The Impact of CO_2 Emission on Climate Change: Evidence from Sea Level

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Abstract. Against the backdrop of global warming has become the main climate issue at present. Not only climate change itself, but some phenomena which occur together with it also has the worth of studying in order to deal with the current global warming problem that human beings are facing. To be specific, the Sea Level Rise caused by carbon dioxide emission. This paper will discuss the evidence from sea level which can prove how serious the impact of CO_2 emission on climate change. According to the analysis, CO_2 emission can enhance the tendency of the Sea Level Rise (SLR) and this trend will not stop at present even if the whole world stops to emit greenhouse gases including carbon dioxide, but will continue to affect people's daily life in a long period of time. With this in mind, the public should be more alert for the reducing of emission of greenhouse gases and the adaption of Sea Level Rise.

1 Introduction

Upon these years, climate change has already been a common topic in the meteorological field. Unlike some researchers' claims, climate change does affect people's daily life and its influence should not be neglected. According to IPCC AR6, greenhouse gas emissions, which is the main form of human activity. In the second decade of the 21st century, the temperature has increased for 1.1 degree Celsius, which is far more than the former several centuries. That result proves that the increase of temperature cannot attribute to the end of Quaternary glaciation, because the tendency of the temperature increase and sea level rise is intensifying as the human society are creating more emission of greenhouse gases. It is believed that human activity has caused about 1.07°C global warming from 1850–1900 to 2010–2019.

Since the human society had larger demand of consuming fossil fuels, the traditional balance of greenhouse gases, which increases in a much smaller slope, had been broken [1]. If the tendency of emission does not change now, it can be more serious. For example, children born in 2020 will experience 2.5-degree Celsius higher temperature when they are in their 70s if the future emission is very high (seen from Fig. 1) [2].

However, the public lack intuitional impression of the increasing of the amount of carbon dioxide in the atmosphere. After all, the change of the carbon dioxide content in the atmosphere is not visible to the naked eyes. In that case, measure sea level may be one of the best ways for the public to understand this process. In addition, people may endure 1- or 2-degree Celsius temperature increase, but flooded offshore surface may cause a large problem for daily production work, and that is why how emission of carbon dioxide affect the sea level becomes a quite serious and worth studying question.

This study aims to show the principle of the greenhouse effect, which is mainly caused by CO_2, several examples of the sea level rise will also be involved to explain how carbon dioxide emission affect people's life in the way of sea level rise and what kind of measures can be taken to deal with this situation.

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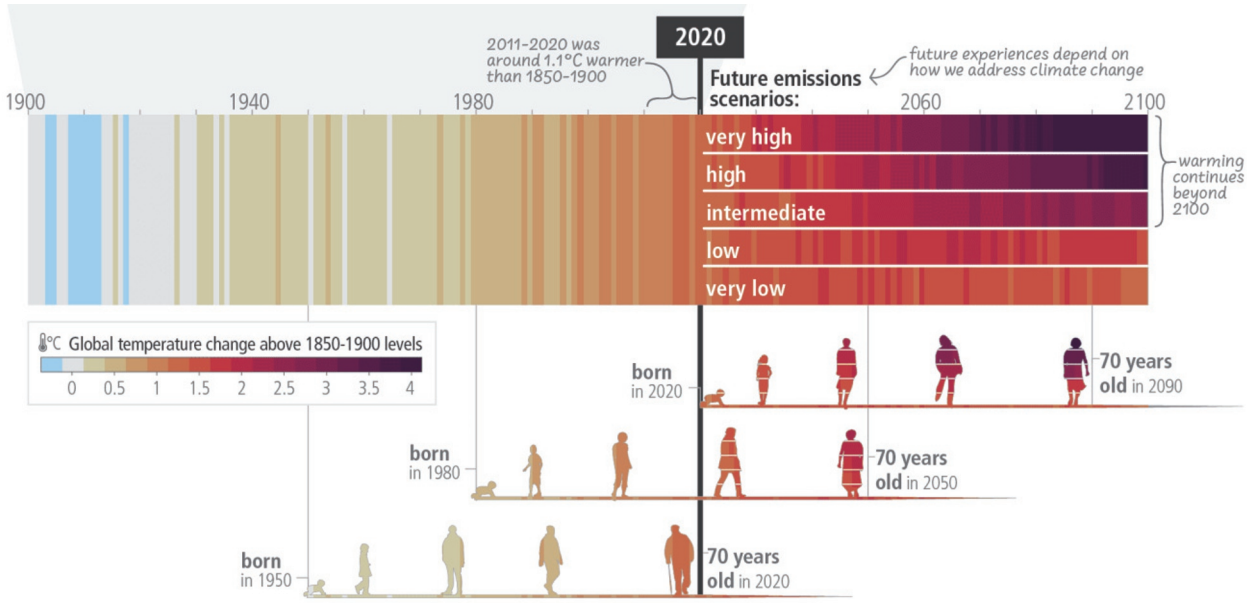

