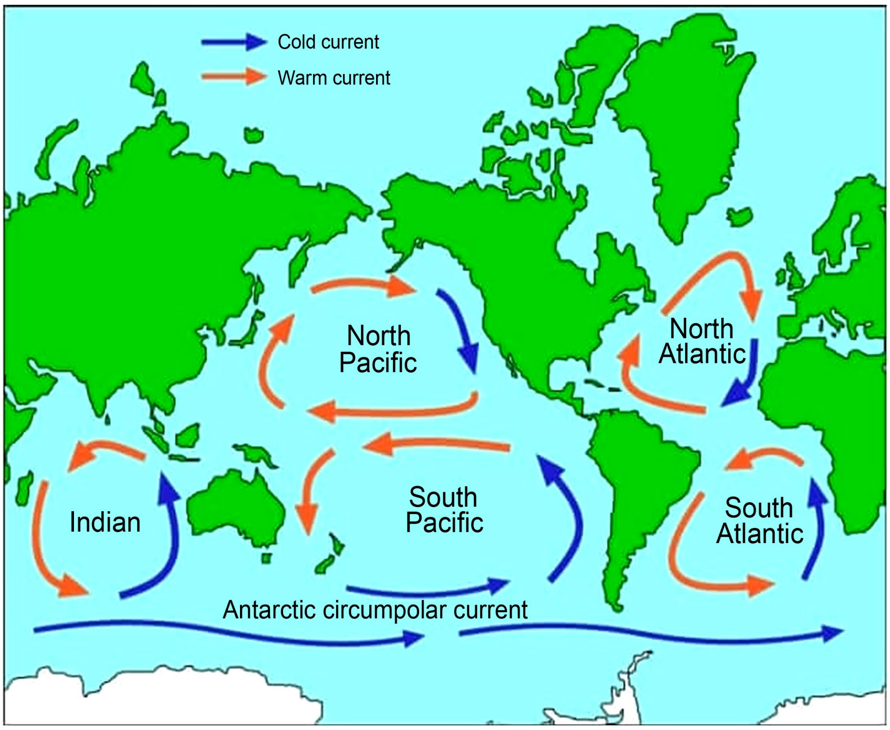


**Figure 5.** This map broadly shows the formation of different gyres in the ocean [21].

The Niño 3.4 region shown in **Figure 1**, which is used to monitor the ONI, is located near the equator, and the ocean currents flowing through this region head westward. Then, at the western end of the Pacific Ocean, they turn northward in the Northern Hemisphere, whereas in the Southern Hemisphere, they turn southward. The warm current flowing east of the Japanese Islands is called the Kuroshio Current. During El Niño events, the Kuroshio Current may cause an increase in temperature near the Japanese Islands. Therefore, the relationship between the ONI and temperature changes in Japan was investigated during two El Niño events. **Figure 6(a)** compares the changes in the ONI values obtained from NOAA and the temperature anomalies in Japan from the Japan Meteorological Agency between Jan. 2015 and Dec. 2016. The correlation coefficient between the two is 0.0194. The global temperatures lag behind the ONI, and the correlation coefficient between the two is 0.855 after moving temperatures by 5 months ahead. Similarly, **Figure 6(b)** compares the changes in the ONI and temperature anomalies in Japan between September 2022 and August 2024. The correlation coefficient between the two is 0.809 and 0.843 after moving temperatures by 5 months ahead. The local temperature changes with a lag of five months compared with the ONI value during these El Niño events.

We found here that temperature changes can be observed at a global scale and in selected places where warm currents flow. They are particularly noticeable when El Niño events occur. We next investigate ONI fluctuations, subsequent fluctuations in global temperature, and how $CO_2$ changes due to fluctuations in global temperature.

