Climate Changes in Recent and Distant pasts Depend on the Management of Heat Supplies by Water, not on a CO2-based Radiative Forcing

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Abstract:

Global warming due to carbon dioxide-based radiative forcing did not resist to a critical analysis largely based on fundamentals of chemistry, physics and thermodynamics. This finding led to giving water an essential role in an alternative mechanism in which heat and not CO_2 is climate determinant. This mechanism is based on ice ↔ liquid water and liquid water ↔ vapor interphase equilibria combined with the physics of infrared waves when they pass through the atmosphere. Accordingly, future global average temperature and ocean level rises should be smaller than predicted in the case of radiative forcing. Climatic events depending on chaotic perturbations, increases in strength and frequency are expected if anthropogenic heat releases become significant relative to solar heat supplies. Applied to distant past climate fluctuations, the water-based heat-management mechanism showed that ice melting, evaporation and humidity also determined the ups and downs of temperature and ocean level during glaciation-deglaciation alternating periods. The present times are part of the last post-deglaciation pseudo plateau in which variations of global temperature are limited to ± 2°C, a range respected during the last 8,000 years, including the recent industrial era, and comparable to plateau periods in distant past. It is in this plateau period that anthropogenic heat releases are presently complementing historical heat supplies from the Sun. Heat being a physical phenomenon independent of the sources, global temperature and level of oceans should continue to vary within the rather narrow ranges typical of past plateau periods provided anthropogenic heat releases remain negligible relative to solar supplies. If it is not the case, ice melting and evaporation may become unable to compensate anthropogenic heat supplies. The + 2°C limit would then be exceeded with progressively more evaporation, more winds, more hurricanes, more tornadoes, more clouds, more rains, more floodings and droughts, and at the end shortening of the time to next glaciation. Trend may seem already manifest on the basis of local recent climatic events felt unusual. However, the stock of ices is such that the evolution should extend over several centuries, may be more if evaporation acts in complement.

Keywords: global warming, radiative forcing, anthropogenic heat releases, waste heat, paleoclimatology

Key points

- Carbon dioxide-based radiative forcing as source of global warming do not resist to critical analysis based on fundamentals of chemistry, physics and thermodynamics

- Thermal properties of water, water interphase exchanges, formation of clouds and radiative elimination to space control heat supplies and climate changes since water is present on Earth
- Anthropogenic heat releases should not affect much temperature and ocean levels provided they remain negligible relative to solar heat supplies, but heat-dispersing local climatic vents should increase in strength and frequency

1. Introduction

So far, important climate changes in distant decades are predicted by the Intergovernmental Panel on Climate Change (IPCC) in reports issued from an international consensual exploitation of available meteorology and climatology literatures. The claimed global warming is presently assigned to a difference between inputs and outputs of electromagnetic infrared radiations (IR) caused by an anthropogenic surplus of atmospheric greenhouse gas limited to carbon dioxide (CO_2). The process results is a radiative forcing that warms atmosphere and environment since carbonaceous compounds, in particular fossil ones, are burned to produce energy. (IPCC, 2014; NASA, 2009; Mackenzie & Lerman, 2006). So far, the heat generated by cumulated radiative forcing is considered primarily stored in oceans (Hansen, et al., 2011; Trenberth et al., 2014; IPCC, 2022). The last AR6 report published by the IPCC in 2022 states that "*ocean warming accounted for 91% of the heating in the climate system, with land warming, ice loss and atmospheric warming accounting for about 5%, 3% and 1%, respectively (high confidence)*". The report indicates an average rise of temperature of 0.02°C for an annual average radiative forcing of 0.79 [0.52 to 1.06] W/m^2 over the period 2006–2018. So far, ice loss has been considered a source of ocean rise in parallel to temperature-dependent dilatation (Allan & Liepert; 2010), the ability of ice melting to absorb heat being neglected. Yet, ice melting is a powerful heat absorbent. Global disappearance of ice is now certain, especially over the recent years. It concerns ice caps, sea ice, glaciers and permafrost (Rignot et all, 2019). Also neglected is anthropogenic heat (AH) released at the production and the exploitation stages of the energy needed by humanity to fulfil needs of comfort, techniques and work.

