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Applying paleoclimatic reconstruction of greenhouse gases and correlation analysis of global and Yangtze Estuary SST changes with industrial revolution

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Abstract. This study explores the differences of different proxies in paleoclimatological reconstruction. It was found that N_2O content increased first and then decreased after the first industrial revolution, while CO_2 and CH_4 content increased. After the Second Industrial Revolution, the three kinds of greenhouse gases all increased sharply, and the amplitude was relatively consistent. The analysis shows that the annual variation of the Changjiang Estuary is larger than that of the whole world, showing a canine shape. Compared with other historical thermal events, it is found that global change is directly related to the Industrial Revolution.

Keywords: Palaeoclimatic Reconstruction, Sea surface temperature (SST), Yangtze River Estuary, Greenhouse gas.

1. Introduction

Due to global warming, the surge in greenhouse gases and the rise in sea level temperatures have brought increasing attention to these issues. To explore these questions, scientists have used paleoclimate reconstruction methods and temperature comparison methods to explore the causes of global warming. For example, Lin et al. used two proxies, $U^{k'}{}^{37}$ and TEX^{H} 86, to investigate hydrological changes in the northern South China Sea over the past 45,000 years [1]. Kong et al. explored the possible relationship between SST variation and solar illumination in the northern South China Sea [2]. Luan et al. explored the seasonal and interannual changes of SST in the Yangtze River Estuary and their influencing factors [3]. Ma et al. investigated the contribution of water vapor to local evaporation in southeast China based on hydrogen and oxygen isotopes [4]. Zhang et al. reconstructed the paleoclimate of the East China Sea over the past 14,000 years based on lipid markers [5]. Liu et al. report a palaeontological record for the last 37.0 cal kyr BP in the Xixi Basin, eastern China [6]. Deng et al. studied Anthropogenic effects on tropical oceanic climate change and variability from the South China Sea over the past 2000 years [7]. Thompson et al. studied annually resolved Ice Core Records of tropical climate variability over the Past ~1800 years [8].

Using some of the methods mentioned above, this paper will reconstruct the paleoclimate based on other substitutes, such as carbon dioxide, nitrous oxide, methane, etc., and explore the temperature changes since the Industrial Revolution and the direct relationship between the Industrial Revolution and global warming by taking the Yangtze River Estuary as the research area.

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Zhao et al. studied warming events that occurred in different historical periods [9]. Zhang et al. researched the changes in the mean and extreme temperatures in the Yangtze River Basin over the past 120 years [10]. Westerhold et al. investigated an astronomically dated record of Earth's climate and its predictability over the last 66 million years [11].

These articles help support the evidence for a direct relationship between today's extreme warming and the Industrial Revolution.

2. Data and Methodology

2.1. Data

In this study, the data comes from the NOAA Paleoclimatology Program and NOAA Climate Data Records(CRR). The above two data sources are mainly used in paleoclimate reconstruction and comparative study of global and Yangtze River estuary mean annual SST changes. For the paleoclimate reconstruction part. Data from the ice cores was used in this experiment. The CO_2, N_2O, and CH4 content data with gas age from 155-1995CE were obtained from Law Dome, Antarctica 2000 Year Ice Core CO2, CH4, N2O, and $\delta^{13}C$-CO_2 Data[12]. In the study of global and Yangtze River estuary mean annual SST changes, the Monthly 1×1 SST dataset from 1850 from the Japanese Mateorolgical Center (JMA) was mainly obtained from COBE-SST 2 and Sea Ice. Monthly SST data was obtained from 1850 to 2019. Geographical locations include the global (0°E-360°E, -90°S-90°N) and the Yangtze River Estuary region (120°E-130°E, 25°N-35°N).

2.2. Methodology

In this experiment, we used the method of paleoclimate reconstruction [1,4,5,6,8]. The use of CO_2, N_2O, CH_4 to reconstruct the long-term climate. Because the above substitutes are temperature-dependent. Therefore, the contents of the above substances in different periods were collected, and the images of the time and the contents of the above substances were represented by line charts. After drawing the relevant line chart, the method of comparative analysis is used to analyze the reaction of different substitutes to the rise in temperature after the Industrial Revolution and the differences in the sequence of time scales. In this paper, comparative analysis is used to compare the annual average SST data of the world and the Yangtze River Estuary from 1850 to 2019, and tables and line charts of relevant numerical transformations and growth trends are produced.

