Evidence for Deep Geotemperature Rise and Abyssal Ocean Warming Due to “Human-Induced” Changes to the Earth’s Insulation System

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Abstract Using an argument approach and a combination of historical, contemporary data sets, we show that the evidence for deep geotemperature rise and abyssal ocean warming due to “human-induced” changes to the Earth’s insulation system. This warming deepened the soil and sea change and triggered large mass losses from glaciers, resulting in an n times increase in delivery of glacial melt waters, sediment, organic carbon and legacy contaminants to oceans and near certainty of arctic summer ice-free conditions in the near future. Concomitantly, the energy exchange in the ocean and mechanical structure of the Earth’s crust shifted dramatically with declining ice cover and abyssal warming more and more. Everything becomes unpredictable. These changes are unprecedented in nearly a century.

1. Introduction

Entering the 21st century, global carbon emissions have reached a record high, and CO2 emissions are increasing. But the question arises, on the one hand, global warming has slowed significantly and not as much as had been expected; on the other hand, extreme weather events have become more and more frequent. There are clear signs that the climate crisis has become very serious. Heat waves and cold snaps have swept the globe, with extreme high and low temperatures hitting new highs, and precipitation and drought duration setting new records. So, why are climate change and natural disasters now more intense?

Fossil energy is the product of a series of complex chemical reactions in the earth under high temperature and pressure after a long geological time. Hence, where there is fossil energy, there is a large amount of thermal resources under high pressure. But there is not any “oil sea” or “gas sea” in the Earth’s crust. Oil and natural gas exist in the Earth’s crust rock pores, cracks, caves, faults, and gravel, forming a huge “capillary network.” Although fossil fuels make up only a “small” fraction of the Earth’s surface (in fact, the “capillary network” inside the crust has doubled and redoubled larger than surface oil-gas field area), but oil and gas effectively seal up pores, cracks, caves, faults, and gravel in rocks. The huge pressure inside the oil and gas field before exploitation formed a natural heat insulation mechanism for the relative balance of acting force and reaction force, preventing excessive leakage of heat from the Earth’s interior. Industrial exploitation of fossil fuels (coal, oil, natural gas, oil shale, natural gas hydrate, etc.) gradually weakens the insulation layer of the Earth’s crust, a large amount of extremely dispersed heat forces gases in the Earth’s crust, such as water vapor, CO2, and CH4 to enter the atmosphere and oceans, damaging the energy balance of the atmosphere and causing climate change and meteorological disasters. The arctic is sparsely populated. However, this area is rich in oil and gas resources, and the large-scale exploitation by neighboring countries (Russia, Alaska, Alaska, Norway, Canada, Denmark, etc.) leads to abyssal ocean warming in the arctic ocean (Osterhus & Gammelsrød, 1999; Timmermans et al., 2018) and accelerates the melting of arctic sea ice, which is a vivid example.

This article is based on the several influential literatures in recent years, the response of energy exploitation to climate change is reviewed after oil-gas field exploitation, and Earth thermal insulation consumption leads to internal heat release and deep geotemperature rise and abyssal ocean warming and other aspects.

2. Data and Method

Recent studies have shown that global deep geotemperature and abyssal ocean temperature have an obvious rising trend since the end of 1970s, especially in the northern hemisphere. In the context of global change, to study and assess the trends of deep geothermal and deep-sea temperatures and their responses to climate...
change, in particular, comparing the rate and magnitude of its change with the fact that the Earth’s climate system continues to absorb heat even as greenhouse gas emissions continue to rise at an accelerating rate in recent decades, but global surface temperature shows a trend of slowing down or even stagnation (Easterling & Wehner, 2009; Lima & Wethey, 2012); it is helpful to understand the mechanism of deep geothermal rise and abyssal ocean warming. The data used in this paper are mainly from two aspects: first, by referring to a large number of references, we have collected some field survey data included published by SCI and EI in recent 5 years, the second is the specific analysis of typical cases.