Earth is too complex to be represented experimentally. Calling on climate models combining hypotheses and calculations was necessary. The method was selected by climatologists to elaborate their predictions and is still exploited despite more and more critics emitted by scientists of other disciplines. To overcome hypotheses and calculations, we recently considered a different approach based on estimates of annual global energy consumptions derived from various sources (fossil ones, biomass, electricity, etc.) (Vert, 2021) and on global ice imbalance, a better marker of climate changes than temperature and ocean level variations that are still very small. In other words, heat was taken as a general phenomenon relevant to physics and thermodynamics and not as a particular phenomenon due to greenhouse effect and radiative forcing. The result was an alternative mechanism of heat management based on water and water interphase equilibria that led to a different vision of climate changes (Vert, 2022a).

Until recently, heat on Earth was taken into account in terms of radiative energy inputs and outputs expressed in W/m^2, anthropogenic heat releases (AHR) being considered negligible. However, this vision is changing. AHR are more and more involved but only as part of local heat budgets (Yang et al, 2017; Liu et al., 2021). Prior to showing that the new mechanism of heat management based on water can also explain glaciation-deglaciation cycles that occurred in distant past, let us consider some unusual reasons to doubt of the mechanism of radiative forcing and to look for a new mechanism.

2. Doubts and critics about CO_2-related greenhouse effects

2.1 Global CO_2 concentration in the atmosphere

The averaged global atmospheric concentration in CO_2 is mostly determined from data collected at 3,400 meters on the slop of the Hawaiian Mauna Loa volcano. These data are expressed in moles/moles of atmospheric gas after various data adaptations including elimination of humidity. The annual global CO_2 concentration thus obtained progresses rather regularly with seasonal zig-zags (Fig. 1). The present concentration is around 415 ppmv, a value generally considered similar in stratosphere and troposphere. However, CO_2 is not distributed uniformly as shown by a visualization proposed by the NASA Center for Climate Simulation (NASA, 2017). This visualization consists in a combination of OCO-2 satellite and GEOS model data that yielded the first 3D dynamic picture of carbon dioxide throughout the Earth's atmosphere between November-2014 and August-2015. According to this 3D video, carbon dioxide was primarily present in the Northern hemisphere with a concentration high in Winter and Spring, low in Summer and Autumn, dependent on latitude, longitude and altitude. On another hand, the Mauna Loa volcano is located in the middle of the Pacific Ocean in a zone where high winds blow often directly or indirectly from the West after passage above China which is now the main producer of anthropogenic CO_2 in the world (Ritchie, 2019). Whether the rather regular increase of the Hawaiian averaged CO_2 concentration may depend on the growth of Chinese CO_2 releases in the atmosphere has not yet been discussed to the most of our knowledge, although trends in Figure 1 look in favor of some relation.

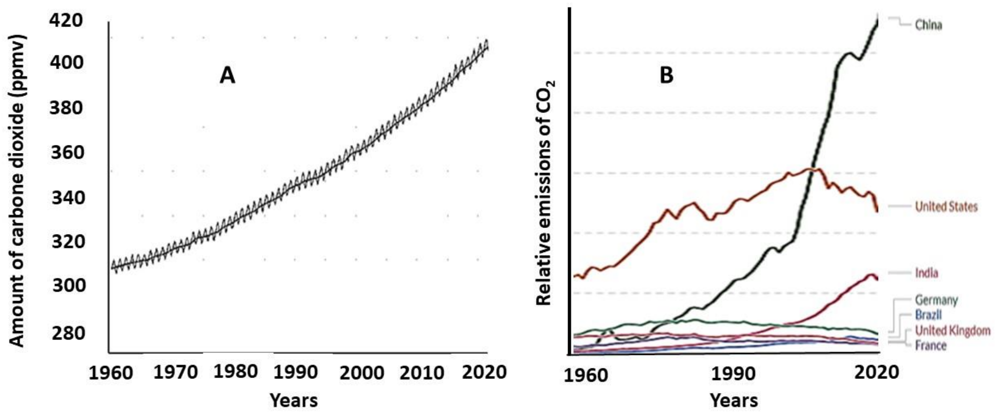

Figure 1: A) Evolution of the average concentration in carbon dioxide around the Mauna Loa volcano (Lindsey, 2022); B) Variation of the emission of CO_2 by China and other countries during the last decades compared to other producing countries (Ritchie, 2019)

2.2 Ocean level rise

The annual rise of ocean level is presently about 3.7 mm, an estimate deduced from averaged satellite data. The global rise between 1901 and 2018 was not more than 20 cm, a rather low value deduced from estimates affected by a change of method to collect data. These estimates are based on disappeared ice and on thermal dilatation of oceans (IPCC, 2022). They do not take into account water evaporation that works against dilation. Yet, ice melting and water evaporation play important roles in the control of the thermic effects of heat supplies as exemplified by the melting of an ice cube in a glass of water or by the evaporation of sweat that allows to keep the human body at 37°C, or by the evaporation of water from a swimming pool on a sunny day in summer, the rate of evaporation being too small in this latter case to avoid water warming.

