

The Effects of Soil Moisture on Carbon Dioxide Emission in Tibetan Plateau

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Abstract. With the development of society, an increasing amount of greenhouse gases is discharged into the atmosphere. Carbon dioxide concentration is more than 50% higher than pre-industrial levels. Previous studies have shown that the lower the soil moisture, the more sensitive the lime's dark breathing is to changes in CO₂ concentration. There are also experiments on a plant. However, most of these studies have focused on the observation of sample plants and have not rigorously sought correlation. Using data from AIRS and GLDAS VIC satellites, this paper analyses the trend of data over the Tibetan Plateau from 2003 to 2010 in summer. A linear regression equation was used to analyze the correlation between soil moisture and carbon dioxide production. The experiment shows that there is a negative correlation between soil moisture and carbon dioxide concentration.

Keywords: greenhouse gases, Carbon dioxide, Tibetan Plateau, linear regression equation

1. Introduction

Since the first industrial revolution, atmospheric concentrations of greenhouse gases have increased. Glaciers have melted. Sea levels have risen and extreme weather has been frequent throughout the world. In 2022, summer temperatures in southern China reached an all-time high. Researchers have predicted not only extreme heat in summer but also extreme cold in winter. The fourth report of the Intergovernmental Panel on Climate Change (IPCC) assesses that there is a 90% chance that human activity will lead to an increase in greenhouse gases, the fifth report reports that human activity has a 95% chance of causing an increase in the average global surface temperature, and the sixth report in 2021 states that human activity undoubtedly contributes to global warming [1].

Terrestrial ecosystems transport nutrients to organisms through soil solutions in the medium of soil and atmosphere. Soil moisture is closely related to plant photosynthesis, which produces the largest greenhouse gas, carbon dioxide. The greenhouse effect of carbon dioxide is caused by the fact that visible light emitted by the sun is reflected from the earth in infrared radiation. These infrared radiations are absorbed and maintained by the atmosphere and become a source of heat for the greenhouse effect. Although carbon dioxide molecule accounts for much less in the atmosphere than nitrogen and oxygen molecule, it has a strong ability to absorb infrared radiation [2]. So, in recent years, it has become a research hotspot to find out exactly where the carbon dioxide with excessive concentration comes from. However, most of the research focuses on the relationship between human activities and carbon dioxide emissions, but there are few studies on the effect of soil moisture on carbon dioxide emissions. For example, under different soil moisture conditions, when CO₂ concentration is not saturated, the response of photosynthetic rate of lime to CO₂ concentration is linear. The lower the soil moisture, the more sensitive the lime's dark breathing is to changes in CO₂ concentration [3], but this is only for the sample experiments.

The purpose of this paper is to take the data of AIRS and GLDAS VIC satellites as the experimental basis. From the macro perspective, construct the correlation model between data. This paper attempts to reveal whether there is an inevitable relationship between soil moisture and the molar mass fraction of tropospheric carbon dioxide.

2. Methods

2.1. Monitoring data

AIRS has a spatial resolution of $2^\circ \times 2.5^\circ$ and a temporal resolution of one month. It observes the molar mass fraction of tropospheric carbon dioxide. The GLDAS VIC has a spatial resolution of $1^\circ \times 1^\circ$ and a temporal resolution of one month. It observes the humidity of 30cm below the land. Take the data from 2003 to 2010 in June, July and August.

2.2. Calculation method

The experiment selected the Tibetan Plateau, calculated the average value of the data of carbon dioxide and 30 cm humidity below the land from 2003 to June, July and August 2010, fitted the change trend, and drew a straight line. Use the above data to plot. Draw a linear regression equation straight line of one variable with time as x and mole fraction of carbon dioxide in free troposphere count as y using formula (1). Draw a linear regression equation straight line of one variable with time as x and SoilMoi0 30cm inst in free troposphere count as y using formula (1). Draw a linear regression equation straight line of one variable with mole fraction of carbon dioxide in free troposphere count as x and SoilMoi0 30cm inst as y using formula (1). The slope b in formula (1) is derived from formula (2). The intercept a in formula (1) is derived from formula (3). Formula (4) is used to calculate the coefficient R^2 to determine the degree of fit.