Fig. 1. The difference of the temperature from people born to the year when they are 70 years old. (https://www.ipcc.ch/report/ar6/syr/figures/summary-for-policymakers/figure-spm-1)

2 Basic descriptions

Several simple models are described in order to demonstrate the impacts of CO_2 on climate change. For example, the atmosphere can be easily considered as a single layer. The radiation from the sun that is absorbed by the surface equals to the difference of the longwave radiations, that is:

$$\frac{1}{4}(1-\alpha_p)S_0 = (1-\varepsilon)S_\uparrow + A_\uparrow = S_\uparrow - A_\downarrow \quad (1)$$

Here, α_p represents the planetary albedo, which is usually about 0.3; S_0 represents the solar constant; ε is the absorptivity. The meanings of the other terms can be seen in the Fig. 2.

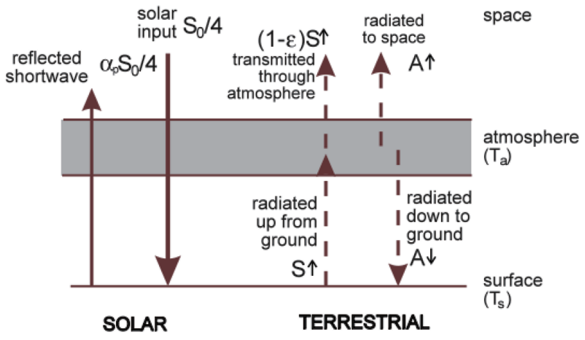

Fig. 2. A single layer model of the atmosphere [3].

In Eq. (1), it can be concluded that the main values that can affect the surface and atmosphere temperature are planetary albedo and absorptivity, and greenhouse gases play a significant role in the absorption process. Carbon dioxide and other kinds of greenhouse gases can absorb more longwave radiation like some infrared radiation reflected from the ground surface, preventing the radiation from diffusing into outer space. When the atmosphere gets heated, it will absorb more water vapor, which can also absorb long wave radiation. It will finally lead to higher temperature of the atmosphere and form positive feedback [4]. This situation is well known as the greenhouse effect.

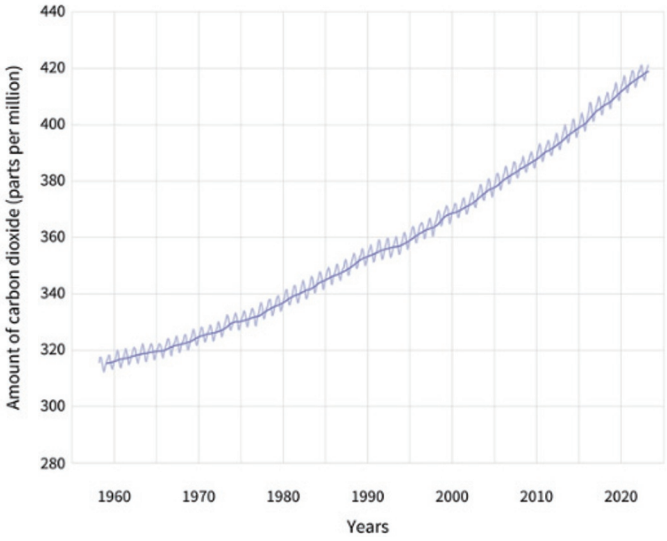

Fig. 3. The atmospheric carbon dioxide since 1958. (https://www.climate.gov/maps-data)