2.3 Ices loss

This phenomenon is often assessed and discussed relative to the surface areas of Arctic and Antarctic ices, and to glaciers receding (Scott et al., 2016). However, the energy exchanges during the melting of land ices depend on mass and on thickness and not only on surface. The global loss of ices was recently estimated at the level of 28,000 Gt between 1994 and 2017 (Slater et al., 2021). To melt at 0°C, this amount of ice needed or absorbed 9.34 ZJ of thermal energy a value rather close to the 7.2 ZJ anthropogenic heat estimated from the energy consumed over the same period deduced from all sources converted in oil equivalents (BP, 2019; Vert 2021). During the same period, the CO_2-based radiative forcing was estimated about 170 ZJ from data provided in (IPCC, 2022). Therefore, one can conclude logically that much more ice should have disappeared if the amount of heat to be absorbed was 170 ZJ. The large excess of heat not absorbed by ice melting may have been absorbed by evaporation of surface water, another well-known heat absorbing physical phenomenon. As far as we know, water interphase equilibria have not yet been taken into account in the context of global warming and climate control. The last AR6 IPCC report even states that: "*it is virtually certain that evaporation will increase over the oceans*". This is all.

2.4 Greenhouse effect

In physics, the greenhouse effect is observed when a closed space is irradiated from outside by infrared waves going through a transparent window. Some of the transmitted infrared radiations interact specifically with the inner gas that can absorb some of these radiations. The interior is then overheated because of lack of the convection that, normally, disperses heat in an open environment.

The greenhouse effect exploited by climatologists is different. The atmospheric CO_2 captures some of the infrared radiations emitted by the surface of the Earth previously warmed by the Sun. These radiations excite CO_2 molecules that release the captured radiative energy by reemitting the same waves in all directions so that half of the initial radiative energy returns to the surface and causes radiative forcing whereas the other half goes to space. Such mechanism does not respect some fundamentals of modern physics of electromagnetic waves. In particular, it does not take into account the Beer's laws that governs the absorption of electromagnetic waves by a mixture containing an absorbing substance (for instance a so-called greenhouse gas in the atmosphere). The absorbance of such a mixture in which the absorbent is at concentration **C** varies according to the relation:

$$\mathbf{A = \log (Io/I) = \varepsilon_\lambda . L . C}$$

where **Io** is the intensity of a radiation characterized by its wavelength λ, **I** is the intensity of the radiation for a pathlength **L** inside the absorbing medium, **A** is the absorbance, ε_λ is the absorptivity at the wavelength specific of the absorbing medium.

All other things being equal, this law shows that doubling the concentration in CO_2 in the atmosphere halves the distance to total absorption but the amount of absorbed energy $\mathbf{I_0}$ is the same in both cases and not doubled.

Therefore, in terms of modern physics, CO_2 is not a greenhouse gas. It is a gas the molecules of which absorb specific IR radiations under the form of discrete vibrational excitations. The excited molecules reemit the absorbed radiative energy that is partly turned to kinetic energy that increases the Brownian motion of surrounding atmospheric molecules, including the non-absorbent oxygen and nitrogen ones. The increased agitation of atmospheric molecules is reflected by a rise of local temperature. As IR absorbents, CO_2, methane, ozone, and water vapor are all sources of atmospheric heating according to their respective structural and thermal characteristics and also to their location in the various parts of the atmosphere. Amid the atmospheric gas, water vapor is the most efficient IR absorbent in the low troposphere. Therefore, it must be an important source of atmosphere heating by absorption of specific solar IR radiations on the way in. On the way out, IR radiations emitted from the surface cool it and warm the atmosphere but, in this case, $\mathbf{I_0}$ is much smaller that solar $\mathbf{I_0}$, the ratio of $\mathbf{I_0}$s being not proportional to the ratio of the temperatures of the sources.