3. Result and Analysis

3.1. Results and Analysis of Paleoclimate Reconstruction

Since CO_2, N_2O, and CH4 are the main greenhouse gases emitted by the Industrial Revolution, they are more relevant in the study of the changes of the Industrial Revolution and sea surface temperature. Therefore, three gases, CO_2,N_2O and CH_4 were selected to reconstruct the climate from 155CE to 1950CE

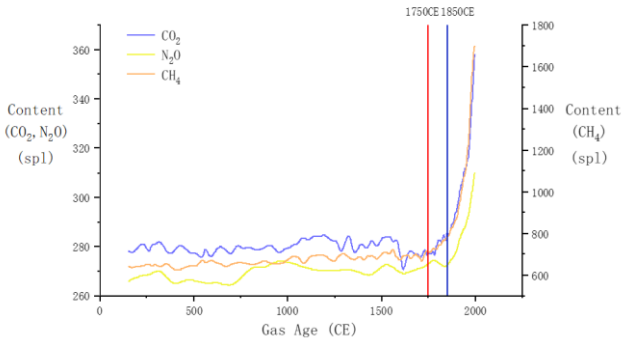

Figure 1. CO_2, N_2O and CH_4 content changes from 155CE to 1950CE [12]

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As shown in Figure 1, After the first industrial revolution (that is, after 1750CE), the content of CO_2 and CH_4 showed a fluctuation rise, and the content of N_2O showed a first increase and then a decrease until the second industrial revolution occurred (that is, 1850CE), the content of the three gases showed a substantial increase and the growth rate was almost the same. In terms of content, the CH_4 content increased the most, which was 1057.13spl. Compared with before the Industrial Revolution, the content of all three gases has increased significantly. This trend is consistent with the global warming trend.

3.2. SST Changes after the Industrial Revolution

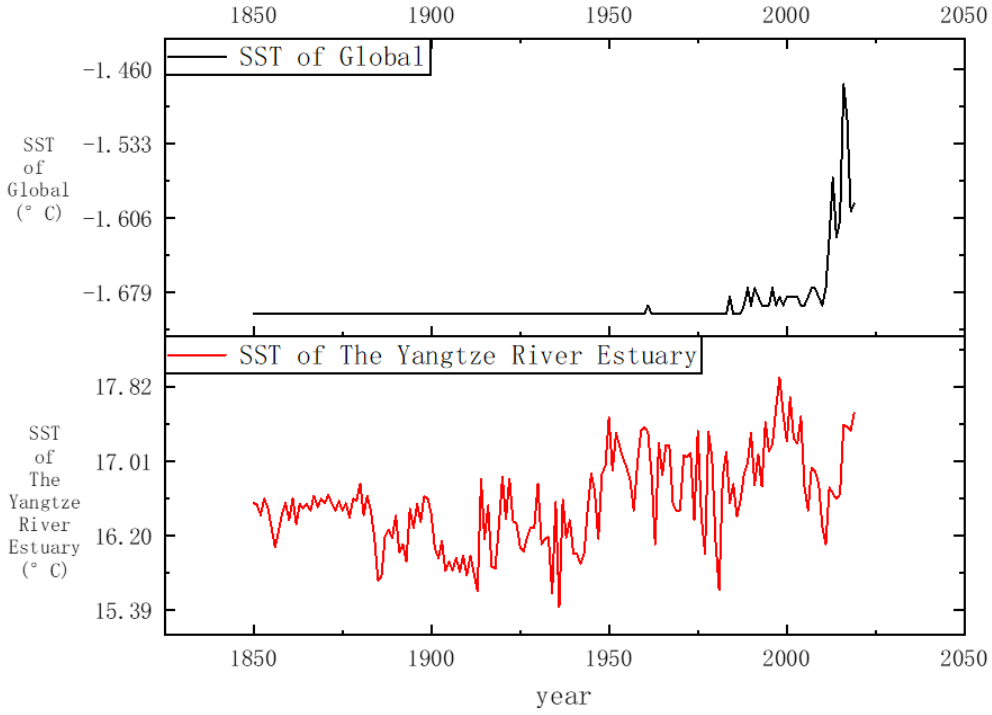

Figure 2. 1850CE-2019CE global average annual sea surface temperature change curve and the Yangtze River estuary area average annual sea surface temperature change curve

After the second Industrial Revolution, mankind entered the electrical age, which significantly increased greenhouse gas emissions. Figure 2 shows the annual average sea surface temperature changes in the world and the Yangtze River Estuary region from 1850CE to 2019CE. It can be seen from the figure that the global SST changes occurred around 1988, while for the Yangtze River Estuary region, although an upward trend can be seen [2,3,7], the range of changes is large, and the broken line in the figure shows a canine shape.