2.1. Energy Mining Depletes Earth’s Thermal Insulating Layer as Well as Destroys Geothermal Reservoir

According to the hydrocarbon-generating theory of late thermal degradation of kerogen, liquid hydrocarbon formation temperature in the range of 60–120°C (the Ro is between 0.6% and 1.35%), when geotemperature exceeds 120°C (Ro > 1.35%), organic matter and liquid hydrocarbons will decompose and form gaseous hydrocarbons dominated by methane. Most of the world’s discovered oil both exist in 65.5–149°C; above that range, oil is replaced by natural gas. This temperature limit is called “liquid window.” As a result, therefore, where there is fossil energy, there must be heat sources. Fossil fuels are the best insulators of heat. The fossil energy in the Earth’s crust naturally forms a thermal insulation layer, which effectively prevents the leakage of geothermal, thus making the Earth’s surface suitable for the growth of all things. In terms of insulation effect, natural gas thermal insulation effect is the best, followed by liquid and solid state. The thermal insulation layer of the Earth’s crust is damaged by large-scale exploitation of fossil fuels, and among them, the exploitation of natural gas is the most serious damage, followed by oil and coal.

Take Daqing and Ankleshwar Oilfield as an example: Daqing Oilfield across between latitude 45°05′N to 47°00′N and longitude 124°19′E to 125°12′E. The oilfield is 140 km long from north to south and 70 km wide from east to west, with a total area of about 6,000 km² and an oil-bearing area of 2,334.4 km². The main body of Daqing Oilfield is Daqing incline, a large anticlinal structural belt, including Lamadian, seven anticlinal structure oilfields; there are 45 oilfields such as Xingxi, outside anticlinal. Daqing Oilfield is the general term of the above-mentioned series of oilfields. Opened in 1960, it is now China's largest oilfield and one of the few mega-fields in the world. By 2014, the cumulative production of crude oil was $22.8 \times 10^8$ t and natural gas $1266.16 \times 10^8$ m³. Angqing (2016) conducted field investigation, evaluation, monitoring, and research work in Daqing Oilfield. He found that the oil-gas combinations and geothermal reservoirs system in the oil field basically correspond one to one, and the oil-gas combinations and geothermal reservoirs system are indivisible and unified geological bodies. That is to say, there is a geothermal reservoirs system in the oil-gas combinations, and there is also oil-gas combinations in the geothermal reservoirs system (Table 1). The oil-gas wells and water injection wells of mining construction in Daqing Oilfield have penetrated through the upper and middle geothermal reservoirs system cap rocks; part of it penetrates the lower and deep geothermal reservoirs system cap rocks; a lot of geothermal energy is lost. Crude oil reservoirs are generally located in the crustal heating layer; heat flow causes higher formation temperature; the produced water in the oil field absorbs a lot of heat in the reservoir along with the crude oil in the stratum; when the water and crude oil was mined out, temperature is around 40°C and contains abundant heat energy. If according to the extraction of 10°C temperature difference of heat energy calculation, the annual loss heat energy in Daqing Oilfield is equivalent to $69.4 \times 10^8$ t standard coal at present.

The west India continental margin is composed of three major rifted sedimentary basins: Kutch, Cambay, and Narmada. The Cambay is a narrow intra-cratonic rifted basin; it is situated in Gujarat's alluvial plains and is one of the most widely explored sedimentary basins in India. It is between latitude 21°N to 25°N and longitude 71°30′E to 73°30′E, stretches about 425 km, and covers an area of about 56,000 km². There are several petroliferous structures in the Cambay basin; Ankleshwar Oilfield is one of the major oilfields, located at the southernmost end of the basin. The oilfield was discovered in May 1960 and put into production on 15 August 1961. As of April 2011, the oil field has produced $0.6535 \times 10^8$ t of crude oil. Ganguli et al. (2018) vertical drilling was studied in Ankleshwar Oilfield; the maximum depth is about 1,630 m; some of these borehole logs data take the form of Bottom Hole Temperatures (BHT) and contain formation temperature information up to 2,000 m. The results show that eight heat flow values have been reported in the basin; the range is between 55 and 93 mW/m².
In the northern basin, where the Ankleshwar Oilfield is located, heat flow values are higher (Average 83 mW/m², range 75–93 mW/m²). At a depth of about 1,200 m in Ankleshwar, based on temperature measurements made in four boreholes, the reported heat flow is about 67 mW/m². The temperature gradient of BHT at a depth of 44–1,306 m is approximately 38.2°C/km. Below 1,200 m depth, the temperature gradient has a sharp increase. Compared with the shallow layer of 38.2°C/km (44–1,306), temperature gradient estimates are about 52.9°C/km between 1,277 and 1908 m.