2.5 Atmosphere and environment heating

Earth was formed about 4.5 billion years ago. Half a billion year later, atmosphere and water appeared followed by the first living organisms. Since then, the global climate fluctuated with alternating warm and cold periods as shown by paleoclimatologists. About two centuries ago, anthropogenic heat started being injected in the environment as complement to the dominant solar heating. AHR includes many sources of heat and waste heat. For instance, trains and cars, thermic and nuclear plants, boats, planes and space rockets, missiles and bombs, computers, data storage centers, arson, humans, and cattle, are all sources of heat that warm atmosphere and environment. Among these different sources of heat energy, natural ones (Sun, volcanoes, forest fires …) are characterized by discontinuities in supplies like during day and night, summer and winter, or between eruptions and fires. The regime of anthropogenic heat releases is rather different with some sources almost permanent in average, like those related to transports and energy production, and others mismatched with natural sources like heating during the night or in winter when the Sun is less active. In physics, heat is a phenomenon independent of the origin of supplies. Therefore, we came to the conclusion that heat supplies to Earth and thus climate changes must depend on a unique mechanism regardless of the origin of the sources of heat. Noteworthy, the independency of heat relative to sources is not respected by the mechanism of radiative forcing that is completely different from the mechanism of solar heating.

3. A unique mechanism of heat management on Earth

In the climate literature, temperature is sometimes confounded with heat. Temperature is a parameter that reflects the equilibrium obtained after heat transfer from hot to cold media in contact. Therefore, the temperature depends on relative masses and on thermal properties of the media in contact.

According to the previous critical analysis, water and water interphase equilibria were selected as suitable means to absorb heat on Earth and to control climate changes. Water was thus given a role of refrigerant comparable to that of the volatile compound the thermal properties and interphase equilibria of which allow to maintain the temperature determined by the thermostat inside a refrigerator (Vert, 2022a).

Figure 2 summarizes schematically the management of heat independently of the sources. The process is characterized by interdependent successive stages, namely: - compensation of any supply of heat to the environment by ice melting and liquid water evaporation; - cloud formation after condensation of the evaporated warm humid air that transfers heat from the surface to a cold zone in altitude where humidity (the concentration in water vapor) is low enough to facilitate heat radiative elimination from the top of clouds to space through the window of transparence specific of IR radiation emitted by water. When for any reason, heat is added to the atmosphere or the environment, it tends to be compensated by ice melting first followed progressively by evaporation with at the end formation of more and more clouds. The cloud layer is a key factor in terms of global climate because of cooling due to solar radiations screening on the way in and heating due to the blockade of IR surface radiations on the way out, the consequences of which are familiar to meteorologists.

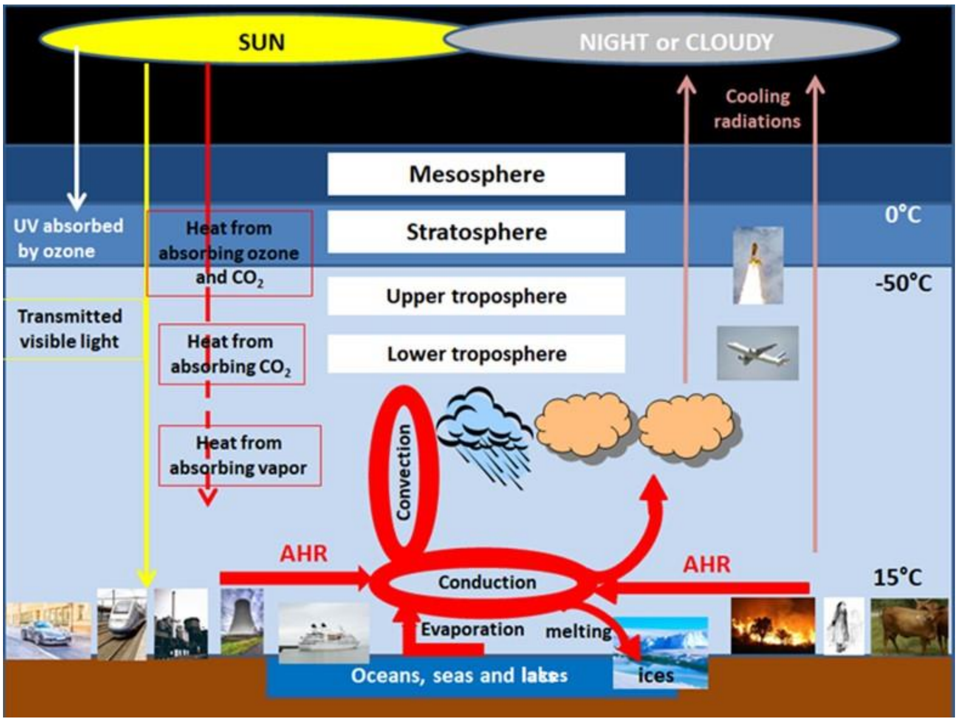

Figure 2. Schematic representation of the water-based management of solar and anthropogenic sources of heat that allows to account for the still very low rises of global average temperature and ocean level while ices are disappearing importantly (Vert, 2022b).