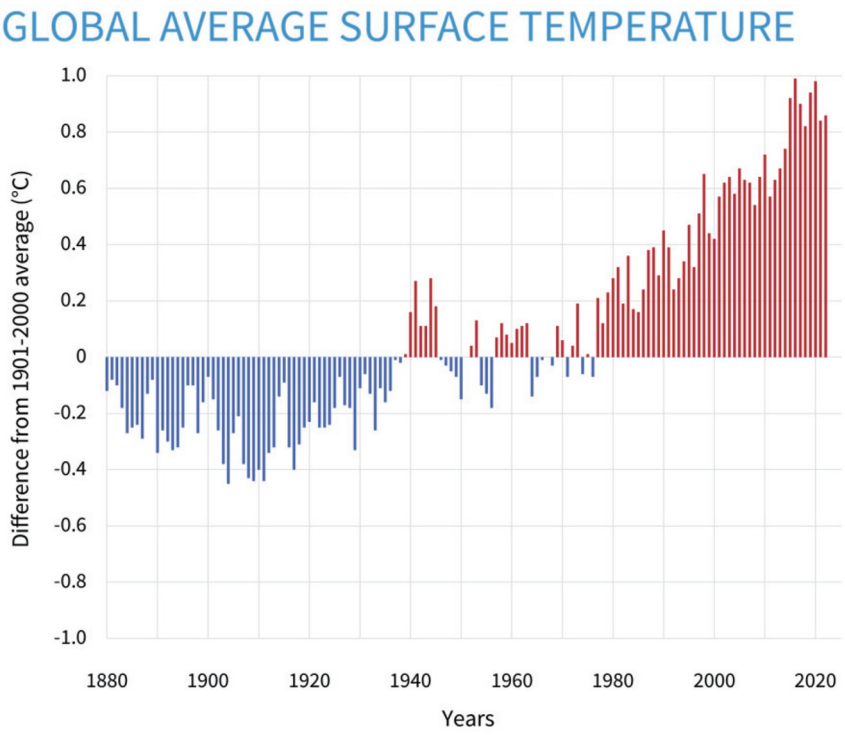

Fig. 4. Yearly global temperatures from 1880-2022 compared to the twentieth-century average. (https://www.climate.gov/maps-data)

Fig. 3 shows the change of the amount of the carbon dioxide from 1958 to 2021, which increase from 315.70ppm to 421.00ppm. In 63 years, the amount of carbon dioxide increases about 33%, which is about 0.53% per year in average [5]. As for the surface temperature, it tends to increase. The Fig. 3 and Fig. 4 show that the carbon dioxide content in the atmosphere and the global surface temperature do increase in the past hundreds of years. This situation should not be neglected. However, this data alone cannot prove the relationship between the temperature increasing and the emission of carbon dioxide. More data is necessary to show the relationship. The former researches show the fact that at same altitude, the larger the carbon dioxide content is, the higher the temperature of the surface and troposphere is. However, when it comes to the stratosphere, the situation changes. As carbon dioxide content increases, temperature of stratosphere decreases. This fact proves that more carbon dioxide in troposphere will cause more heat absorption [6].

