Global Anthropogenic Heat as Source of Ices Disappearance; Consequences for the Future of Earth and Humanity

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Key points

- The anthropogenic heat released between 1994 and 2017 was estimated from the global energy consumption converted in oil equivalents.
- This estimate was high enough to have caused the melting of a large part of the ices disappeared during the same period.
- The role of global anthropogenic heat may impose decreasing production of heat instead of CO_2 to control the future of ices and climate.

Abstract:

The heat energy necessary to melt the recently reported 28 trillions tonnes of ices disappeared between 1994 and 2017 was estimated. This heat energy was compared to an estimate of anthropogenic heat energy released in the world during the same period. Both heat energies being of the same order of magnitude, it was concluded that anthropogenic heat energy was sufficient to have caused the melting of a large part of the disappeared ices. Ice melting was not the only source of anthropogenic heat absorption. It is shown that interphase equilibria between ice-liquid-vapour physical forms of water acted as thermal buffers. If more and more anthropogenic heat has to be absorbed in the future, interphase equilibria will move water from ices and liquid to vapour and clouds. In parallel, atmosphere and ocean turbulences that contribute in dispatching solar heat over the world should be enhanced because of the extra heat to manage. The role assigned to anthropogenic heat and water interphase equilibria will be confirmed if ices continue to disappear increasingly while global CO_2 production decreases as expected in the future.

Plain language summary

Presently, global warming and atmosphere temperature and ocean rises are assigned to a surplus of greenhouse effect due to anthropogenic carbon dioxide. This assignment is based on an international consensus since Earth is too complex to allow experimentation. The dramatic atmosphere temperature and ocean level rises predicted for the far future are still small whereas ices disappearance is dramatic. This study aimed at checking whether the heat produced by and for human's activities plays a role in ice imbalance. For this, comparison was made between an estimate of the heat necessary to melt the ices disappeared between 1994 and 2017 and an estimate of the human-related (anthropogenic) heat released during the same period. The two estimates being close; it was concluded that anthropogenic heat was sufficient to have largely caused ice imbalance. Actually, ice melting is just one component of the ice-water-vapour interphase equilibria that absorbed anthropogenic heat. These equilibria acted as stabilizers for atmospheric and oceanic temperatures, and as enhancers for climate perturbations (winds, hurricanes, rains, etc.), this at the expenses of ices. According to the role of anthropogenic heat, the decrease of anthropogenic production of CO_2 presently proposed as solution to control global warming may not be sufficient.

Keywords: global energy production, anthropogenic heat release, AHR, ice loss, ice imbalance, climate perturbations, global warming, water-interphase equilibria.

Introduction

As a neophyte in climate change prediction, the chemist I am is puzzled by the information that is disseminated by greenhouse effect experts and revived at every turn by media, politicians, environmentalists and various associations. What we hear is: "Global warming and climate changes are caused by a surplus of greenhouse effect due to the release of anthropogenic gas, especially carbon dioxide (CO_2) as reported in successive reports issued by the Intergovernmental Panel on Climate Change that predict dramatic increases of environmental temperatures and ocean level for the far future (IPCC, 2014). This surplus is said causing global warming via the absorption of a part of solar infrared radiations. Decreasing the sources of anthropogenic CO_2 is the systematically and universally recommended solution today, especially by the successive conventions on climate changes (for instance: UNFCCP, 2014). However, there seem to be arguments against the surplus of greenhouse effect as source of global warming (Oreskes & Conway, 2019; Scirocco, 2018; Gerlich & Tscheuschner, 2009). Some opponents contest predictions based on hypotheses and calculations whereas others emphasize the still small atmosphere and ocean temperature increases or oppose fundamentals of interactions between infrared electromagnetic waves and molecules [Gerlich & Tscheuschner, 2009]. In general, alternatives to the "greenhouse effect" consensus and consideration of effects related to heat exchanges by conduction were missing until recently. This is changing with the increasing consideration paid to anthropogenic heat releases (AHR) by some authors (Chen, B. & Dong, L., et al., 2016; Jin, K., & Wang, F., et al., 2019; Pan, Z. & He, Y., et al., 2019).

Let us forget polemics to retain indisputable facts only. Earth is losing more and more ice from glaciers, permafrost, floating ice and polar caps (Rignot, F. & Mouginot, J., et al., 2019; Zidek, C., 2018; Shepherd, A. & Erik, I., et al., 2018).

