The Earth's Imbalanced Heat Budget and its Relationship to Past, Present and Future Climate Change

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Abstract: Climate changes predicted by the International Panel on Climate Change are currently linked to the growth of an excess of carbon dioxide in the atmosphere, as successive reports have asserted. The forecasts are based on an unusual exploitation of greenhouse physics that results in ocean warming due to radiative forcing. In the absence of experimental support, the mechanism and predictions are universally adopted but only by consensus. Many scientists have opposed the consensus on the grounds that the bases do not respect the fundamentals of hard sciences. Recently, we proposed an alternative mechanism in which the radiative forcing due to carbon dioxide is replaced by heat, a fundamental phenomenon in physics and thermodynamics. According to this new mechanism briefly recalled, heat is managed on Earth by water and its interphase equilibria, whatever the sources. Previously developed for the present, it is used here to show that the Earth's heat balance, hitherto said to be balanced in terms of radiative flux inputs and outputs, has never been balanced in terms of heat. The thermal imbalance in the distant past was estimated from the energy necessary for the melting of the ice during the last deglaciation, during the current Holocene interglacial plateau, and between 1994 and 2017. The melting of the ice progressed almost linearly during the first 80% of the deglaciation period with a slow decline towards near-steady-state during the Holocene. Estimates of ice loss over the period 1994-2017 showed that the imbalance is increasing again, a feature that should lead to a proliferation of sun-obscuring clouds followed by the inversion of the imbalance required to initiate the next ice age. The confirmation of the disqualification of carbon dioxide as a source of global warming could put back in the saddle certain applications currently penalized due to the production of this gas. In any case, it is the fight against anthropogenic heat sources that should be promoted in the future.

Keywords: global warming, paleoclimatology, heat management, thermal infrared radiations, glacial cycles,

Key Points

* The Earth budget is said to be balanced in terms of radiative input and output, but it is not balanced when thermal infrared waves present in solar irradiation are converted to heat.

* The thermal imbalance on Earth, significant during past glaciation periods, was almost stable during the Holocene interglacial plateau but is currently increasing again en route to the reversal necessary to cause the next glaciation

* Thermal imbalance provides credible justifications of glacial cycles and Holocene climate changes but leaves open the question of the responsibility for increased anthropogenic heat.

I Introduction

Climate change is a source of concern, as it is currently linked to an increase of atmospheric carbon dioxide (CO_2) attributed to human activities. Excessive carbon dioxide in the atmosphere is believed to be the cause of global warming at the origin of dramatic climate forecasts for coming decades. Both the mechanism and the forecasts result from successive reports issued by the Intergovernmental Panel on Climate Change (IPCC), an organization created in 1988 with the mission of assessing and exploiting the climatology publications fund [1]. In the absence of experimental support, the forecasts come solely from hypothesis and models in which a greenhouse effect, different from that well known in physics, and the resulting radiative forcing stored in oceans play essential roles. There are many reasons to contest this mechanism [2], not least because it lacks scientific consistency and does not respect the fundamentals of hard sciences [2]. This may be due to the fact that climatology is a field where state of the art and advances are not discussed in a multidisciplinary and contradictory manner in national or international congresses and conferences, unlike what is usually done in science. Until now, protest arguments, generally considered to be signs of climate skepticism, were mainly limited to the "state of the art" in the absence of alternative mechanism.

To fill this gap, an alternative mechanism has recently been proposed [3] in which heat is the physical phenomenon that warms the planet, while water and its interphase equilibria are the means by which heat is managed until radiative removal in space is possible. Water exists in solid, liquid and vapor physical forms in the environment and in the atmosphere, unlike CO_2 and other greenhouse gases (GHGs), which are only gaseous. In the hard sciences, melting of ice and evaporation of liquid water are recognized as highly efficient heat absorbers and transmitters. Based on these undisputable facts, it has been demonstrated that the role of water in heat management on Earth is comparable to that of the volatile refrigerant operating in a refrigerator to absorb internal heat and release it to the outside through evaporation-condensation cycles [4]. This new vision had several important consequences.

First, on Earth, the melting of ice in combination with evaporation and condensation phenomena absorb and manage the natural heat inputs (solar, volcanic, and from forest fires) since water and life exit on Earth. Today, the anthropogenic heat inputs are added that must be managed by the same mechanism.