3 Case Background

Until 1960s, researchers were able to find the evidence that the carbon dioxide was building up in the atmosphere. In these years, the increasing of the amount of carbon dioxide in the atmosphere reach 2ppmv. It is very large comparing to 1.3ppmv, the average level from 1958 to 2000 [7], which means the emission of CO_2 is still increasing though the problem has been well known to the public since the millennium. However, there is also many researchers who claimed that the global warming is not as serious as the public thought. This situation may due to the hiatus period. Hiatus period theory suggested that the global warming had stopped since 1990s according to the observation. However, it has been proved to be wrong these years, because opponents of this theory prove that the occurrence of hiatus should partly attribute to the cooling of tropical Pacific, and anthropogenic greenhouse forcing is considered to be responsible for climate change [8]. In 2016, global sea level was 3.2 inches (82 mm) above the 1993 average, i.e., the highest annual average in the satellite record (1993-present) [7].

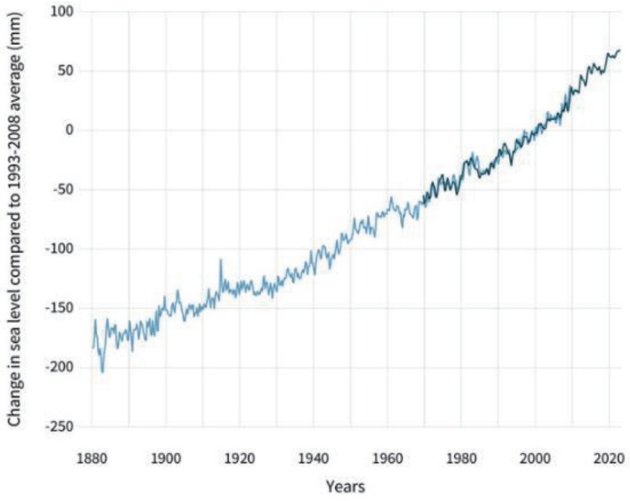

Fig. 5. Seasonal sea level compared to the 1993-2008 average, based on a combination of tide gauges (light blue) and satellite data (darker blue). In 2020, global mean sea level hit a new record high: 91.3 mm (3.6 inches) above 1993 levels (https://www.climate.gov/maps-data) [4].

Fig. 5 shows the change in sea level compared to 1993-2008 average(mm). It is easy to spot that the sea level is continuously increasing since 1880, and has already increased for about 21–24 centimetres [9], and the

increasing rate is obviously larger nowadays. By the figure, the average sea level increase less than 50mm from 1880 to 1900, while from 2000 to 2020, the difference is more than 50mm. In one word, the sea level keeps ascending and does not show any sign of stop. Other data also support the result. The rising speed of SLR in 20th century was 1.7 ± 0.3 mm/year in average [10], while the speed nowadays should be 3.2 ± 0.4 mm/year according to the Commonwealth Scientific and Industrial Research Organisation (CSIRO) [11], nearly twice of the speed in 20th century. Although the Sea Level Rise (SLR) is not very obvious according to the data, its effect will be devastating when the rise is large enough.

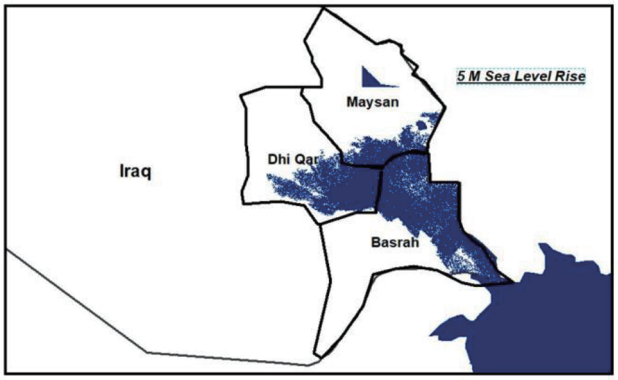

Fig. 6. the map of Maysan, Dhi Qar and Basrah city, Iraq, when 5m SLR. (https://www.scirp.org/journal/paperinformation.aspx?paperid=105898)