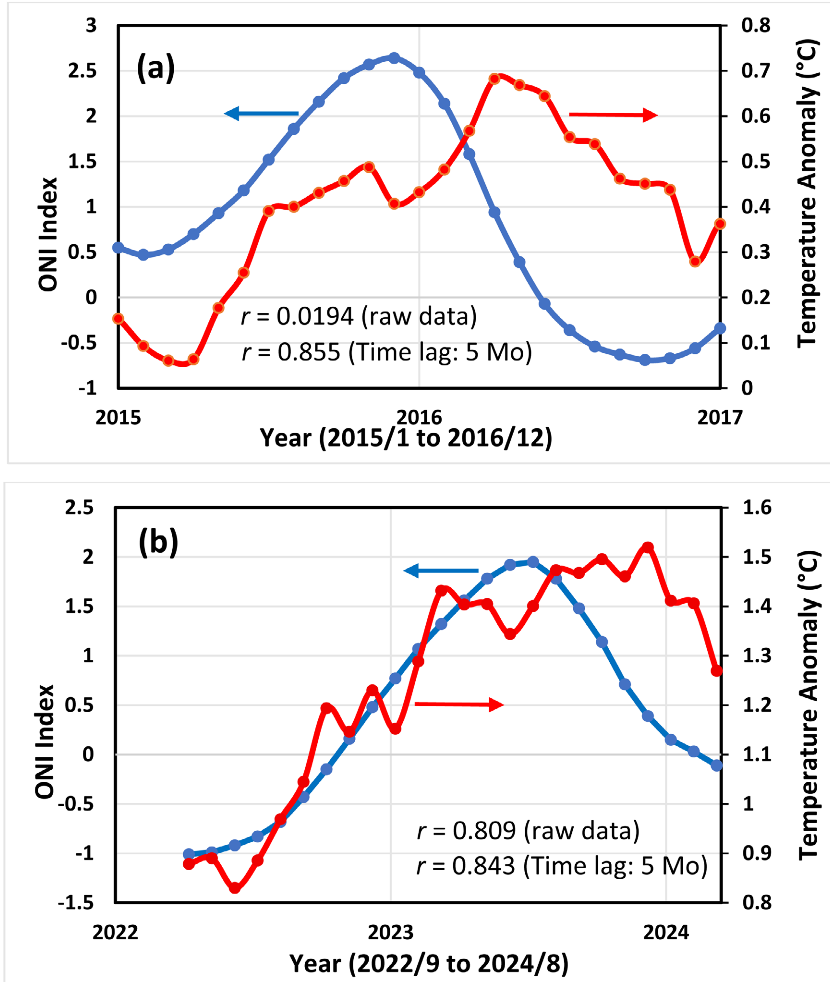


**Figure 6.** Correlation between temperature anomalies in Japan (by the Japan Meteorological Agency) (red line, scale: right axis, ˚C) and the ONI (blue line, scale: left axis): (a) Durations of Jan. 2015 and Dec. 2016 and (b) Durations of Sept. 2022 and Aug. 2024.

Global temperature anomalies and $CO_2$ annual growth rates are correlated over 40 years, as reported in our recent paper [5]. The 12-month average $CO_2$ annual growth rates are reported by NOAA [18]. The latest correlation between July 1979 and December 2023 is shown in **Figure 7**. Its correlation coefficient $r$ is 0.744, and the correlation is relatively good.

Since the 13-month average of temperature change and the annual average of the rate of $CO_2$ increase are used in **Figure 7**, a time lag within 12 months between two variables cannot be effectively analyzed. **Figure 8(a)** compares global temperature anomalies and $CO_2$ monthly growth rates instead of $CO_2$ annual growth rates between 1980 and 2023. The correlation coefficient between the two is 0.664. The $CO_2$ growth rates lag behind the global temperatures. Therefore, the correlation coefficient between the $CO_2$ growth rates and global temperatures was investigated by changing the lag time (in months). **Figure 8(b)** shows the result. The value at which the correlation coefficient is maximized indicates that the $CO_2$ growth rate changes with a lag of approximately four months compared with the global temperature.