$$\hat{y} = bx + a \quad (1)$$

$$b = \frac{n \sum_{i=1}^n x_i y_i - (\sum_{i=1}^n x_i)(\sum_{i=1}^n y_i)}{n \sum_{i=1}^n x_i^2 - (\sum_{i=1}^n x_i)^2} \quad (2)$$

$$a = \bar{y} - b\bar{x} \quad (3)$$

$$R^2 = \frac{\sum(\hat{y} - \bar{y})^2}{\sum(y - \bar{y})^2} \quad (4)$$

3. Results and discussion

3.1. Overview of observation sites

The climate types of the Tibetan Plateau are plateau mountain climate and subtropical monsoon climate. It has various geomorphic types, mainly including mountain canyons and wide valley lake basins. Its overall terrain is high in the northwest and low in the southeast, with an average elevation of more than 4000 m.

The first research object is the humidity 30cm below the surface of the Tibetan Plateau. Take the data of GLDAS VIC satellite from 2003 to the summer of 2010 (June, July and August). The average soil moisture of the Tibetan Plateau in summer is calculated. The second object is the molar mass fraction of carbon dioxide in the troposphere over the Tibetan Plateau. Acquire AIRS satellite data at the same time and place. The average value of CO_2 molar mass fraction in the troposphere over the Tibetan Plateau is calculated. Use Excel to draw a line chart to reflect the change trend. It can be seen from the figure that the molar mass fraction of carbon dioxide in the troposphere of the Tibetan Plateau has been increasing over the past eight years, and the fluctuation of soil moisture has decreased. Summer is the season of vigorous plant respiration. Soil moisture affects plant photosynthesis. Water is the raw material for photosynthesis and light reaction. Plant water shortage will reduce the production of photo reactive ATP and reductive coenzyme II. Influence the reduction of C3 in dark reaction. The rate of photosynthesis slows down, resulting in a slower absorption of carbon dioxide. Plant water shortage will also affect the stomatal conductance of leaves. When plants are in a state of water shortage, the stomatal conductance of leaves will decrease. Directly lead to the decrease of carbon dioxide absorption rate and the decrease of intercellular carbon dioxide concentration. This leads to a decrease in the fixation rate of carbon dioxide in the dark reaction, thus

affecting the intensity of photosynthesis. It will also reduce the absorption rate of carbon dioxide [4]. However, the increase of the molar mass fraction of carbon dioxide in the troposphere is also affected by human activities. Global grassland degradation has different manifestations in different regions. In the headwaters of the rivers and rivers in the Tibetan Plateau, it takes the form of "black soil beach" and "black soil slope" [5]. The response of plants and vegetation to climate and other environmental factors is comprehensive. Overgrazing deteriorates the site conditions of alpine grassland, leading to grassland degradation and severely reducing the regeneration capacity of meadow vegetation and soil degradation. Long term grazing greatly reduces the biomass of meadow vegetation [6]. The ecosystem of the Tibetan Plateau is relatively low in energy flow, material circulation and information transmission and self-renewal. Against the background of increasing global carbon dioxide concentration, the Tibetan Plateau can't be carbon neutral through vegetation. Under the comprehensive influence, the fluctuation of soil moisture from 2003 to 2010 is one of the reasons for the observed increase of carbon dioxide concentration.