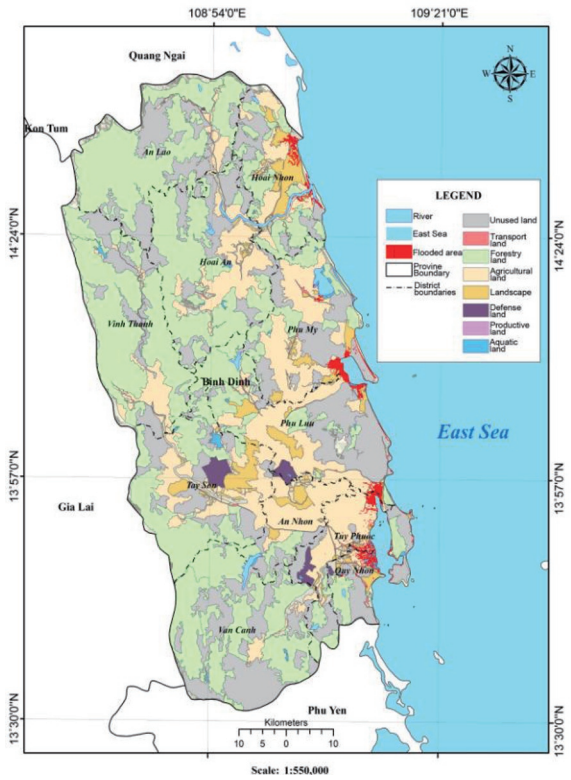

Fig. 7. the area flooded when 50cm SLR (red region). (https://www.scirp.org/journal/paperinformation.aspx?paperid=93366)

According to the Fig. 6, when the sea level increase only for 5 meters, nearly half of the Basrah city will be under the sea level [12]. If 5m increasing is too far away, 50cm Sea Level Rise can happen much sooner. In Binh Dinh Province, Vietnam, the whole area of Tuy Phuoc district, Hoai Nhon district, Quy Nhon City and Phu My district flooded after the SLR increase 50cm will be about 5804.408ha [13], or 58.04 square kilometres, which is about 0.8% of the area of Binh Dinh Province. Considering the rising speed now, which is about 3.2mm every year [8], the prediction in Fig. 7 may come true in about 156.25 years.

4 Analysis

Based on the relationship between carbon dioxide and climate change, how does the climate change work on Sea Level Rise is necessary in order to prove the causality. It is convinced that there are mainly two reasons of Sea Level Rise. First, the higher temperature caused by greenhouse gases can lead to the expansion of sea water. Second, the increasing temperature can accelerate the melting velocity of mountain glaciers and ice caps, and ice sheet in polar region, which will create more liquid water flowing into the sea.

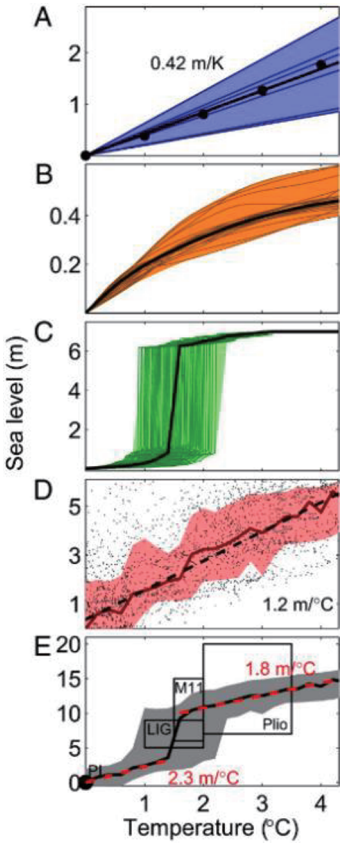

Fig. 8. The different reasons that cause sea level rise (A) ocean warming, (B) mountain glaciers and ice caps, and (C) the Greenland and (D) the Antarctic Ice Sheets. (E) The corresponding total sea-level commitment. (https://www.pnas.org/doi/10.1073/pnas.1219414110)