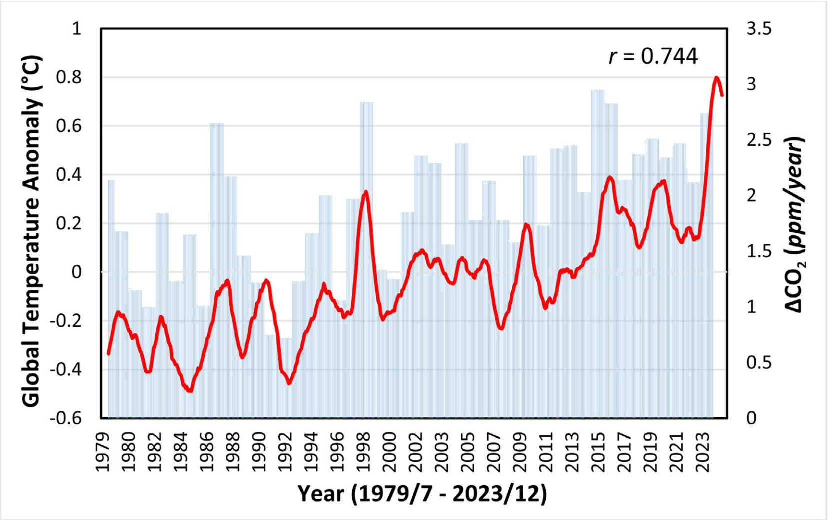


**Figure 7.** Correlation between the global temperature anomaly (red line, scale: left axis, ˚C) and 12-month average annual $CO_2$ growth rates (blue bar, scale: right axis, ppm/year).

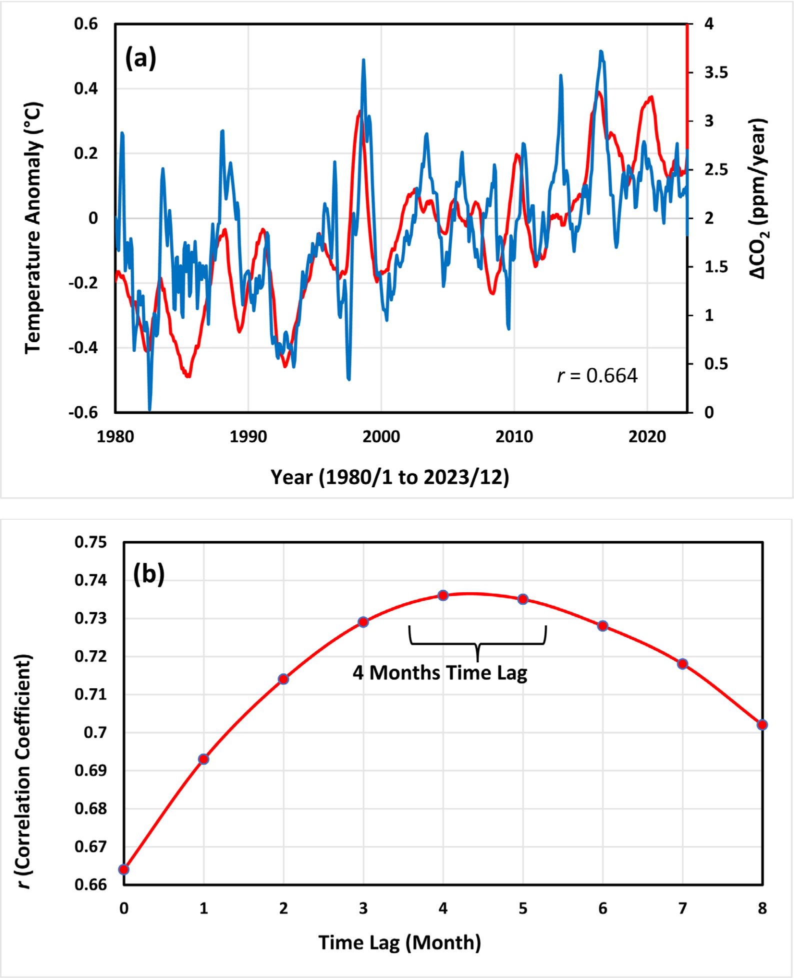


**Figure 8.** (a) Correlations between global temperature anomalies (red line, scale: left axis, ˚C) and monthly $CO_2$ annual growth rates ($\Delta CO_2$, blue line, scale: right axis, ppm/year) and (b) changes in correlation coefficients with time lag (in months).