In parallel, humanity is producing and using more and more energy from different sources (Table 1).

Table 1: Evolution of the global annual primary energy deduced from main sources of energy in millions of oil equivalent (MToe).

Year	Coal	Oil	Natural gas	Biomass	Electricity	Renewable	Total
1900	480	25	5	580			1,100 0.046 [a)]
1950	955	505	153	545			2,158 0.090 [a)]
2000	2,116	3,542	2,206	465	1,096		9,242 0.394 [b)]
2018	0.158	0.191	0.139		0.061	0.026	0.576 [b)]
2019	0.158	0.193	0.141		0.073	0.029	0.584 [b)]

a) Conversion in Zj of data in Mtoe from (Wikipedia, entry « Consommation mondiale d'énergie) using the 1 Mtoe = 4.18 x 10^{10} j equivalence.
b) In Zj from (British petroleum, 2020).

Until recently, AHR was considered negligible relative to global warming and climate perturbation. This is no longer the case but until recently estimates of AHR were limited to local contributions when the challenge is at the global level (Chen, B. & Dong, L., et al., 2016; Jin, K., & Wang, F., et al., 2019). The historical evolution of AHR was recalled in a recent publication in which authors proposed a novel method based on a new algorithm to provide an estimate of global AHR from data on urban zones with emphasis on the limits of the approach (Yang, W., & Luan, Y., 2017).

In order to avoid the problems raised by direct estimate from local data that requires hypotheses and complex calculations, AHR may be considered as being part of the global energy provided by the main sources of energy exploited by humans. Everybody can feel heat around even during the night when solar does not contribute much.

In the present study, an indirect mode of estimation was selected to show whether the amount of disappeared ices and that of released anthropogenic heat can be correlated at the level of the whole planet. To minimize the effects of annual fluctuations, the period between 1994 and 2017 was selected because exploitable data were found in scientific and technical literatures. The strategy was based on these data and on chemical and physical fundamentals only. Despite the unavoidable uncertainties related to the use of estimates imposed by the complexity of environmental phenomena at the world level, available data were considered consistent enough to test whether a relation exists between AHR and ice imbalance. The result was discussed with respect to global warming and climate perturbations as well as impact on the future of humanity.

Data and methods

Estimate of the heat that caused the melting of lost ices

The first estimate concerned the thermal energy that was necessary to melt the amount of ices disappeared between 1994 and 2017. This amount was reported as 28 ± 2 trillion tonnes from various measurements and calculations (Slater & Lawrence, 2020). The thermal energy necessary to melt this huge amount of ice was c.a. $9.34 \pm 0.6 \times 10^{21}$ joules or 9.34 Zj, according to the 333.55×10^{3} J/kg ice enthalpy of fusion.

Estimate of global energy

The second estimate concerned the amount of energy produced during the reference period. Academic literature being relatively silent on global energy production and consumption data, such information was found more or less concordant in reports (Wikipedia, entry « Consommation mondiale d'énergie ; Martin-Amouroux, 2015 ; Enerdata, 2020; Wikipedia, entry World energy consumption). The retained global energy produced by the main sources of energy between 1994 and 2017 was provided by a BP report (British Petroleum, 2018). The total amount of oil equivalents was c.a. 268,400 MToe for the selected 23 years. Therefore, the corresponding global amount of energy was estimated as 12 ZJ on the basis of oil combustion that produces an average of 45 MJ/kg.

Facts on which the study was based

- When two media are brought into contact with each other, the hottest transfers heat to the coldest. The temperature of the two media changes in opposite directions except in the case of interphase equilibria (ice melting and water evaporation) during which the temperature is fixed (Ellgen, 2020).

- When ice is in the presence of heat, it melts and form water which turns to vapour if heating persists. In contrast, vapour in contact with a cold environment condenses back to liquid water and ice if cooling persists, such evolutions being under the control of interphase equilibria.

- Anthropogenic sources of heat are multiple and include heat at the stage of energy production, heat from the combustion of fossil products and biomass (including criminal forest wildfire), heat from electricity, as well as heat from machines that produce work and heat from animal and human metabolisms, each, and thus the sum of them, being difficult to quantify precisely at the globe level.