During drilling, Cambay-15 and Kathna-4 encountered hot water with steam pressure, respectively. The former well encountered steam at 750 m and the latter at 1,958 m. The steam flow is almost 3,000 m³/day and bottom hole temperature of about 160°C. They noted that in the Narmada Broach block of the south Cambay basin, where the Ankleshwar field is located, the deeper temperature gradients of several boreholes (BH-19, BH-23, BH-69, BH-62, etc.) rise sharply. Below 1,200 m, the high-temperature gradient zone is of one to one correspondence to the overpressure zone.

The underground temperature-depth distribution of Ankleshwar oil-gas field is estimated as well as the calculated temperature-depth results. Taking the lithosphere bottom as the intersection of the curve of geotherm and peridotite initial melting point, this creates a thin lithosphere, located about 50 km below the area; the contribution of heat flow from the mantle is very high (about 56 mW/m²).

Ganguli et al. also analyzed the crustal properties, rock types, and thermal conductivity of Ankleshwar Oilfield. Here, we compare it to the thermal conductivity of fossil energy. As can see, fossil energy has obvious thermal insulation effect (Table 2).

Oil-gas fields all over the world have the same or similar situation and experience with Daqing and Ankleshwar Oilfield. The process of industrialized exploitation of fossil energy, without exception, depletes thermal insulating layer. This causes heat under high pressure in the Earth's interior flows to the surface. In a word, depleted Earth's thermal insulating layer caused by energy exploitation and consequent deep geotemperature rise and abyssal ocean warming are facts that can be judged without macro statistical data.

In a word, fossil energy is formed by tens of millions of years of biological, chemical, and physical changes deep in the Earth's crust under

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**Table 1**

*Correlation Between the Oil-Gas Combinations and Geothermal Reservoirs in Daqing Oilfield*

| Upper oil-gas combinations (Heidimiao reservoir) | Cap rocks: Nenjiang 4, 5 section Reserve.: Nenjiang 3, 4 section | Upper geothermal reservoirs Cap rocks: Nenjiang 4, 5 section Geoth. reserve.: Nenjiang 3 section (buried depth more than 1,000 m, Geotemp. 40°C below) |
| Middle oil-gas combinations (Saertu, Putaohua, Gaotaizi reservoir) | Cap rocks: Nenjiang 1, 2 section Reserve.: Nenjiang 1 section, Yaojia group Source beds: Qingshankou 2, 3 section, Yaojia 2, 3 section | Middle geothermal reservoirs Cap rocks: Nenjiang 1, 2 section Geoth. reserve.: Qingshankou 2, 3 section, Yaojia group (buried depth 835.4–1,947.0 m, Geotemp. 42–82°C) |
| Lower oil-gas combinations (Fuyu, Yangdachengzi reservoir) | Cap rocks: Qingshankou 1 section Reserve.: Quantou 3, 4 section | Lower geothermal reservoirs Cap rocks: Qingshankou 1 section Geoth. reserve.: Quantou 3, 4 section (buried depth 1,479.0–2,389.0 m, Geotemp. 54–92°C) |
| Deep oil-gas combinations (Nongan reservoir) | Cap rocks: Quantou 1 section Reserve.: Quantou 1 section, Denglouku 3, 4 section | Deep geothermal reservoirs Cap rocks: Quantou 1, 2 section Geoth. reserve.: Quantou 1 section, Denglouku 3, 4 section (buried depth 3,101.0–4,700.0 m, Geotemp. 170–210°C) |

| Source beds: Denglouku 1, 2 section, Jurassic |

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**Table 2**

*Comparison of Crustal Rock Type, Thermal Conductivity, and Thermal Conductivity of Fossil Energy, Under the Ankleshwar Oil-Gas Field, Cambay Basin*