Figure 9 shows the correlation between global temperature anomalies and monthly $CO_2$ growth rates during two El Niño events between (a) Jan. 2015 and Dec. 2016 and (b) Sep. 2022 and Aug. 2024. The correlation coefficients between the two variables increased (a) 0.901 from 0.705 and (b) 0.973 from 0.822 when time lags of (a) five months and (b) four months were considered. The temperature change and rate of $CO_2$ change are correlated with a time lag, as reported in a previous paper [5]. The time lag of $CO_2$ behind the change in temperature was five months. The time lags of four and five months in Figure 9 are coincident with the results in the previous paper [5].

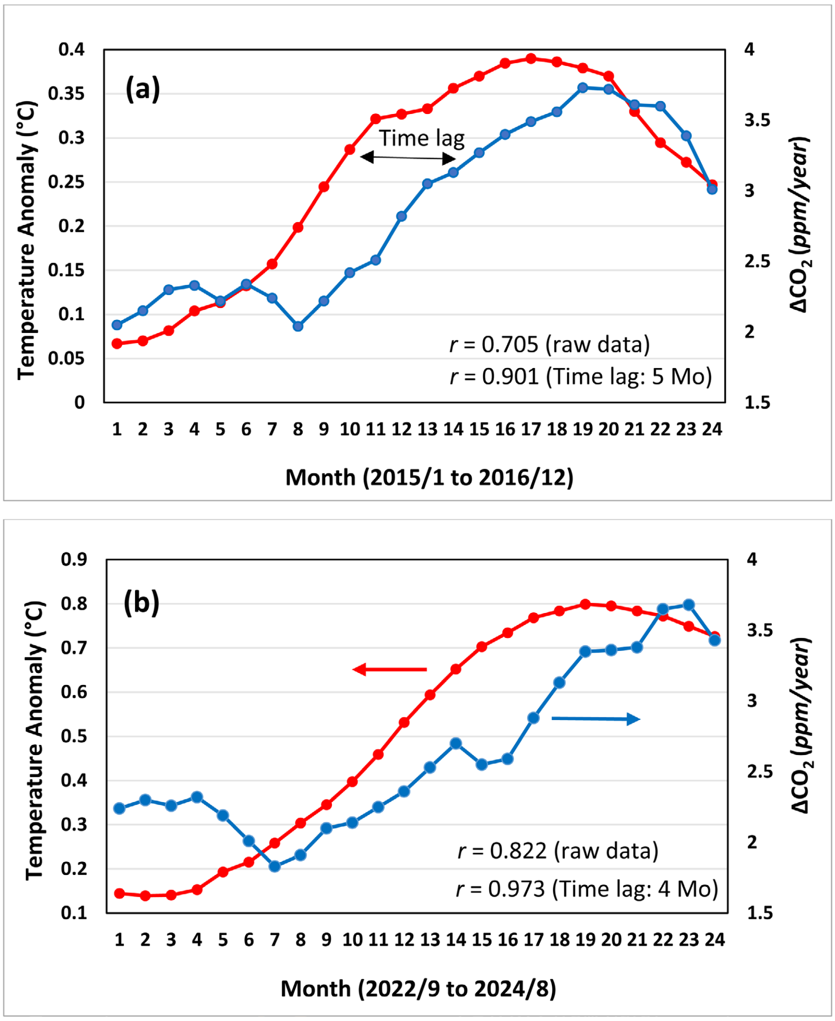


Figure 9. Correlation between the global temperature anomaly and monthly $CO_2$ growth rates during El Niño between (a) Jan. 2015 and Dec. 2016 and between (b) Sep. 2022 and Aug. 2024.