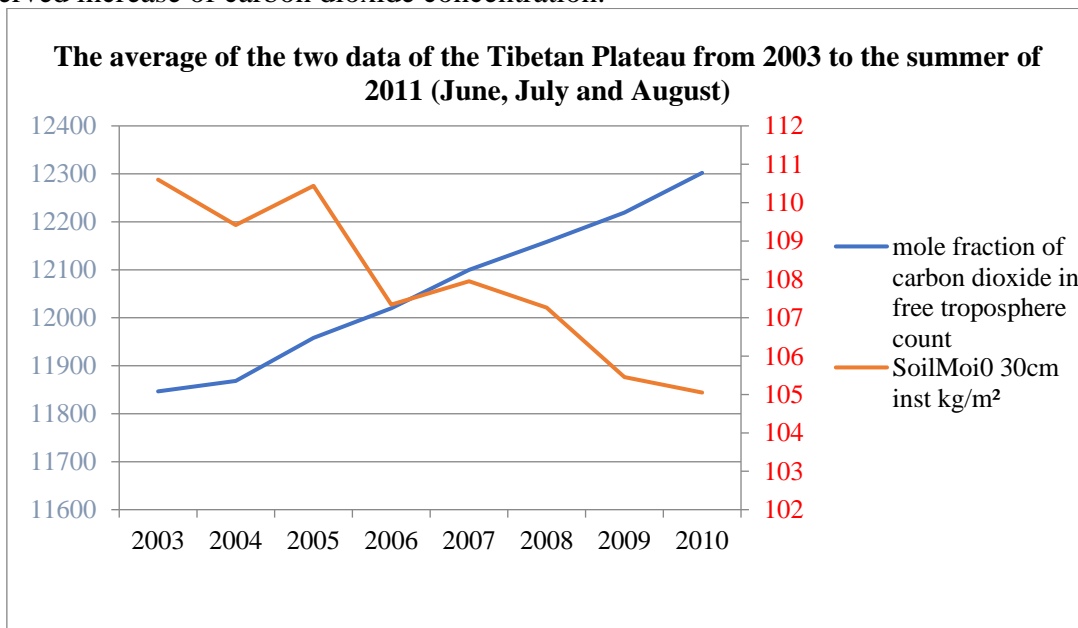


Figure 1. Tendency

3.2. Specific data of soil moisture and carbon dioxide molar mass fraction on the Tibetan Plateau on July 1, 2010

Select the highest point of carbon dioxide molar mass fraction and the lowest point of soil moisture 30 cm below the surface for mapping. Verify whether there is an obvious negative correlation between the two, as shown in the trend chart. Matlab is used to rasterize the data of two satellites. Use ArcMap to realize vector map of Tibetan Plateau to cut raster data. Finally, adjust the color and display the legend to get the following effect.