Second, while solar irradiance passes through space unchanged, some waves are more or less absorbed specifically as soon as they encounter molecules and matters present on Earth, including GHGs present in the air. Despite this undisputable fact, it is common strategy to consider the solar irradiance in its entirety when discussing the Earth's Heat Budget. This means that visible light is capable of heating atmosphere and land, which is obviously not observed in the environment. Reflection and diffraction are taken into account, but the selection of waves by absorption and the conversion of thermal infrared ones in heat are not. Physics teaches us that a thermal infrared radiation with a wavelength in the range of about 4 to 30 µm is absorbed (its intensity decreases proportionally to the concentration in absorber and to the path length) to generate heat. The process reflects an energetic harmony between the radiative energy of such a wave and the discrete interatomic vibrational energy of an asymmetric transition forming an electric dipole. Therefore, water vapor that absorbs strongly thermal infrared waves is an absorber (greenhouse gas) in reality much more efficient to generate heat than CO_2. Despite this essential property, water vapor is neglected in climatology [1] and by NASA as well [5] because its residence time in the atmosphere is too small, particularly relative to the long-lived CO_2. This is not correct because in chemistry and physics, it is the concentration that must be considered when it comes to interaction with and absorption by electromagnetic waves moving at the speed of light. Therefore, in addition to ice that cools the environment on melting, we have attributed to water vapor a major role in the water-based mechanism because when the temperature of the liquid water at the surface increases, evaporation tends to absorb the heat by generating warm vapor rising to a cooler zone to form clouds when local conditions are favorable. The result is a transfer of the heat from the surface to a cool zone from where it can be directly eliminated to space, notably through the 8-14 µm spectral transparency window specific of the atmospheric water vapor [6], or indirectly from clouds above which the concentration in water vapor is very small and favorable to radiative elimination of heat, as well schematized in a video [7]. Transparency above clouds or when the humidity is low has an unexpected advantage in the case of aircrafts flying high in the sky. Indeed, the heat due to hot CO_2 and hot water vapor ejected by the engines can be easily removed in space radiatively, a property that can mitigate the negative role attributed to aircraft in terms of radiative forcing of CO_2 and of carbon footprint. In other words, in terms of anthropogenic heat releases, an airplane at altitude could be more acceptable than a car on the surface, which remains to be proven quantitatively.

Third, whatever its origin, if the heat input into the environment increases, the ice stock decreases and gradually evaporation increases, as does cloud formation. In addition to being a source of heavier rainfall, or even flooding, a dense cloud layer can block thermal infrared radiation on the way in and out, a process that must first lead to a rise in temperature under the clouds followed by a rapid inversion towards cooling, as is easily felt in cloudy weather. If the cooling is severe, as in winter when solar heat gain is minimized by longer nights and a longer Sun-Earth distance, or when the night-time atmosphere is dry, icing occurs. The process is well illustrated by a dark, stormy sky under which a fairly high temperature suddenly drops, while ice stones form and eventually fall to the surface. Environmental events such as winds, hurricanes, tornadoes, air and ocean streams are the means by which heat is distributed and tend to average out local temperatures and meteorological differences. In reality, the average is largely limited by the size of the planet, the heterogeneity of its components and the involvement of chaotic phenomena affecting the air, seas and oceans. It remains to be seen whether the various recently identified anthropogenic heat sources are sufficiently large to worsen natural climate change [8].

The balance between the input and output of radiative fluxes is a fundamental basis of climatology. This is no longer the case when thermal infrared radiation is converted into heat. A good reason for this is kinetic. In space and in a transparent medium, electromagnetic waves travel at and near light speed, respectively. Conversely, heat exchanges and balancing occur through slow convection and conduction phenomena. Currently, the small variations in global temperature and sea level occurring during the Holocene are in favor of balance, but if we consider ice loss and glacial ups and downs in distant past, they point to time-dependence of thermal imbalance. Indeed, glacial cycles are characterized by changes in temperature and sea level of up to around 10°C and 120 m, respectively [9]. A complete cycle lasts between 120 and 150 thousand years (kyrs), according to the last four glaciations reported by paleoclimatologists [9]. A cycle is made up of a period of fairly rapid deglaciation lasting 10 to 20 kyrs, followed by an interglacial plateau lasting 10 to 20 kyrs and a period of very slow glaciation lasting at least 100 kyrs. The case of the pre-Holocene deglaciation that covered the period from -20 to -10 kyrs before the present (BP) is schematized in Figure 1. The preceding glaciation period was about 10 times longer, a difference attributed in part to the involvement of several interphase transitions not involved in the deglaciation process [2].