Fig. 8 shows the main reasons that cause SLR. The first reason, ocean warming(A), are considered as the

second largest type of Sea Level Rise, which is believed to be about 0.42m/K. Ice melting, which is the largest type of Sea Level Rise, can be divided as ice sheet and mountain ice. The ice sheets (C and D) affect the sea level in the same way: the melting of sea ice. The main ice sheets including Greenland(C), Antarctica(D) and others, and the Antarctica ice sheet has the largest contribution among them. While The mountain glaciers(B) have less contribution compared with the other two, and its sensitivity will reduce when the warming increases, which is 0.21m/K at preindustrial temperature levels and 0.4m/K at 4℃ warming [14]. Except that 1.2m/K contribution, if the whole Antarctica ice sheets are melted, it can produce 55m to 60m Sea Level Rise.

Numerically, according to the former research, the ratio of Sea Level Rise can be considered as a function of temperature:

$$\frac{dS}{dt} = \frac{S_{eq}(T(t),\alpha) - S(t)}{\tau} \quad (2)$$

In this function, S(t) is the sea level contribution dependent of time, τ is the response scale, $S_{eq}(T(t),\alpha)$ is the long-term sensitivity for the sea level component as the function of mean temperature T and the commitment factor α [14].

5 Suggestions & implications

It is proved that Sea Level Rise is a very slow process. Even if the whole world stop emitting carbon dioxide and other kinds of greenhouse gases since today, Sea Level Rise will not stop soon. It is believed that the effort of reducing the emission of carbon dioxide can only affect the world in the future, exactly after about 2050 years [16]. There is no way to stop Sea Level Rise at present. In conclusion, the only way for humans to deal with Sea Level Rise now is to adapt it.

The first method is to construct seawalls. To prevent tide, many countries have already had rich experience of building a seawall. This strategy has lower technical requirements. However, continuous maintenance and supervision will be necessary for the seawalls, which means it can lead to much economic costs and labour costs.

The second method is to transfer coastal industries and residents inland. The advantage of this method is that it can be much faster than the velocity of Sea Level Rise, as the Sea Level Rise can take a year to increase about 3.2mm [11]. On the other hand, retreating to the inland without taking other measures means accepting the eternal loss of the coastal aera. Besides, for the cities of large population, it is much harder to arrange the coastal population.

The third method is to improve the coastal environment. Instead of building a manmade seawall, some countries tried to replace it with a natural “seawall”. Plants like red mangroves can not only absorb carbon dioxide, but also can prevent the tides, just like a seawall. But this method is not as perfect as it sounds like. For example, planting red mangroves in nutrient enrichment and saline conditions can be a great challenge, which means Sea Level Rise itself can cause the loss of red mangroves [17]. There are still some technical difficulties to overcome for this method.

Fortunately, the three methods can compensate for each other's shortcomings. For instance, constructing sea walls can start at present, when the mature technology of planting red mangroves in saline condition is developed, natural “sea wall” can be another option. Industry transfer can be alternative option if the situation has not improved after the former two methods are taken. Nevertheless, no matter what kind of strategy is going to be taken, continuous emission of greenhouse gases is unacceptable. It has to be reduced otherwise all the efforts are in vain. Compared with the different kinds of ways to adapt the Sea Level Rise, there is only one final solution of this question.

6 Conclusion

Sea Level Rise is evidence of global warming, which is the direct consequence of climate change. The continuous increase of sea level is the best proof that can support the view that climate change has never stopped. However, this paper only shows the causality of emission of carbon dioxide and Sea Level Rise. There are also more kinds of greenhouse gases that can cause climate change, carbon dioxide is only one of them. For quantitative analysis of how much temperature increase is caused by greenhouse effect, future researches based on all kinds of main greenhouse gases (e.g., calculating the total consumption of fossil fuels) is necessary. Compared with the further research, this study aims to find the evidence of climate change from researches on Sea Level Rise and lead to more attention on climate change problem by showing how climate change can affect peoples’ daily life in the way of Sea Level Rise.

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