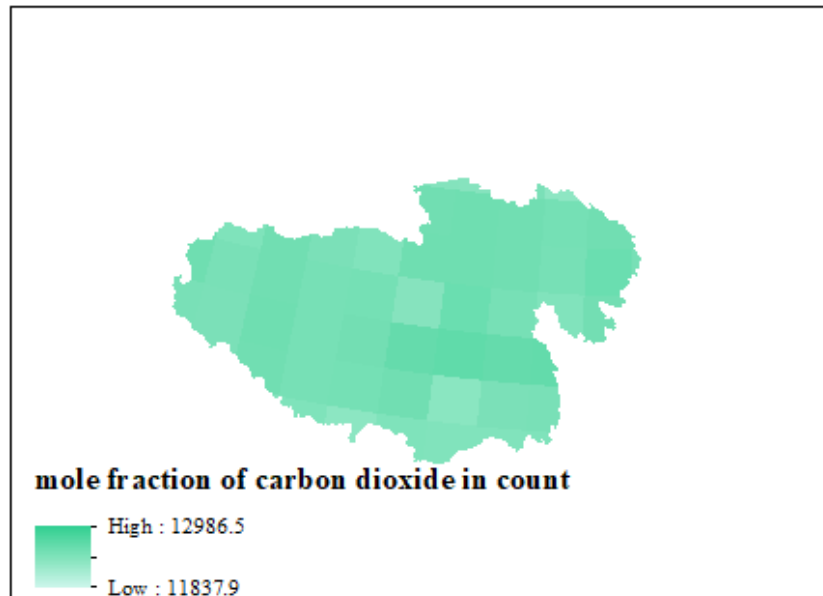


Figure 2. Carbon Dioxide's Raster graphic

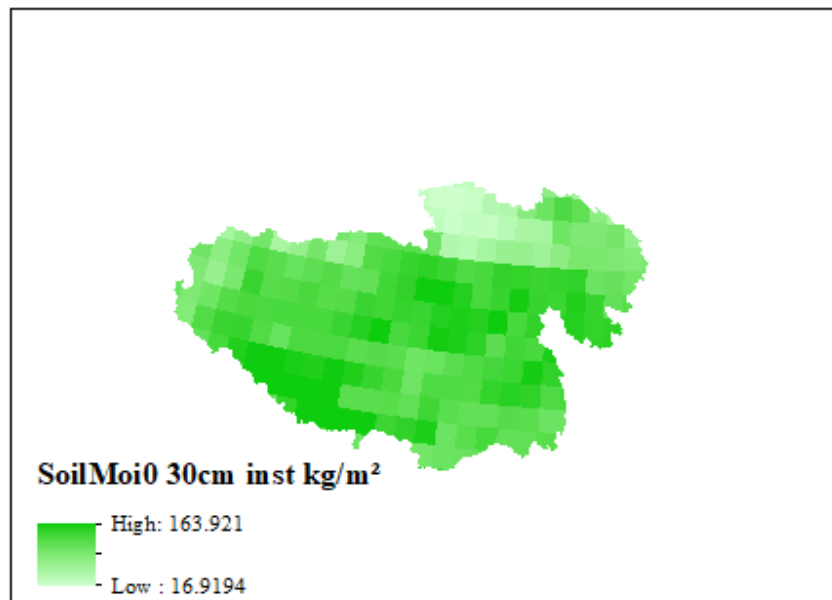


Figure 3. Soil Moisture's Raster graphic

From the image, the darker the color is, the greater the value is. The places with large molar mass fraction of carbon dioxide correspond to the places with low humidity 30 cm below the land on that day. Almost every region is negatively correlated. Some grids cannot show negative correlation because the resolution of AIRS does not match that of GLDAS VIC. More detailed information cannot be reflected through existing data. CO₂ data is tropospheric. The mobility of carbon dioxide in the troposphere is too strong, and the molar mass fraction changes all the time but uncertainty of carbon dioxide molar mass fraction monitored by satellite [7]. The experiment can only rely on site monitoring to get more specific and accurate data and results.

3.3. Correlation between carbon dioxide emissions and soil moisture

Draw the image of linear regression equation of one variable to judge the correlation of two groups of data. According to the change trend of the data, the change trend can be fitted with a linear regression equation. Calculate the correlation between the molar mass fraction of tropospheric carbon dioxide and the time.

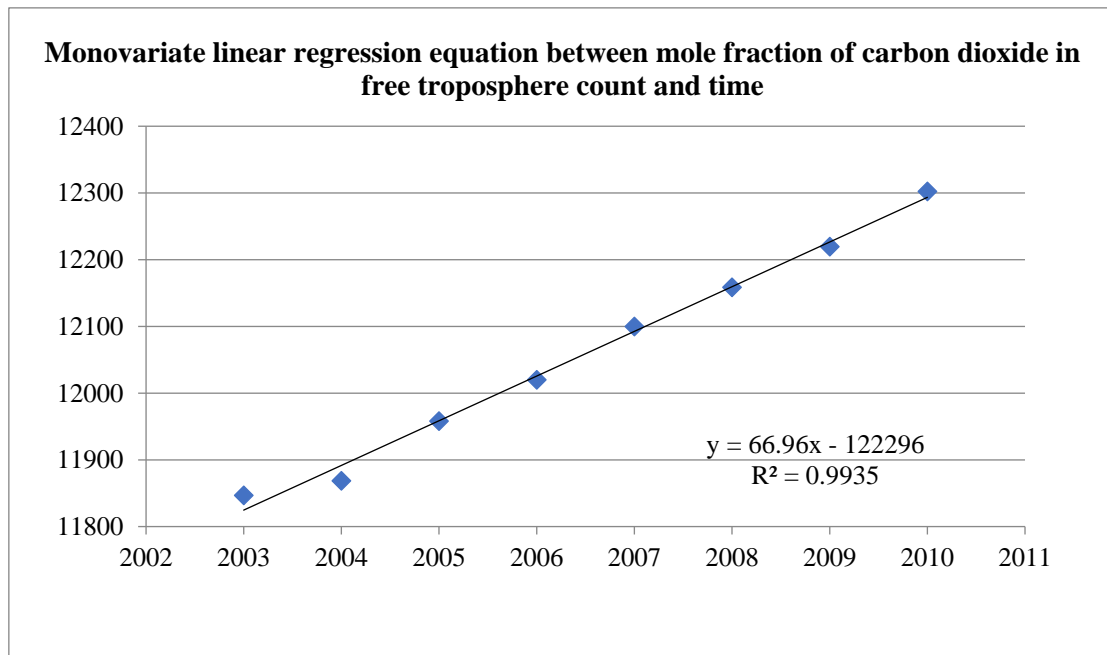


Figure 4. Correlation between mole fraction of carbon dioxide in free troposphere count and time
 Calculate the correlation between the humidity 30cm below the surface and the time.