Monitoring climate change is difficult, if not impossible, because it depends on many factors, most of which are time- and location-dependent, such as solar heating, temperature, evaporation and cloud formation. The corresponding data vary from one source to another and, unlike in many other scientific fields, the extent of errors and uncertainties is difficult to quantify. Although far from perfect, solid ice is a better indicator of change. Although rare, *in situ* glacier mass balance surveys date back to the 1890s [11]. It was not until the 1970s that substantial records of changes in the cryosphere became available through satellite observations. The extent of ice shelves has been monitored by satellite imagery since the 1940s [12]. The extent of sea ice has been monitored by satellite since the late 1970s [13]. Changes in ice cap, ice shelf, sea ice and glacier thickness have been systematically recorded by satellite altimetry since the 1990s [14].

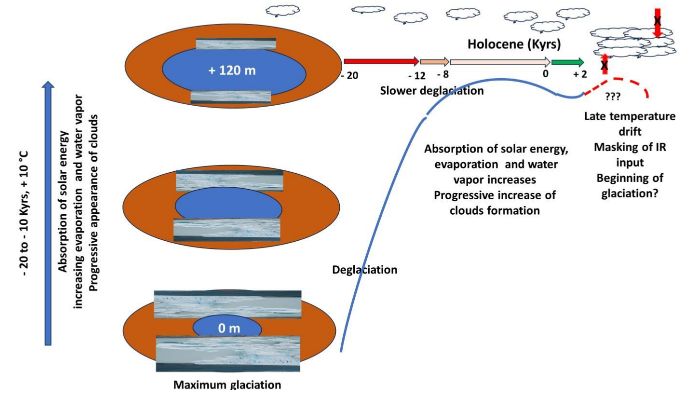

Figure 1: **Figure 1: Schematic representation of the temperature changes during the pre-Holocene and the current Holocene periods according to the water-based heat management applied in the distant past [9-10].**

In this work, we wanted to test the idea that, while the data may be questionable, the trends are sufficient to show that the radiative energy, which is balanced in climatology, is unbalanced once the absorbed infrared radiation part of the solar irradiance is turned to heat. The method is based on an estimate of the thermal energy required to melt the amount of ice that caused sea levels to rise during the last deglaciation period. To compare the evolution of the thermal imbalance during deglaciation until recent decades, the thermal energy required to cause a 120 m rise in ocean level was compared with the thermal energy during the Holocene and that required to cause the loss of 28,000 Gt of ice reported for the period 1994-2017, a multi-year period chosen to mitigate the effect of annual fluctuations [15]. Data were discussed in terms of anthropogenic heat releases evolution and the future of global climate change that will unavoidably leads to the next glaciation.

II Method and Results

II.1 Volume of water generated by ice melt during the last deglaciation

The surface area of oceans is about 361 x 10^6 km^2 or 3.61 x 10^{16} dm^2 (S1 in Fig. 2) [16]. The decrease of this surface was proposed to be 7 % to 9% when going from 0 to the -200 m level in the water above the average submerged shelf. The slope being greater close to the coastline [17], the variation of area between 0 and - 120 m was taken as 4.5 %. The surface at - 120 m was thus approximately 3.46 x 10^{16} dm^2 (S2). To determine the volume of liquid water generated during deglaciation, an equivalent cylinder 1200 dm high with a circular surface of 3.53 x 10^{16} dm^2 [(S1 + S2)/2] at - 600 dm was used (Fig. 2). The corresponding volume of water involved in the deglaciation process was thus about 4.24 x 10^{19} dm^3 coming from about 4.24 x 10^{19} kg of melted ice between the maximum of glaciation and today. To melt this quantity of ice, approximately 1.4141 x 10^{25} J or 14,141 ZJ were required according to the 333,55 kJ/kg specific heat of melting.