Basically, the average temperature should be kept constant. However, on Earth, constancy is precluded by various factors that affect ideality. Let us mentioned the huge size of the planet unfavorable to heat homogenization, the fluctuations of winds and ocean streams, the chaotic heat dispatching at the origin of local climates, and the variations of solar cycles and position of Earth relative to Sun. Overall, the average temperature varied but there was no accumulation of heat in distant past. During the last two centuries, more and more anthropogenic heat and waste heat from dramatic carbonaceous fossil compounds and, more recently, from electricity, was injected in the low atmosphere at both the production and the exploitation stages. In parallel, only about 30-35,000 GT of ices were lost. This loss looks dramatic presently but it is still very small with regard to the 30 million GT estimate of ices present in the cryosphere. Basically, the potential of heat absorption is so high that anthropogenic heat should not affect the climate much more in the future than in the recent past provided AHR remain negligible relative to solar heat supplies, evaporation being available to complement ice melting if necessary.

A paleoclimatologist who reviewed positively a previous paper that was nevertheless rejected found the idea of climate control based on water of interest. Despite the absence of further comments, his remark drew my attention to distant past climates.

4. The distant past climate evolutions in the light of the water-based mechanism

The previously section was limited to the last 200 years period with AHR releases. The distant past concerns billions of years exemplified by the last 400,000 years presented in Figure 3 constructed from the literature.

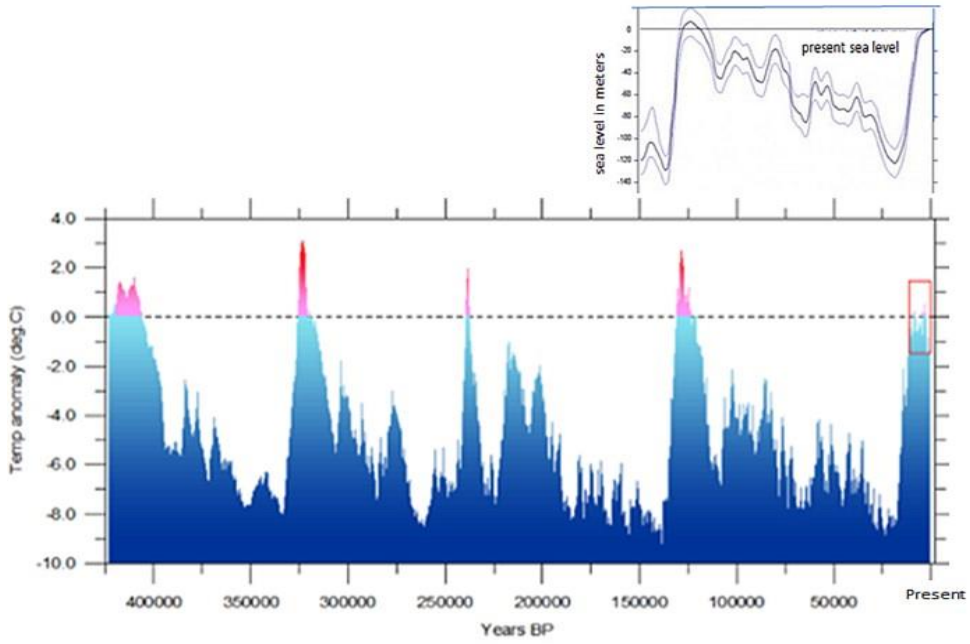

Figure 3: Reconstructed global temperature over the last 420,000 years based on the Vostok ice core from the Antarctica (Petit et al., 1999) associated with the sea level variations reconstructed from (Waelbroek et al., 2002) for the sake of comparison over the last 150,000 years.

The temperature changes and sea level variations during the 150,000 years of the last glaciation-deglaciation period were related as suggested by the similarity of the profiles compared in Figure 3. The application of the water-based management of heat supplies to such a cycle is schematically presented in Figure 4.

Let us start the cycle at the time of maximum glaciation (bottom). A large part of the water is under the form of ice whereas temperature and ocean level are very low and atmospheric humidity absent. In absence of IR absorbing water vapor, solar radiations are not screened and thus the temperature rise is rather fast, meaning within about 10,000 years. When it is well advanced, deglaciation leads to plateauing because humidity is back. Temperature and ocean level fluctuations are now controlled as they are today according by the water-based heat management mechanism described in the previous section.