- The different sources of energy are not equivalent relative to heat and CO_2 productions. When burned in the presence of atmospheric oxygen (O_2), charcoal (C) generates hot carbon oxides (CO and CO_2) but no primary hot water vapour. In contrast, the combustion of hydrocarbons composed of carbon and hydrogen (oil, peat, lignin, natural gas, wood, and even animal and human metabolisms) generates CO_2 plus hot vapour, both hotter than the atmosphere. In all cases, atmospheric oxygen is consumed. There has been indeed a slight decrease of oxygen in the air and in the oceans over the years (Keeling, 2013). As for the production of electricity by nuclear power plants and by renewable resources, it does not generate CO_2 but it generates heat immediately during the production and later on during exploitation of the produced electricity (Manowska, & Nowrot, 2019).

- Chemistry teaches two important fundamentals: a) on Earth, "nothing is created, nothing is lost, everything is transformed" (this holds for electromagnetic radiations too through absorption, transmission and refraction phenomena); b) solid ↔ liquid (ice ↔ liquid water) and liquid ↔ vapour (clouds and rains) interphase equilibria consume or generate thermal energy depending on the direction they move. For instance, on a sunny day, an ice cube in a glass of water melts to bring and maintain the temperature of the water at 0°C until the cube disappear. Then, the temperature of the water increases up to the local value that is then maintained by slow evaporation of the liquid unless heating is too fast relative to evaporation-based cooling process. In humans and animals, perspiration and evaporation are used to maintain the temperature of the organism fixed (37 °C for man) despite internal or external heating by metabolism and Sun, respectively. When sick, a mammalian organism gets inflammation and fever, i.e. faces extra heat, a situation quite comparable with anthropogenic, volcanos and wildfire heats in the case of the planet.

- Huge quantities of fossil energy (actually solar energy stored millions years ago) have already been consumed and transformed in parts as heat, water, CO_2 and biomass. Large quantities of energy are still stored (oil, coal, gas, radioactive minerals) or are going to be produced in the future (electricity). When exploited this stored energy will released new heat of the anthropogenic type.

- Based on the energy preservation principle, the AHR generated by the combustion of fossil charcoal, oil, gas and biomass, by electricity-producing plants, and by machines and devices using this electricity is transferred to the components of the environment, notably ices, atmosphere and ocean. If ice melting is easily detected, hot vapour becomes visible when it is rapidly cooled. In winter, it can be seen from lung exhalation, from car exhausts at the start or in the upper atmosphere behind planes. It is the same for nuclear plant cooling towers topped with large clouds.

Results and consequences relative to global ice imbalance

Estimate of global AHR was limited to a 23 year period because there was no available data on ice imbalance covering a longer period of time. Estimate global AHR was challenging because AHR includes contributions from a large number of different sources of energies exploited to generate work. For instance, electricity-producing plants release heat in the environment, heat by wires is released during transport, and electric devices that use this electricity release also heat when they provide work (Electric radiators, TV sets, smartphones, etc., all heat). A part of the energy needed by electric cars and trains is used to move (work), the rest is released as heat, the amount of which depends on the yield in work. In addition, these machines also release part of the kinetic (work) energy as heat when they brake (brakes heat up). So, all sources of heat and not just fossil fuels disperse heat in the atmosphere and, more generally, in the environment.

Regardless of its origin, the heat released in the world was estimated as c.a. 60 % of the whole energy produced annually, 40% only being used for work (Manowska, A. & Nowrot, A., 2019). This proportion was applied to estimate the global anthropogenic heat released over the 1994 – 2017 period from the annual global amounts of energy. Therefore, AHR between 1994 and 2017 was c.a. 7.2 ZJ, i.e. 60% of the 12 Zj of energy consumed during the period. It is important to note that contributions of criminal forest fire, and cattle and human metabolisms could not be included in this AHR estimate because of a lack of consistent data.

During the same period, the amount of thermal energy necessary to melt the disappeared 28 trillions tonnes of ices was 9.34 Zj, a value rather close to the 7.2 Zj found for AHR. Therefore, the estimate of anthropogenic heat was significant enough to have caused the melting of a large part if not all of the global disappeared ices, something always in force today. The melting of the disappeared ices between 1994 and 2017 yielded c.a. 28 x 10^{12} m^3 liquid water initially at c.a. zero °C. This cold water was dispatched in the hotter environment and contributed to limit the temperature rises normally expected from any extra source of heat energy and thus of AHR.

Impact on climate

Anthropogenic CO_2 cannot be considered any longer the sole phenomenon accounting for recent ices disappearance and global warming. Anthropogenic heat releases and associated conductive transfers of heat to components of the environment must also play a role on the climate.