Table 1. The data of the Second Industrial Revolution and the current data

Year	Global SST	Global SST Increase	Yangtze River Estuary SST	Yangtze River Estuary SST Increase
1850	-1.7	6.38%	16.55833	5.89%
2019	-1.59167		17.53333	
Total	+0.1084	——	+0.975	——

In order to see the comparison between the data of the Second Industrial Revolution and the current data more directly, Table 1 is made in this paper, from which we can see that the global SST growth rate is relatively consistent with that of the Earth SST growth rate of the Yangtze River Estuary, but in

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numerical terms, the SST growth rate of the Yangtze River Estuary is 0.975, and that of the global SST growth rate is 0.1084.

4. Discussion

In order to explore whether the cause of today's global warming is directly related to the increase of human activities after the Industrial Revolution, this paper quotes some articles to analyze the cause of some historical thermal events. In Zhao's study [9], major thermal events such as Paleocene- Eocene Thermal Maximum (PETM), the Latest Maastrichtian warming event(LMWE), Early Danian thermal event(Dan-C2 and L.C29n), End Danian thermal event(LDE and D/STE), Early Eocene thermal event(ETM-2 and H2) were discussed, and Figure 3 was drawn to reproduce the paleoclimate at that time with data such as $\delta^{13}C_{Benthic}$ and $\delta^{18}O_{Benthic}$, and the occurrence period of the above thermal events was labeled.

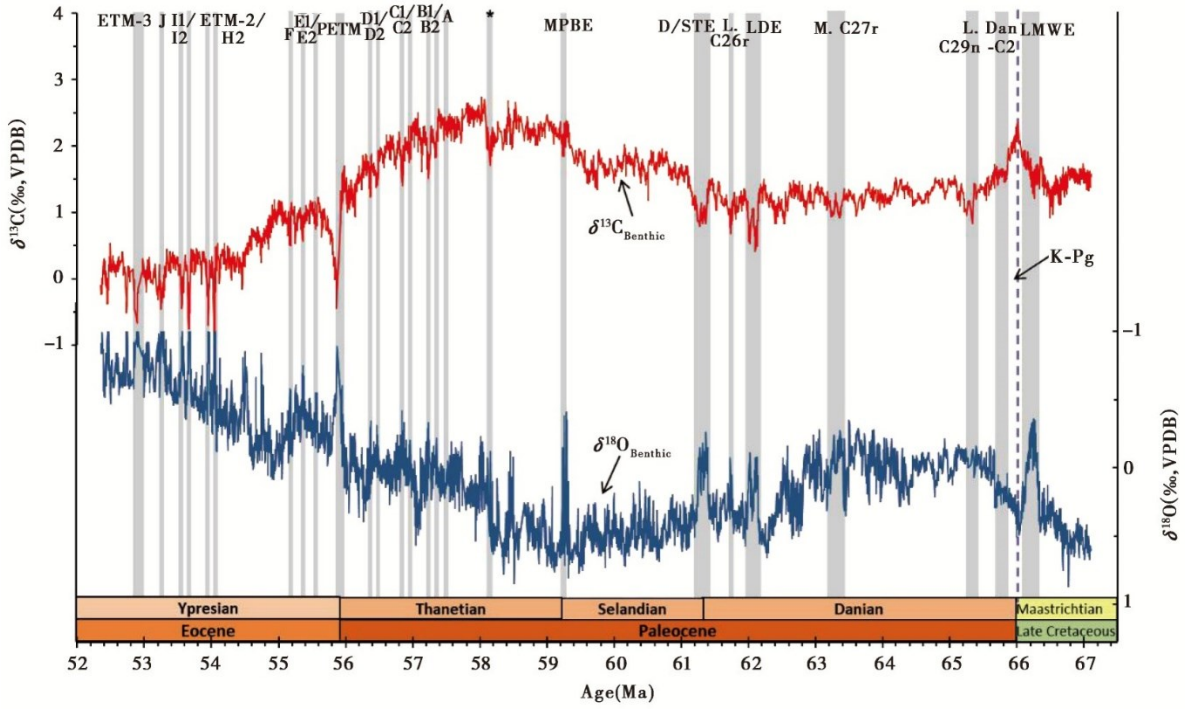

Figure 3. Stable carbon and oxygen isotope records(67~52 Ma)from ODP Site 1262 and major hyperthermals [9]

In the above historical thermal events, scholars generally believe that most of the thermal events are determined by changes in the Earth's orbit (except PETM and LMWE). Some thermal events also superimposed volcanic activity under astronomical activities, such as LDE, L.C29n, and D/STE, occurred in the first stage of NAIP(the North Atlantic volcanic activity) volcanism, and Dan-C2 is closely related to the third stage of the Deccan Plateau volcanic eruption. The PETM event is associated with NAIP, as well as the impact of extraterrestrial objects, such as the discovery of a large number of ferromagnetic particles and iridium anomalies in the sediments of this period, and is also associated with tectonic uplift. LMWE is mainly associated with volcanic activity in the Deccan Plateau.