| Crustal | Rock type     | (W/m °C) |
|---------|---------------|----------|
| Upper crust | Sediments     | 3.5      |
|          | Deccan volcanics | 1.7     |
|          | Mesozoic sediments | 3.5    |
| Middle crust | Granite-gneiss | 3.0      |
|          | Amphibolite-granulite | 2.5    |
| Underplated crust | Mafic magma | 2.6      |
| Mantle   | Ultramafics    | 3.0      |
|          | Shale gas      | 0.049    |
|          | Natural gas    | 0.052    |
|          | Oil shale      | 0.08     |
|          | Gas hydrate    | 0.121    |
|          | Petroleum      | 0.14     |
|          | Coal           | 0.21     |
extremely high temperatures and pressures. Due to the different geological conditions and ages, different kinds of fossil fuels have been produced. The temperature range of liquid hydrocarbon formation is 60–120°C (that is, Ro is between 0.6% and 1.35%). When the formation temperature exceeds 120°C (Ro > 1.35%), organic matter and liquid hydrocarbon will decompose to form gaseous hydrocarbon dominated by methane. Most of the discovered oil in the world exists in the range of 65.5–149°C, and the oil above this range is replaced by natural gas. Therefore, where there is fossil energy, there must be a heat source. Fossil energy is the best natural insulator for heat. The fossil energy in the Earth’s crust naturally forms a thermal insulation layer to effectively prevent the leakage of geothermal energy, so as to make the Earth’s surface suitable for the growth of all things. In terms of thermal insulation effect, natural gas has the best thermal insulation effect, followed by liquid and solid. Large-scale exploitation of fossil fuels will inevitably lead to the destruction of crustal thermal insulation layer, which will lead to global deep geotemperature rise and abyssal ocean warming.

2.2. Global Deep Geotemperature Rise and Abyssal Ocean Warming

Geotemperature is the direct expression of soil heat content. Underlying surface heat basically comes from two aspects: One is the solar radiation and the other is the heat release of the crust interior. The monthly, seasonal, and annual climate disturbances have little influence on 3.2 m value of the geotemperature anomaly (\(t_{3.2}\)); that is, \(t_{3.2}\) influence source should be from the crust below 3.2 m. Therefore, the 3.2 m geotemperature anomaly field is more a reflection of geothermal activities below 3.2 m, especially when \(|t_{3.2}| > 0.5°C\); high (low) geotemperature central area basically is the reaction of the underground thermal activity.

After more than half a century of high-intensity exploitation, Daqing oilfield is destructive to the original geology of the thermal storage system and geothermal resources and has had a negative impact. Directly caused by Amur River upstream areas during the period of 1958–1990 10 m deep, geotemperature rose by 0.3°C to 0.6°C (Shengqing & Wang, 1993). The region where Daqing Oilfield is located shows obvious signs of melting permafrost. Mainly manifested as lower limit moves up, the thickness of active layer increases, the melting zone expands, the permafrost area decreases, the south boundary moves north, and the deep geothermal temperature increases. The average annual temperature of permafrost at all depths increases year by year. In 13 m depth, in 1984–1997 it increased about 0.2°C and increased about 0.4°C in 1997–2010. In permafrost areas, deep geotemperature and thawing index rises significantly. Annual mean geotemperature growth rate is 0.61°C (10 a)\(^{-1}\); thawing index growth rate is 9.96°C day a\(^{-1}\) (Shanshan et al., 2018). Mazhitova et al. (2008) study shows that the thawing depth of active layer in discontinuous permafrost area continues to increase; thawing depth of active layer in the permafrost area fluctuates and increases. The temperature of permafrost increases obviously in all regions of the world, and the permafrost area decreases to different degrees (Douglas et al., 2008; Romanovsky et al., 2008; Sherstyukov et al., 2008).

Biskaborn et al. (2019) used a global dataset of permafrost temperature time series from the global permafrost surface network to assess temperature changes in permafrost regions since the international polar year (2007–2009). Between 2007 and 2016, the annual amplitude of depth near zero in surface temperature increased by 0.39 ± 0.15°C in the continuous permafrost region. At the same period, discontinuous permafrost heat up 0.20 ± 0.10°C. Globally, the permafrost temperature increased by 0.29 ± 0.12°C, in particular Russia’s permafrost, which is drilling for rich in oil and gas resources, has seen the largest geotemperature rise.