Situation when AHR was negligible

In the past, the number of humans on Earth was rather small and AHR was negligible. Only the Sun heated the planet with local fluctuations like ice melting and reformation, atmosphere perturbations (temperature, winds, hurricanes, streams, flooding's, etc.) and ocean heating over summers and winters alternately in the Northern and Southern hemispheres, all including greenhouse effects free of humanity-related contribution (Figure 1).

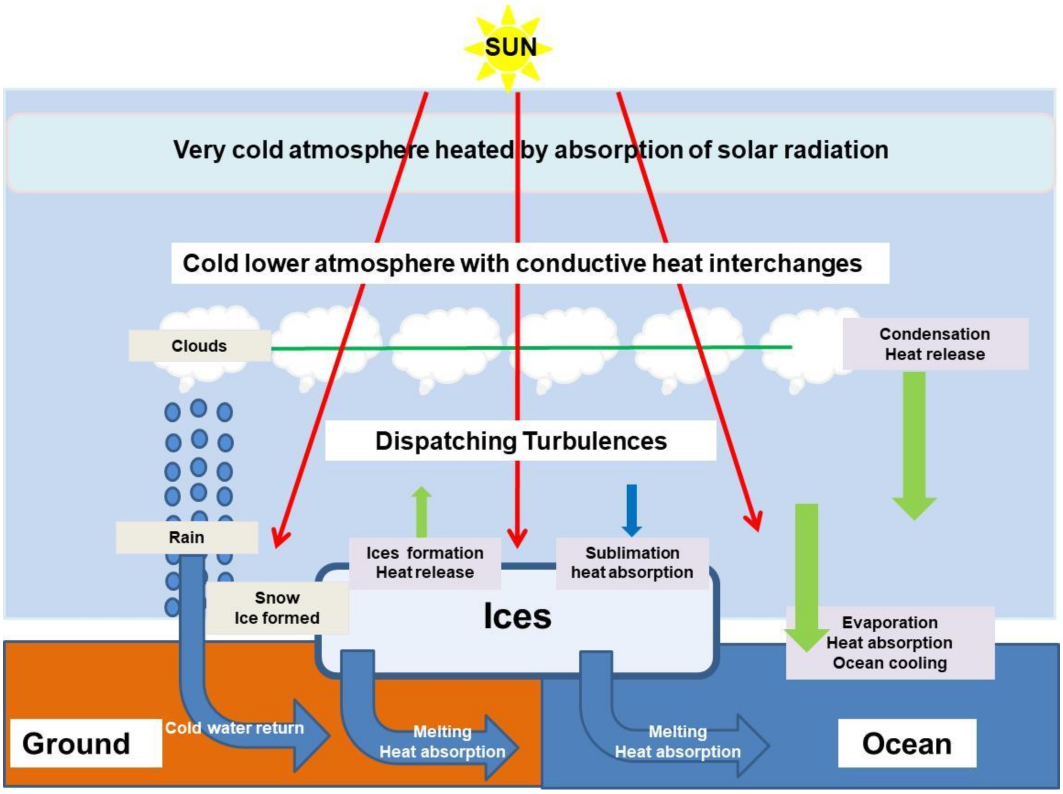

Figure 1: Schematic representation of the water cycle, including ices, and heat released or absorbed at the different levels.

Ices disappearance is only one part of the environmental changes related to heating by the Sun. From the physical and thermodynamic viewpoints recalled in the data and methods section, any heating is dispatched among the components of the environment, especially the different physical form of water as exemplified by the example of ice cube in a glass of water. Therefore, any source of energy that heats up the globe is controlled by complementary ice ↔ liquid water and liquid water ↔ vapour equilibria that are normally sources of temperature constancy despite some dependence on secondary factors like salt in sea water (Salhotra & Adams, et al., 1985). These interdependent phase equilibria shift in one direction or the other depending on the amount of energy to be managed positively or negatively while the temperature should remain constant. This cannot be confirmed experimentally, Earth being too large and too complex but one can find a simple model in the cooking domain. Let us consider a saucepan with water in it. If the saucepan is heated gently, the water evaporates and when there is no more water inside, the saucepan become overheated and the content is wasted. If now a cover with cold water on it is used to close the saucepan. On gentle heating, the water inside evaporates as when there was no cover but this time the vapour is condensed on the cover cooled by the outer water the evaporation of which eliminates the heating energy. Inside the saucepan, the temperature is fixed by the evaporation-condensation cycle provided water is present on the cover. The higher the heating rate, the higher the temperature inside the close saucepan is. This is how cooks control the temperature inside saucepans to avoid overheating and burning a stew inside.