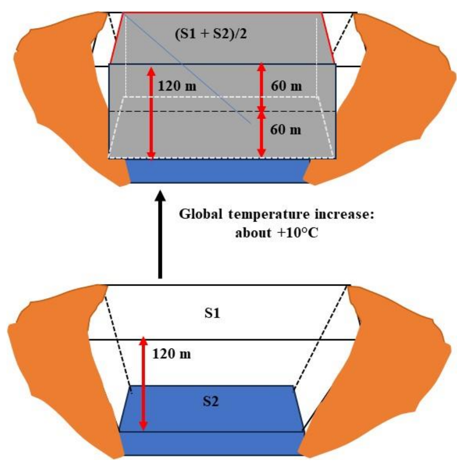

Figure 2: F

Schematic representation of the volume of water equivalent to the volume of water generated during the pre-Holocene deglaciation.

II.2 Thermal Energy necessary to melt 28,000 Gt of ice

The heat energy absorbed to melt the 28,000 Gt of ice or 28 x 10^{15} kg lost between 1994 and 2017 was about 9.34 x 10^{21} or 9.34 ZJ. The rise in ocean level due to the melting of the ground ice was about 35 mm, i.e. 1.5 mm/year [15].

III Discussion

III.1 The distant past

During the last deglaciation, melting was very active and formed liquid water which caused the ocean level to rise. The available data differ slightly from one source to another but we have retained respectively + 120 m of ocean level rise and +10°C of temperature rise [9,18]. These increases were rather rapid since they spread over around ten kyrs. Basically, the melting of ice indicates the presence of excess of heat mainly due to solar radiation and more precisely to the conversion of incoming solar infrared radiation into heat after absorption mainly by water vapor molecules [7]. In terms of ocean level change, the melt of floating ice has almost no effect. Only the land ice contributes. In contrast, in terms of heat absorption, the floating ice contributes significantly but its contribution was not included in our assessment because of inaccessibility. This drawback affected the consistency of the heat imbalance derived from the ocean level change but left the possibility of exploiting the trends for comparison purposes. According to our assessment, deglaciation involved 4.24 x 10^{19} kg of land ice, an estimate close to the 52 x 10^{6} km3 (about 4.7 x 10^{19} kg) determined by a more complex method applied to - 134 m ocean level at the maximum glaciation [18]. The melt of 4.24 x 10^{19} kg of ice required at least 14,141 ZJ of heat energy. During the first -20 and -12 Kyrs BP, atmospheric humidity was very low and the solar heating was thus very efficient over the icy areas. The ocean levels rose rapidly and almost linearly despite minor intermediate variations [18]. Between –20 and –12 Kyrs BP the annual thermal imbalance and the ocean rise were approximately 1.6 ZJ and 12.5 mm, respectively. Today the stock of ice on Earth is estimated at about 2.6 x 10^{19} kg [19-20]. Therefore, the amount of land ice lost during deglaciation was almost twice as large as the current stock. After a transition period of about 4 kyrs, the changes levelled off and the Holocene interglacial plateau was established with rather small ocean level and global temperature variations. Over the last 6 kyrs BP, the annual rise of the oceans was about 0.2 - 0.5 mm [21]. Meanwhile, temperature fluctuations were limited to a rather narrow ± 1°C range [22] even if the occurrence of minor intermediate warming has been reported [23-24]. In the case of archaeological studies cited in the AR4 IPCC report, Roman ruins built near sea level in Israel and the west coast of Italy suggest a mean eustatic component of 0.07 mm per year over the last 2000 years [25]. Taking 0.3 mm as the annual average ocean rise between - 6 and - 2 kyrs BP and 0.1mm for the next 1.8 kyrs before the start of the industrial era, annual heat imbalances were respectively approximately 4 x 10^{-3} ZJ and 1.4 x 10^{-3} ZJ, which means almost three orders of magnitude lower than during deglaciation. The relative steady state observed during the Holocene agrees well with the control by ice loss, evaporation and humidity taught by the water-based heat management mechanism. This mechanism complements the fund of possible origins emitted so far to account for glacial cycles [26].

II.2 The present and the future

Today, the heat budget includes anthropogenic heat input. Anthropogenic heat is generally discussed in terms of waste heat from energy consumptions [2, 27-30], and loacal and urban contributions [31-32]. However, we recently expanded the list to include inputs due the artificial enclosed spaces like cars, buildings, photovoltaic and thermal panels, etc., which are all greenhouse-like systems as defined in physics [6].