There are two main ways for the geothermal release of the seabed: One is through powerful but short-lived undersea volcanoes; the total energy released during the eruption can reach 10\(^{23}\)J. The hot magma caused the deep sea to rise suddenly to nearly thousand degrees Celsius, but this kind of high-temperature and high-pressure water vapor group is very unstable, making the stability of surrounding water changes instantaneously; most of the heat is rapidly extended to the surface by convection processes and diffusion in the deep layer is minimal (Liu et al., 1998). The other is through the sea floor geothermal flux in the form of heating of the seawater slowly and continuously. Although undersea geothermal flux accounts for a small proportion of the ocean’s heat budget, the long-term effects on the ocean cannot be ignored because it is acting on the entire ocean floor and it is constantly heating. First, the undersea geothermal flux is constantly heated at the bottom of the ocean to increase the buoyancy of the underlying water, and then changing oceanic stratification. It has certain influence on ocean temperature distribution and circulation.
(Dutay et al., 2010; Mashayek et al., 2013). Second, it will affect the chemical properties of the ocean, the distribution and circulation of carbon and nitrogen, and the distribution and life of organisms in the seawater (Hofmann & Maqueda, 2009). Undoubtedly, consumed thermal insulating layer has significantly increased the geothermal flux on the seabed.

Measurements in deep ocean of the Indian Ocean show that 900 m deep water temperature increased by 0.5°C in 1962–1987 and deep south Pacific have yielded similar results (Wong et al., 1999). In the Southern Ocean, the use of Self-recording Lagrange Floating Buoy (ALACE, calibration accuracy between 0.001–0.003°C) since the 1990s has yielded large amounts of seawater temperature data at depths of 700–1,000 m. These data are higher than previously observed temperatures in the same area. The middle temperature in the Southern Ocean was 0.17°C higher in 1980s than 1950s (Gille, 2002). Research shows that Sea of Japan in the past 40 years, seawater temperature below 2,000 m depth increased by 0.01°C, the heat content below 500 m increased at a rate of 0.54 W/m² (Kim et al., 2001). The latest European Centre for Medium-Range Weather Forecasts Ocean Reanalysis System 4 (ORAS4) estimates that global ocean heat content evolution during the 1958–2009, the deep sea below 700 m showed a significant warming trend. Over the past decade, the deep ocean has continued to warm, and the ocean as a whole has continued to warm at an accelerating rate (Balmaseda et al., 2013). Johnson et al.’s (2007) rough estimation of changes in ocean heat content shows that deep-sea warming may have accounted for a significant portion of the upper world’s ocean heat gain over the past few decades. Located at 66°N, 2°E Marine meteorological station Mike multi-year ocean observations show that the Norwegian Sea deep water temperature rising is about 0.01°C each year (Østerhus & Gammelsrød, 1999). As Mary-Louise Timmermans et al. reported, measurements show that the heat content inside the Arctic Ocean has almost doubled relative to freezing temperatures in the last 30 years (1987–2017) (Timmermans et al., 2018). Antarctic bottom water (AABW) is the coldest and densest body of water in the Southern Ocean. Research shows that AABW is also warming (Purkey & Johnson, 2013; Sloyan et al., 2013). Significant warming has also been observed in the north Atlantic and the Southern Ocean at depths of 2,000–4,000 m (Desbruyères et al., 2017). In the Weddell Sea, deep water heating up speed in 1990–1998 period was 0.09°C year⁻¹ (Fahrbach et al., 2004). In the Ross Sea, there is also warming in the middle and deep waters (Jacobs et al., 2002). Abyssal waters of Scotia Sea, Argentina Sea, and Brazil Sea have also warmed over the past two decades in the Atlantic (Coles et al., 1996; Johnson & Doney, 2006; Meredith et al., 2008; Walter & Morozov, 2007). Repeated hydrological surveys of across the Pacific section along the 47°N showed that there was a significant warming of the underlying seawater (Fukasawa et al., 2004). Across the Pacific section along the 32°S, 149°E, 24°N, and 30°N repeated hydrological surveys also showed that the potential temperature of lower circumpolar deep water (LCDW) exists generally 0.005–0.01°C heating; the main reason is that cooler LCDW area decreases while warmer LCDW area increases (Kawano et al., 2006). Overall, observational surveys have shown significant warming of the ocean floor. The mechanism that causes this abyssal warming, however, remains unknown and their time scale is also uncertain (Masuda et al., 2010).

The Earth’s climate is not only controlled by the atmosphere but to a large extent by the storage of heat in the oceans, which contain 3,300 times more heat than the atmosphere. Independent data sets consistently show that the heat absorbed and released by the oceans is an order of magnitude greater than expected from the total solar radiation. This also means that there must be a heat amplification mechanism.

As the most important source of water vapor, cold, and heat in the atmosphere, the ocean has been regarded as one of the main causes of climate change. The effects of climate change on the oceans are harder to see than retreating glaciers, but it has profound implications for all human civilizations. There are many oil-gas fields in the northern hemisphere and large amount of exploitation, so the warming rate is higher than that in the southern hemisphere.