The results summarized here show that there is a correlation between ONI (or ENSO) variations, changes in global temperature, and changes in $CO_2$ concentration. There is a time lag between these correlations. The overall results are consistent with the results reported in previous papers and can be summarized, as shown in

Figure 10, from the results in Figure 4(a) and Figure 8(a). The results show that changes in $CO_2$ concentration do not cause changes in global temperature but rather that changes in global temperature cause changes in $CO_2$ concentration.

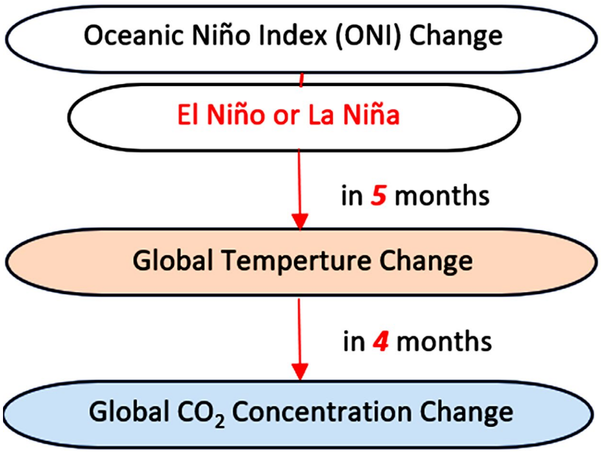


Figure 10. Time lag in changes in global temperature and global $CO_2$ concentration following changes in the Oceanic Niño Index (ONI).

Our recent research has shown that soil respiration and ocean $CO_2$ emissions significantly contribute to atmospheric $CO_2$ concentration changes as global temperatures rise, which is based on the global $CO_2$ balance [13] [14] [16]. The general process changes are shown in Figure 2. The quantitative investigation of ocean emissions is a future challenge. When ONI changes are large, ENSO appears. This event is characterized by small fluctuations in the atmospheric $CO_2$ concentration [16]. Compared with these $CO_2$ balance amounts, the amount of $CO_2$ emissions due to anthropogenic activities is small [16].

## 4. Conclusions

The ONI is an index that indicates the variation in sea surface temperature in the equatorial Pacific Ocean. When the ONI varies greatly, El Niño or La Niña phenomena occur. Changes in global temperature appear approximately 5 months after ONI variations (Figure 4). El Niño events cause the temperature to rise, whereas La Niña events cause the temperature to decrease. There are peculiar places where the direction of the warm current has changed, such as the western end of the Pacific Ocean, such as the Japanese Islands. In these peculiar places, during El Niño events, the temperature changes 5 months later than the ONI value changes (Figure 6).

Additionally, changes in the global $CO_2$ concentration appeared approximately 4 months after the global temperature change (Figure 8). The $CO_2$ concentration tends to increase with increasing temperature. El Niño or La Niña phenomena are small perturbations in the atmospheric $CO_2$ concentration. This is mainly due to increased plant respiration and accelerated decomposition of organic matter in soil due to rising temperatures and is thought to be largely due to $CO_2$ emissions from the ocean. A quantitative investigation of emissions from the ocean is a future task. Compared with these $CO_2$ budgets, $CO_2$ emissions from anthropogenic activities are small.

Our recent results, including those of this work, reveal that temperature and $CO_2$ changes are correlated, but $CO_2$ changes are the result of temperature changes, and we have not found that $CO_2$ changes cause temperature changes (**Figure 2**).