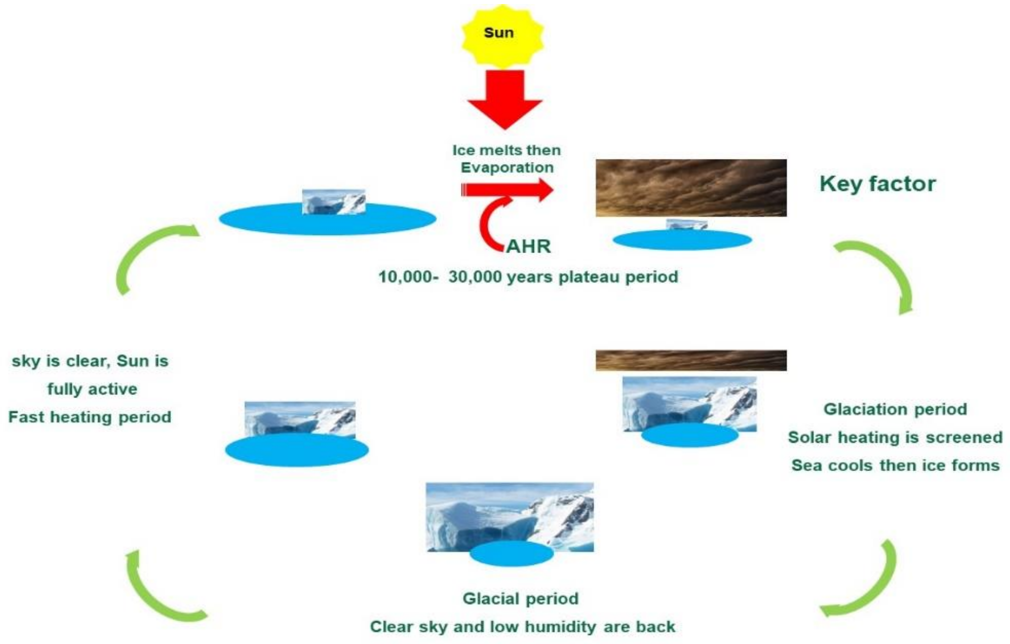

Figure 4: Schematic representation of one of the distant past glaciation-deglaciation cycle shown in Figure 3.

Since the Sun continues to supply heat, more ice melts, more evaporation occurs and more clouds are formed. When the cloud layer is important enough to screen the Sun, cooling become dominant the pseudo-plateau ends and the glaciation period starts. The temperature decreases progressively but the change from clouds to ices needs more time than ice to water ones during deglaciation because several dynamic exchanges are involved, namely coalescence of cloud water droplets to liquid water, raining or snowing, glaciation at about 0°C and cooling the new ice up to the cold ambient.

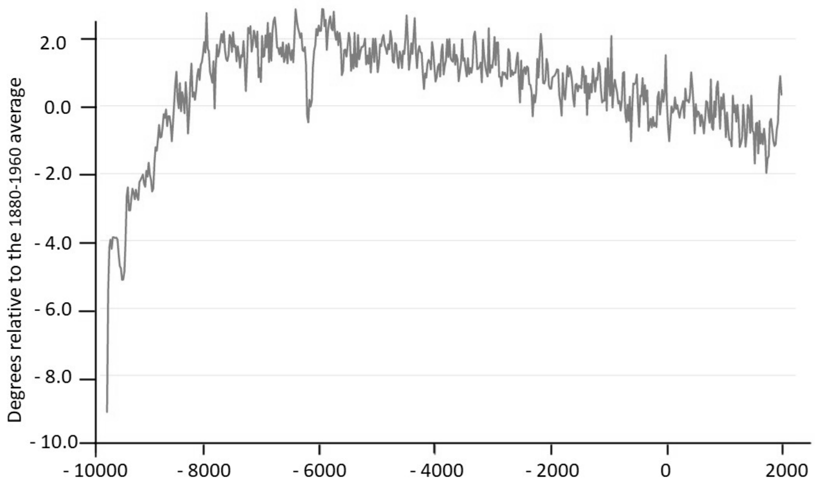

Figure 5: Greenland temperature reconstruction using proxy data from six ice cores (Vinter et al.). Data spans the past 10,000 years with a resolution of 20 years. The timescale corresponds approximately to the small square on the right side of Figure 3.