Make a simple summary. There are natural causes of climate change but are mainly man-made. Among the human factors, the traditional view is that the greenhouse gases emitted by human activities, such as fossil fuel burning and deforestation and land use change, lead to a significant increase in the concentration of greenhouse gases in the atmosphere and the enhancement of the greenhouse effect, thus causing global warming. However, the greenhouse effect has little influence on 3.2 m value of the geotemperature anomaly (t3.2), especially when |t3.2| > 0.5°C; the high (low) geothermal center is basically the reaction of underground thermal activity. The influence of atmospheric temperature on the ocean is mainly in the...
mixed layer and the thermocline. Due to the mixing effect of ocean waves, the temperature of the mixed layer is basically constant, and the temperature of the lower troposphere directly affects its temperature. In the thermocline, that is, between 200 and 800 m, the sea water temperature drops rapidly, which is mainly due to the rapid decrease of solar radiation and the weakening of seawater mixing. Below 1,000 m the temperature is about 4°C, and below 2,000 m it can drop by about 1°C, and it stays the same all year round. So, the atmospheric temperature generally has an impact on the surface water temperature of seawater. Global deep geotemperature rise and abyssal ocean warming have nothing to do with greenhouse effect. There must be something else.

3. Discussion and Conclusions

Changes in the Earth’s climate system are very complex. From a macro perspective, the changes in the time scale of $10^5$ to $10^7$ years are related to the tectonic movement. On a time scale of $10^4$ to $10^6$ years, it is related to the Earth’s orbit and its relative position with other stars. Climate change over a time scale of $10^3$ to $10^5$ years is associated with a number of sudden events. This has been borne out by many results (Hovland et al., 2001).

Climate experts agree that climate change over a certain period of time (about 3 months) is not primarily determined by the atmosphere itself; it can even be seen as a result of the forced response of the atmosphere to several other members (hydrosphere, geosphere, cryosphere, and biosphere) of the climate system (Guo et al., 2004). That means more than 3 months of climate change needs to be explained from outside the atmosphere.

Rothman found that for most of the past 500 million years, the concentration of CO$_2$ in the Earth’s atmosphere fluctuated for 100 million years (as the dominant cycle) at a level equivalent to 2–4 times the current level. All or part of the three historical peaks of atmospheric CO$_2$ concentrations occurred during periods when the earth was relatively cold (Rothman, 2002).

Steig (1999) has pointed out that there is evidence that atmospheric CO$_2$ concentrations rose by 10 ppm between 7,000 and 5,000 years ago, but the world cooled. Indermühle et al. (1999) believed that after the end of the most recent great ice age, between 8,200 and 1,200 years ago, atmospheric CO$_2$ concentration increased by about 25 ppm in a nearly linear manner, but the global temperature in the same period decreased slowly and steadily.

In reality, the interaction between ocean, atmosphere, and land is very complicated, and there may even be a factor (a trigger) that causes this phenomenon; it has just not been discovered by the entire scientific community.

In the past 100 years global temperatures have risen by 0.5°C; most of these growth occurs during this period the first 50 years. CO$_2$ has also increased over the past 100 years, from about 300 to 370 ppm. Interestingly, most of these increases occurred the last 50 years of this period, when temperature increases were at their slowest (Jouzel et al., 1987, 1993, 1996; Petit et al., 1999). Independent data from orbiting satellites have been continuously measuring global temperatures since the 1970s. The data show that global temperatures have actually fallen slightly over the past 25 years. Assuming that the increase in CO$_2$ the last 50 years of this period caused by human emissions of greenhouse gases, so (to an increasing extent) CO$_2$ concentrations in our atmosphere are an effect of temperature, not the other way around (Indermühle et al., 2000; Monnin et al., 2001). As it was, fluctuations in CO$_2$ levels do not have the same synchronous effect on temperature as predicted.

Year after year of oil and gas extraction, day after day the thermal insulation of the Earth’s crust is weakened. Meteorological history extreme value records are constantly being updated, all of these give Earth disasters is only beginning. Only the exact “pathogenesis” is understood; it is only in this way that humans can effectively cope with the challenges brought about by climate change.

Data Availability Statement

All data generated or analyzed during this study are included in this article.
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