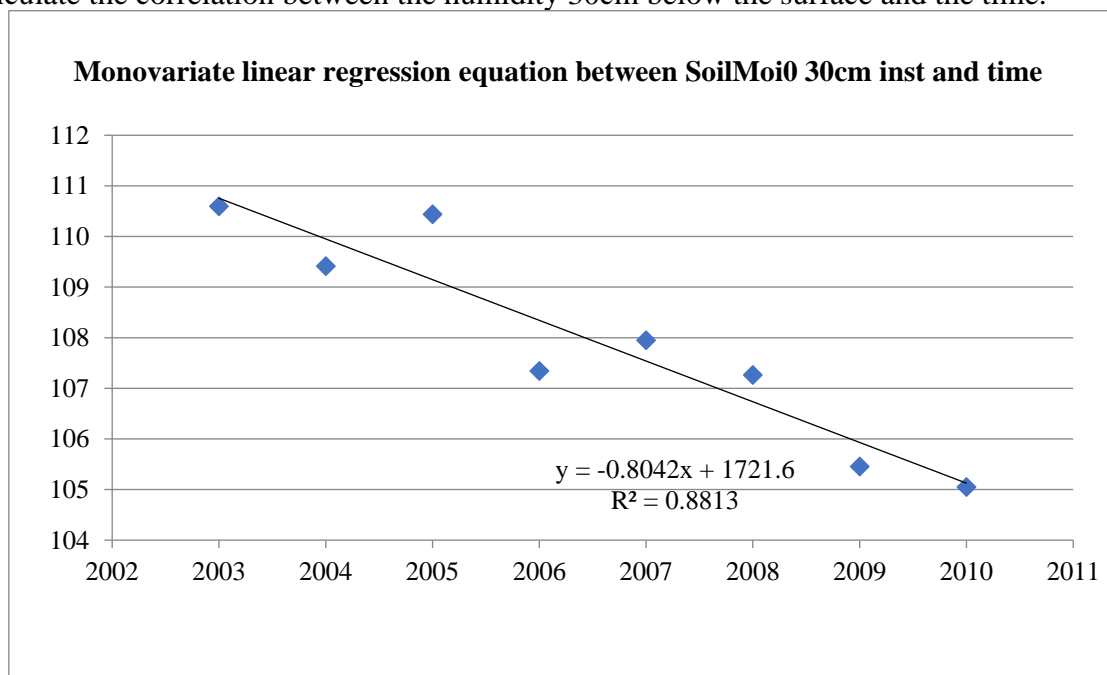


Figure 5. Correlation between SoilMoi0 30cm inst and time

Correlation between the molar mass fraction of tropospheric carbon dioxide and the humidity 30 cm below the surface is analyzed.