At the end, glaciation is maximal again and a new deglaciation-glaciation cycle starts. Figure 3 also shows that we are presently somewhere in the last post-deglaciation pseudo-plateau that started about 8,000 years ago as shown by Figure 5 where temperature fluctuations remained smaller than 2°C and thus limited to a rather narrow range compared with interglacial periods as it was for pseudo-plateau zones of anterior cycles shown in Figure 3. The present times are somewhere in the last pseudo-plateau the end of which is not predictable. Anterior cycles suggest 10 to 30,000 years. Anthropogenic heat is presently injected in between with no dramatic consequences so far.

If, in the future, AHR becomes important relative to solar supply, the surplus of heat to be absorbed will cause greater loss of ice and more evaporation source of more clouds leading to more precipitations with, in parallel, more frequent periods of opposed climate perturbations like droughts and floodings or high and low temperatures in different zones of the globe. Such an evolution should lead to earlier cloud screening, and thus earlier start of the next glaciation phase than in the case of the sole historical solar supply. As underlined in the previous section, such evolution is not for now on the basis of the huge stock of ices still present today.

A similarity between the variations of CO_2 concentration and atmospheric temperature in distant past was mentioned in the literature (Petit at al., 1999). Such correlation can be hardly considered as reflecting a causal relationship between CO_2-based radiative forcing and climate changes because a relation also exists between CO_2 solubility and temperature. The higher the temperature, the lower the solubility in water, and thus the higher the concentration of CO_2 in the atmosphere.

5. Conclusion

The present work confirms the lack of consistency of the CO_2-related radiative forcing emphasized in open literature. Main reasons are incorrect exploitation of the absorption of electromagnetic waves crossing an absorbing medium; neglection of ice melting and of evaporation as efficient heat absorbents, and discordance between ice loss and radiative forcing thermal energies. It was further shown that natural heat supplies (solar, volcanic and wild forest fires) and anthropogenic waste heat generated from the production and the exploitation of the energy necessary to satisfy the needs of comfort, of techniques, and work, depend on a unique mechanism that involves ice ↔ liquid water and liquid water ↔ vapor interphase exchanges. According to this mechanism, global average temperature and ocean level rises should be smaller in the next decades than in the case of radiative forcing. In contrast, local climate events should increase in strength and frequency to disperse the surplus of heat, an evolution that seems already perceptible but not yet proved. The water-based mechanism was developed with regard to the industrial era. It appears now suitable to account for the ups and downs of temperature and ocean level in the successive glaciation-deglaciation periods, and the absence of heat accumulation in distant past. The possibility to extend the mechanism to distant climatic phenomena gave solidity to the new mechanism. Last but not least, original arguments are proposed to consider anthropogenic waste heat and not CO_2 concentration as the right target to minimize the risk of intolerable climate perturbations in the future relative to historical ones.

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Data availability statement

- BP Statistical Review of World Energy, 2019. 68th Edition, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

- IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland. https://www.ipcc.ch/assessment-report/ar5/

- IPCC, 2022: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S., Berger, N., Caud, Y., Chen, L., Goldfarb, M.I., Gomis, M., Huang, K., Leitzell, E., Lonnoy, J.B.R., Matthews, T.K., Maycock, T., Waterfield, O., Yelekçi, R. Yu, and B. Zhou (eds.)]. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

- Lindsey, R., 2022. Climate Change: Atmospheric Carbon Dioxide, *NOAA*. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

- NASA Earth Observatory, 2009. The Atmosphere's energy budget. https://earthobservatory.nasa.gov/features/EnergyBalance/page6.php.

- NASA Center for Climate Simulation, 2017. Carbone dioxide in 3D, https://svs.gsfc.nasa.gov/12445

-Richie, H., 2019. Who emits the most CO_2 today? *Our World of Data*, https://ourworldindata.org/annual-co2-emissions

References

BP Statistical Review of World Energy, 2019. 68th Edition, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

Hansen, J., Sato, M., Kharecha, P., von Schuckmann, K., 2011**.** Earth's energy imbalance and implications. *Atmos. Chem. Phys.* 11, pp. 13421–13449. https://doi.org/10.5194/acp-11-13421-2011

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/assessment-report/ar5/

IPCC, 2022. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S., Berger, N., Caud, Y., Chen, L., Goldfarb, M.I., Gomis, M., Huang, K., Leitzell, E., Lonnoy, J.B.R., Matthews, T.K., Maycock, T., Waterfield, O., Yelekçi, R. Yu, and B. Zhou (eds.)]. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf