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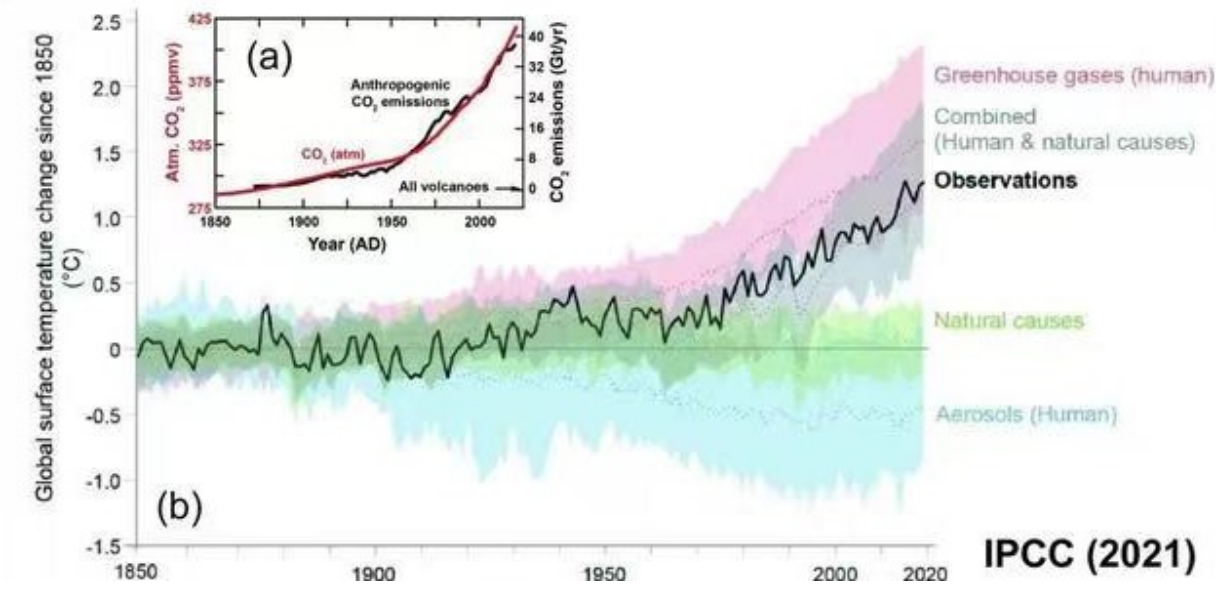

Figure 4. ((a) Changes in the concentration of carbon dioxide in the atmosphere since 1850 and changes in the flux of carbon dioxide released by human activities; (b) The relationship between human-induced temperature changes since 1850 and actual observations)

Since the change of climate is mainly related to the concentration of carbon dioxide in the atmosphere, it can be seen that there is a good correlation between the carbon dioxide content released by human activities and the change of atmospheric carbon dioxide concentration, and all the volcanoes in the world release carbon dioxide fluxes less than 1Gt/yr per year, while the carbon dioxide fluxes released by human activities can reach 40Gt/yr. About 200 times the global volcanic flux (Figure 4a).

To sum up, the historical extreme warming events are mainly affected by the above natural factors, and the current global warming situation has little correlation with the above natural factors, so human activities are the main factor leading to today's climate warming.

5. Conclusion

From the analysis of the above results, the following conclusions can be drawn:

1. After the first Industrial Revolution, the change of N2O content increased first and then decreased, and the content of CO2 and CH4 both increased. After the Second Industrial Revolution, the global CH4 content surged, and CO2 and N2O also increased significantly, which were lower than CH4 in value, but the growth rate was similar.

2. After the Second Industrial Revolution, the change value of SST in the Changjiang Estuary region was larger and more drastic than that in the global SST, and the global SST change occurred later.

3. The Industrial Revolution and global warming are directly related, and human activities are the main cause.

As for the limitation, few proxies were selected in this study, and more detailed studies on the relationship between proxies and temperature need to be further studied. For the comparative study of the SST of the Yangtze River estuary, this paper did not consider the influence of the river flowing into the sea and the underwater dynamic factors on SST. In order to obtain more accurate SST variation data, comprehensive analysis should be made.

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