In reality, the Earth is like a saucepan with the high atmosphere as cold cover and the Sun as heater. In between, the huge size and the complexity of the medium preclude stabilisation and it is chaos that are actually observed locally as temperature wells and peaks, formations and disappearances of ices, clouds, floods and droughts, etc. Exchanges of corresponding opposite thermal effects fluctuate because they are submitted to turbulences at different levels (atmospheric pressure, jet winds, heavy rainfalls, hurricanes, oceanic streams Labrador and Gulf Stream, Niño and Niña, summer and winter, etc.). Conditions are thus far from those scientists are used to play with in a laboratory (far from equilibrium), and because shifts related to interphase equilibria are slow. For these reasons, measuring temperatures and ocean level rises is uncertain as shown by the discordance of data released by the different organisations monitoring climate changes (NASA, NOAA, NCEP, ERA5, RSS, UAH) (Lorck, 2021). In contrast, solid ices are not dramatically perturbed by turbulences though their melting depends on them.

Today situation with extra heating from AHR

Today, the anthropogenic heat diffused in the environment complements the huge energy supplied by the Sun as schematically represented Figure 2. Though the contribution estimated as 0.0163 % of the solar energy is very small (Manowska & Nowrot, 2019), it looks now sufficient to largely account for ices imbalance as exemplified for the 1994-2017 period.

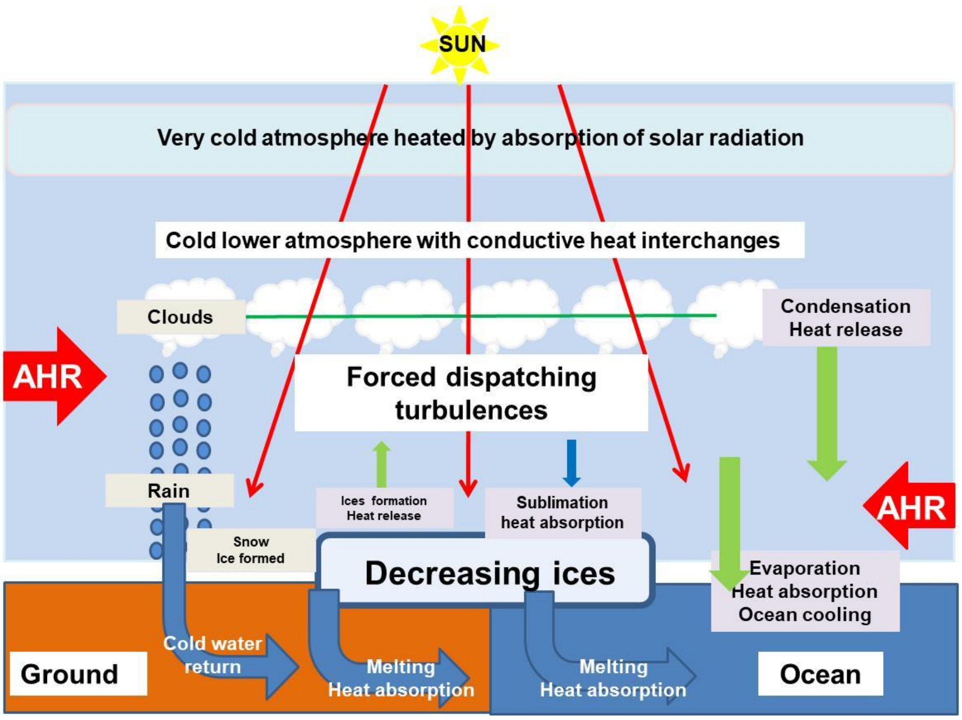

Figure 2: The water circle must now absorb and manage the extra heat provided by AHR with, as consequences, decreasing amounts of ices and enhanced atmosphere and ocean turbulences relative to corresponding effects due to the sole solar heat.