Ice melt and evaporation that limited the increases of global temperature and ocean level during Holocene millennia appeared to have increased over the past two centuries, as evidenced by the ice imbalance between 1994 and 2017 reported in [15]. During these 23 years, the loss of ice was 28,000 Gt that absorbed 9.34 ZJ, with approximately half absorbed by the melt of sea ice [15]. The imbalance due to land ice was thus approximately 4.15 ZJ, the average annual imbalance being 0.18 ZJ. However, in reality, the annual imbalance ranged from an average of 800 Gt in the 1990's to an average of 1,300 Gt in the 2000's [15]. During the study period, the ocean level rise was 35 mm with an annual rate of 1,5 mm significantly higher than in the mid Holocene [15].

According to the water-based heat management, a rise of heat imbalance can be related to a natural loss of efficiency of ice melt and evaporation after 10 kyrs of interglacial glacial plateau, or to an increase of anthropogenic heat, or both. In other words, the question remains open as to whether the acceleration of temperature currently emphasized by climatologists is natural or is the signal of an acceleration due to an increase in anthropogenic heat. Anyhow, the future should be characterized by more and more evaporation and more and more clouds leading to Sun masking and therefore to a reversal of imbalance that will pave the way for a new glaciation. Data by hemisphere are missing. However, ice loss appears to occur more in the Northern hemisphere [33] where a majority of the humanity is located and where an excess temperature is observed [34]. This imbalance between the hemispheres can be seen as an argument in favor of the existence of a relation between anthropogenic heat and an acceleration of climate changes. In particular, the loss of grounded ice is often regarded the main source of ocean level rise. However, such rise is, actually, more or less mitigated by evaporation which leads to more humidity, more clouds in the air and more rains in return, and likely more floods offset by droughts elsewhere. Although minor with respect to the volume of liquid water present on Earth, it is interesting to note that, when burning, hydrocarbons release hot liquid water stored in fossils fuels long ago, or as biomass [4].

IV Conclusions

The large variation in ocean level reported by paleoclimatologists has been used to estimate the thermal imbalance that caused the melting of ice during the pre-Holocene deglaciation period. The imbalance was shown to still be active though largely reduced during the last 8 Kyrs of the Holocene interglacial plateau that includes the 21th century. Once the Holocene was well underway, ocean level and global temperature remained fairly constant, consistent with a control by ice melt and evaporation. Currently, the imbalance is increasing again but, so far, current climate changes perceived as abnormal can hardly be considered a serious threat because they are still within preindustrial limits. However, and independently of its origin, the acceleration in annual ice loss observed today is in favor of a future drift in temperature exceeding the upper limit observed in the Holocene. If so, the result will likely be greater ice loss, more evaporation and ultimately more clouds partly obscuring solar heating, but enough to cause a reverse thermal imbalance, a necessary condition for the occurrence of a new glaciation. In the future, the average global ice imbalance, the humidity of the atmosphere, and the extent and the density of cloudy zones are the markers of climate evolution to follow. Given the stock of ice still present on Earth, the next glaciation is not expected for several centuries unless the release of anthropogenic heat diverges as one might fear if the growth of humanity and the race for better living standard continue.

Last but not least, appealing to excess of CO_2 was not necessary to account for climate fluctuations like warming, floods and droughts perceived today as abnormal. The role given to heat and the management by water and its different physical forms, applicable before the industrial era provides a credible origin as soon as today instead for several decades as the IPCC claims in the case of CO_2. This finding suggests reconsidering certain beliefs and strategies in terms of life cycle assessment. For instance, heat generated by aircrafts burning fossil fuel high in the dry skies should be rapidly eliminated radiatively in space, unlike the heat from surface vehicles moving in a humid air. Therefore, aircrafts may not be as bad as they are made out to be because of CO_2 emissions. On another hand, making hydrogen from oil could arouse interest despite the production of carbon dioxide that is one of the reasons to currently limit the development of this source of energy issued from water and restituting water after exploitation.

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Remark

Failing to respect the consensus on CO_2, I faced reject of some previous papers by journals specialized in Climatology (and I am not the only one (see https://youtu.be/zmfRG8-RHEI?si=Qp1Dlm8XptIdQ-Re). These papers are available in free access archives or published in journals specializing in energy (see the reference list). The present work has again been placed as preprint in open archives and is left to the appreciation and the fair exploitation by readers with citation. Today, publishing is too expensive for a scientist on pension.

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