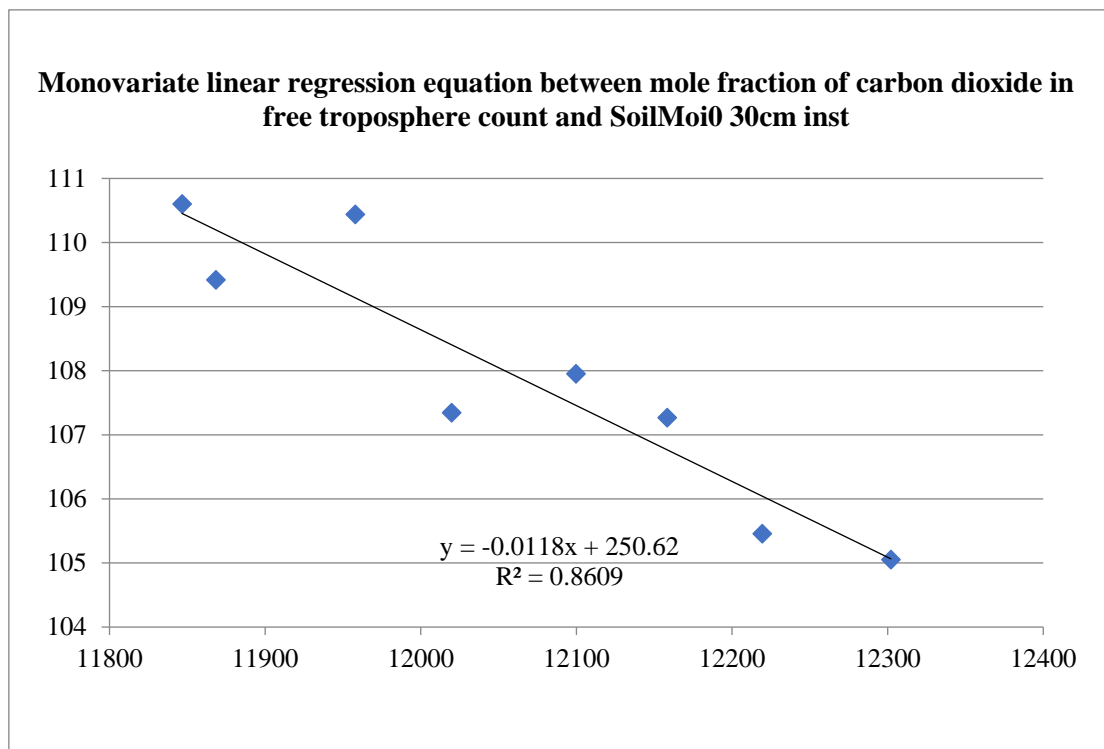


Figure 6. Correlation between mole fraction of carbon dioxide in free troposphere count and SoilMoi0 30cm inst

The closer R^2 get to one, the more relevant they are. There are significant linear relationships between the molar mass fraction of tropospheric carbon dioxide and the year, the humidity at 30cm below the surface and the year, and the molar mass fraction of tropospheric carbon dioxide and the humidity at 30cm below the surface. According to the research on the goodness of fit of the correlation coefficient, the correlation coefficient is of practical significance in two cases and only in two cases. One is when they are regression coefficients. the other is when a variable cannot be measured with a fixed scale. The fitted data is consistent with the above two conditions [8]. Therefore, the molar mass fraction of tropospheric carbon dioxide will increase with the increase of years. The humidity at 30cm below the surface will increase and decrease year by year. The molar mass fraction of tropospheric carbon dioxide will increase with the decrease of humidity 30 cm below the surface.

4. Suggestions

The ecosystem of Tibetan Plateau is very fragile. It cannot cope with the effects of global climate change, especially drought, by itself. There are few studies on the causes of drought in Tibetan Plateau and the mechanism of its interaction. And the existing research conclusions are also quite different. It is difficult to predict drought. The mechanism of drought change in Tibetan Plateau is still unclear [9]. Curbing the trend of global warming is the most fundamental solution. However, before reaching global carbon neutrality, human beings need to actively protect the ecosystem of Tibetan Plateau. Limiting grazing is one of the effective measures. The coverage rate of grassland vegetation increases with the increase of population within a certain limit, which proves that human's protection has played a great role. However, sometimes the trend of grassland degradation will also increase, because large areas of grazing by livestock will lead to grassland degradation. Therefore, relevant departments should formulate relevant policies to protect grasslands and deal with drought [10]. Soil modification is also one of the promising methods. It is a long time to provide good living conditions for vegetation only by improving soil with vegetation. It is not easy to improve the vitality of local soil microorganism, nutrient pool and breeding pool [5]. The cold winter in the Tibetan Plateau has caused a significant decrease in the life activities of plants and animal and microorganisms. Only in summer can the soil be improved under natural conditions. However, due to global warming, the

frequency of droughts on the Tibetan Plateau has increased. Ecosystems are difficult to self-regulate. Ultimately, land degradation occurs. Artificial intervention is one of the better methods to improve soil. For example, insert earthworms to evacuate land to help plants grow. But earthworms can hardly withstand the cold winter. Therefore, how to improve soil in a large scale is a promising topic.

5. Conclusions

This paper analyzes the relationship between soil moisture and carbon dioxide emissions in Tibetan Plateau from a macro perspective. The main conclusions are as follows. Firstly, because of the impact of human activities, if not curbed, the molar mass fraction of tropospheric carbon dioxide will increase over time. Secondly, the natural ecosystem of the Tibetan Plateau is extremely fragile, sensitive to global climate change and vulnerable to natural disasters. Finally, soil moisture mostly affects carbon dioxide concentration through plants. There is a negative correlation between soil moisture and carbon dioxide concentration. The limitation of this study is that the tropospheric carbon dioxide data can't reflect the carbon dioxide emissions of the day in a timely manner. No near-surface carbon dioxide monitoring site has been set up on the Tibetan Plateau. In fact, there are not many near-surface carbon dioxide monitoring stations around the world. It is expected that more near-surface carbon dioxide monitoring stations will be able to obtain near-surface carbon dioxide molar mass fraction in the future.

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