After the method exploited by the scientists of the University of Leeds (Slater & Lawrence, 2020), it appears now possible to estimate global ices loss reasonably. Using ice imbalance increase (in mass and not in surface) is thus preferable to monitor the impact of heat (solar and/or anthropogenic) on the climate. Regardless of whether extra global heating comes from anthropogenic gas via greenhouse effects or from the energy produced and exploited by humans, the trend for the future is clear: - on continuous heating, the buffering effect of ice melting that dominates today will be progressively transferred to the water evaporation-condensation. This mechanism suggests that with an increase of the global energy consumption, more anthropogenic thermal energy will have to be dispatched by the turbulences that normally manage and dispatch solar heat (winds, hurricanes, thunderstorms, tornadoes, oceanic movements and streams). These turbulences should thus increase in strength and frequency locally. There are already climatic signs in favour of such trend (Buis, 2020). Furthermore, ice loss is predominant in the Northern hemisphere relative to the Southern one in agreement with greater production and consumption of energy in the Northern hemisphere and the long distance between these two parts of the world that precludes averaging by mixing (Enerdata, 2020). Data available on annual ices loss (Slater & Lawrence, et al., 2021), and on global energy production (British petroleum, 2020), have all increased between 2000 and 2014 whereas the atmospheric temperature remained stable and was followed by no more than a small increase since 2014 (Rohde, 2018). Being not a proof, this observation is in favour of the present analysis. The observed small rises of atmospheric and ocean temperatures, variable from one source of data to the other, look another version of the half-full or half-empty bottle ambiguity, meaning that small increases may be viewed or not as beginning of dramatic deviations. It is this ambiguity that fuels the polemics relative to global warming climate evolution.

According to the role given to AHR relative to ice imbalance, in the far future, when all global ice is melted with the generated liquid water dispatched between ocean rise, atmospheric vapour, and clouds, the absorption of anthropogenic heat will be supported by the sole back and forth evolution of water evaporation-condensation equilibria with progressive shift towards formation of more and thicker clouds with no dramatic global changes of averaged temperature for a while. Then, the layer of clouds will become so thick that it will screen and reflect more and more solar energy and thus will cause cooling of the environment, with, at the end of the process, reformation of ices as it was in the distant past (Bardeen & Garcia, et al., 2017).

Impact on Humanity and Economy

If global annual AHR is high enough to justify ice loss and increased climate perturbations as suggested before, replacing fossil sources of energy by carbon-free sources to fuel the future energy demand ecologically may appear like using a plaster cast on a wooden leg. As a matter of fact, Earth looks suffering of a kind of cancer and the tumour is humanity because of a quasi-exponential growth of population and a bulimia of energy whose negative effects on the planet go get worse if nothing is done. It is the origin of the new harm (the total anthropogenic heat energy dissipated in the environment) and the excessive demand of energy that will have to be treated. The economy will have to be curbed in order to reduce the production of goods and of energy-consuming means needed today to provide remunerative work and to satisfy the lure of profit. Consequences are well discussed in a recent newspaper article (Brook & Schwartz, 2020) even if the threat is related to greenhouse gas and not AHR. Greenhouse heat or AHR or both, it appears necessary to act without waiting for Nature to limit the human population and its worship of consumption otherwise increasing anthropogenic heat might lead to humanity disappearance as it may have been for dinosaurs in the distant past (Chiarenza & Farnsworth, 2020). Considering the stock of ices and the amount lost during the selected 23 years, total disappearance of ices is not for the coming century but excessive growth of energy consumption may very well contract the time scale.

Conclusions

Taking into account chemistry and thermodynamics fundamentals combined with published global data led to the conclusion that annual AHR was large enough to justify a large part of ice losses observed over 23 years between 1994 and 2017. The heat balancing role assigned to conductive heat exchanges and to equilibria of water phase transitions led to propose maintenance rather than increase of global atmospheric temperatures at least in the close future. It also suggested that turbulences should be increased with local consequences worsened in frequency and intensity. The Sun governed the climate for billions of years with ups and downs. The novelty is that during the last hundred and fifty years or so, humanity has been freeing increasing parts of the huge heat energy stored in fossil or radioactive compounds. Coming in addition to the action of the Sun energy, AHR will more and more alter the climate ups and downs evolutions in force for billions of years if it continues to grow over the future years. The emphasized trends are not proofs but a few years should be enough to confirm or refute the roles assigned to conductive thermal exchanges and physical phase-transfer equilibria, especially if annual ice imbalance progresses while the sources of anthropogenic CO_2 are driven down as expected from efforts to abandon carbon-containing sources of energy.

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Conflict of Interest

The author does not have any conflict of interest to report

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