Lindsey, R., 2022. Climate Change: Atmospheric Carbon Dioxide, *NOAA*. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Liu, B., Xie, Z., Qin, P., Li,R., Wang, L., Wang, Y., Jia, B., Chen, S., Xie, J., 2021. Increases in anthropogenic heat release from energy consumption lead to more frequent extreme heat events in urban cities. *Adv. Atmos. Sci*., 38, pp. 430-445. https://doi.org/10.1007/s00376-020-0139-y

Mackenzie F.T., Lerman A., 2006. Heat Balance of the Atmosphere and Carbon Dioxide. In: Carbon in the Geobiosphere — Earth's Outer Shell —. *Topics in Geobiology*, Vol. 25. Springer, Dordrecht, Chap. 3. https://doi.org/10.1007/1-4020-4238-8_3.

Martin-Amouroux, J.M., 2015. Consommation modiale d'énergie 1800-2000 : Les résultats., *Encyclopédie de l'Energie*, Ecole Nationale Supérieure de l'Energie, l'Eau et l'Environnement. https://www.encyclopedie-energie.org/consommation-mondiale-denergie-1800-2000-les-resultats/

NASA Earth Observatory 2009. The Atmosphere's energy budget. https://earthobservatory.nasa.gov/features/EnergyBalance/page6.php.

NASA Center for Climate Simulation, 2017. Carbone dioxide in 3D, https://svs.gsfc.nasa.gov/12445

Petit, J.R., Jouzel, J., Raynaud, D., Barkov, N.I., Barnola, J.M., Basile, I., Bender, M., Chappellaz, J., Davis, J., Delaygue, G., Delmotte, M., Kotlyakov, V.M., Legrand, M., Lipenkov, V., Lorius, C., Pépin, L., Ritz, C., Saltzman, E. and Stievenard, M., 1999. Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica, Nature, 399, pp. 429-436. http://dx.doi.org/10.1038/20859

Richie, H., 2019. Who emits the most CO_2 today? *Our World of Data*, https://ourworldindata.org/annual-co2-emissions

Rignot E., Mouginot J., Scheuchl B., van den Broeke M., van Wessem M.J., Morlighem M. 2019. Four decades of Antarctic Ice Sheet mass balance from 1979–2017. *PNAS. 116*, pp. 1095-1103. https://www.pnas.org/content/116/4/1095

Scott, M., Hansen, K., Steven, J., Simmon, R., 2016. Sea Ice by NASA. https://earthobservatory.nasa.gov/features/SeaIce/page1.php

Slater, T., Lawrence, I. R., Otosaka, I. N., Shepherd, A., Gourmelen, N., Jakob, L., Tepes, P., Gilbert, L., Nienow, P., 2021. Review article: Earth's ice imbalance. *The Cryosphere, 15*, pp. 233–246. https://tc.copernicus.org/articles/15/233/2021/

Trenberth, K., Fasullo, J.T., Magdalena, C., Balmaseda, A., 2014. Earth's Energy Imbalance. *J. Climate*, *27*, pp. 3129-3144. https://doi.org/10.1175/JCLI-D-13-00294.1

Vert, M. 2021. Relation between Global Anthropogenic Heat Release and Ices Disappearance; Consequences on Climate and Economy. *ESS Open Archive*, April 17, 2021. DOI: 10.1002/essoar.10506806.1

Vert, M., 2022a. Refrigerator as Model of How Earth's Water Manages Solar and Anthropogenic Heats and Controls Global Warming, ESSOAr, published on line, https://doi.org/10.1002/essoar.10507521.3

Vert, M., 2022b. A Different Vision of the Global Warming Based on Chemistry, Physics and Thermodynamics. *International Journal of Energy and Environmental Science*. *7,* pp. 74-79. http://www.ijoees.com/article/602/10.11648.j.ijees.20220705.11

Vinther, B., Buchardt, S., Clausen, H. et al. 2009 Holocene thinning of the Greenland ice sheet. Nature 461, 385–388. https://doi.org/10.1038/nature08355

Yang, W., Luan, Y., Liu, X. *et al.* 2017. A new global anthropogenic heat estimation based on high-resolution nighttime light data. *Sci Data,* 4, 170116. https://doi.org/10.1038/sdata.2017.116

Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J-C., McManusc, J.F., Lambeck, K., Balbon, E., Labracherie, M., 2002. Sea-level and deepwater temperature changes derived from benthic foraminifera isotopic records, *Quaternary Science Reviews*, 21, pp. 295-305. doi.org/10.1016/S0277-3791(01)00101-9