## Conflicts of Interest

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

## References

[1] Climate Data Information. http://www.climatedata.info/proxies/ice-cores/

[2] IPCC Sixth Assessment Report. https://www.ipcc.ch/assessment-report/ar6/

[3] Humlum, O., Stordahl, K. and Solheim, J. (2013) The Phase Relation between Atmospheric Carbon Dioxide and Global Temperature. *Global and Planetary Change*, **100**, 51-69. https://doi.org/10.1016/j.gloplacha.2012.08.008

[4] Wang, J., Zeng, N. and Wang, M. (2016) Interannual Variability of the Atmospheric $CO_2$ Growth Rate: Roles of Precipitation and Temperature. *Biogeosciences*, **13**, 2339-2352. https://doi.org/10.5194/bg-13-2339-2016

[5] Nishioka, M. (2024) Cross-Correlation between Global Temperature and Atmospheric $CO_2$ with a Temperature-Leading Time Lag. *Atmospheric and Climate Sciences*, **14**, 484-494. https://doi.org/10.4236/acs.2024.144029

[6] NOAA Climate Prediction Center. Cold & Warm Episodes by Season. https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

[7] NOAA El Niño Index Dashboard. https://psl.noaa.gov/enso/dashboard.html

[8] Earth Eclipse. What Is El Niño and What Are Causes and Effects of El Niño. https://eartheclipse.com/environment/climate-change/causes-and-effects-of-el-nino.html

[9] NOAA. What is El Niño? https://www.noaa.gov/understanding-el-nino

[10] NOAA. El Niño and La Niña. https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-and-la-ni%C3%B1a-frequently-asked-questions

[11] NOAA. Climate Variability: Oceanic Niño Index. https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-nino-index

[12] Nishioka, M. (2024) Changes in Temperature and $CO_2$ in the Atmosphere at Various Latitudes. *Current Research in Environmental Science and Ecology Letters*, **1**, 1-9. https://dx.doi.org/10.33140/CRESEL.01.01.02

[13] Nishioka, M. (2024) Effects of Plant Decomposition and Soil Respiration on $CO_2$ in the Atmosphere via Global Temperature Changes. *Current Research in Environmental Science and Ecology Letters*, **1**, 1-12. https://dx.doi.org/10.33140/CRESEL.01.01.03

[14] Nishioka, M. (2024) Effects of Anthropogenic $CO_2$ and Thermally-Induced $CO_2$ on Global Warming. *Atmospheric and Climate Sciences*, **14**, 317-327. https://doi.org/10.4236/acs.2024.143020

[15] Nishioka, M. (2025) Relationship between the Standardized Precipitation Index and

Global Temperature on the North American Continent. *Atmospheric and Climate Sciences*, **15**, 321-329. https://doi.org/10.4236/acs.2025.152016

[16] Nishioka, M. (2025) Difficulties in Reducing Atmospheric $CO_2$ Concentrations during the Modern Warm Period. *Atmospheric and Climate Sciences*, **15**, 451-461. https://doi.org/10.4236/acs.2025.152023

[17] Latest Global Temps. https://www.drroyspencer.com/latest-global-temperatures/

[18] Lan, X., *et al*. (2023) Trends in Globally Averaged $CO_2$ Determined from NOAA Global Monitoring Laboratory Measurements. https://doi.org/10.15138/9N0H-ZH07

[19] Japan Meteorological Agency. The Deviation of the Monthly Average Temperature. https://www.data.jma.go.jp/cpdinfo/temp/list/mon_jpn.html

[20] NOAA. Ocean Currents. https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-currents

[21] UPSC (2020) Ocean Currents: Types of Ocean Currents. https://lotusarise.com/ocean-currents-upsc/

## Abbreviations

| | |
|---|---|
| ONI | Oceanic Niño Index |
| ENSO | El Niño-Southern Oscillation |
| IPCC | Intergovernmental Panel on Climate Change (the United Nations body) |
| NOAA | National Oceanic and Atmospheric Administration |
| UAH | University of Alabama in Huntsville |
| r | Correlation Coefficient |