Does a 288 K hot water bottle induce a measurable greenhouse effect?

Posted on September 2, 2020 by Courage dit-il

Physics of the radiations of a hot water bottle and of the heat it induces in the gases which surround it; examination in thermodynamics and infrared (IR).

Introduction

The existence of a greenhouse effect of CO2 in the troposphere having led to the idea that humanity would have an influence on the global climate, the object of the present research is **to verify what are** - by the preparation of experiments in classical physics and calculations in quantum physics - **the upper limit values of the intensity of this phenomenon**, at the local scale.

It is not about doing climatology, but about going back to the physics lab and the computer, to work on measured or calculated values.

Local scale experiences

Let's get a giant bottle of champagne to celebrate the success of the enterprise: its capacity is 30 l. (he's a Melchizedeck); alternatively, you can use smaller bottles, like a 1.5 l Magnum or a more ordinary bottle (0.75 l) within easy reach. You can also use a flat glass surface, like the front of a large aquarium, if you are reluctant to estimate the effects of curvature. Chemically, glass is very close to many rocks, which contain silicates, carbonates and traces of metals that give the green color; this material transparent to visible light is however opaque to “infrared radiation” (IR photons); these are invisible to us, but some are detectable by the skin as "heat" (in this case, as the temperature of your hand is around 310 K, alias 37 ° C, with a radiator like a hot water bottle at 288 K you will not detect ANYTHING, their intensity being too low).

In our experiments, we expect the hot water bottle to emit IR on its surface like a rock on continents does, at the average temperature of the Globe (288 K, alias 15 ° C): it is not the lamp that is the most important of the experiment, but on the one hand the IR spectrum that it emits and on the other hand the behavior of the irradiated gas.

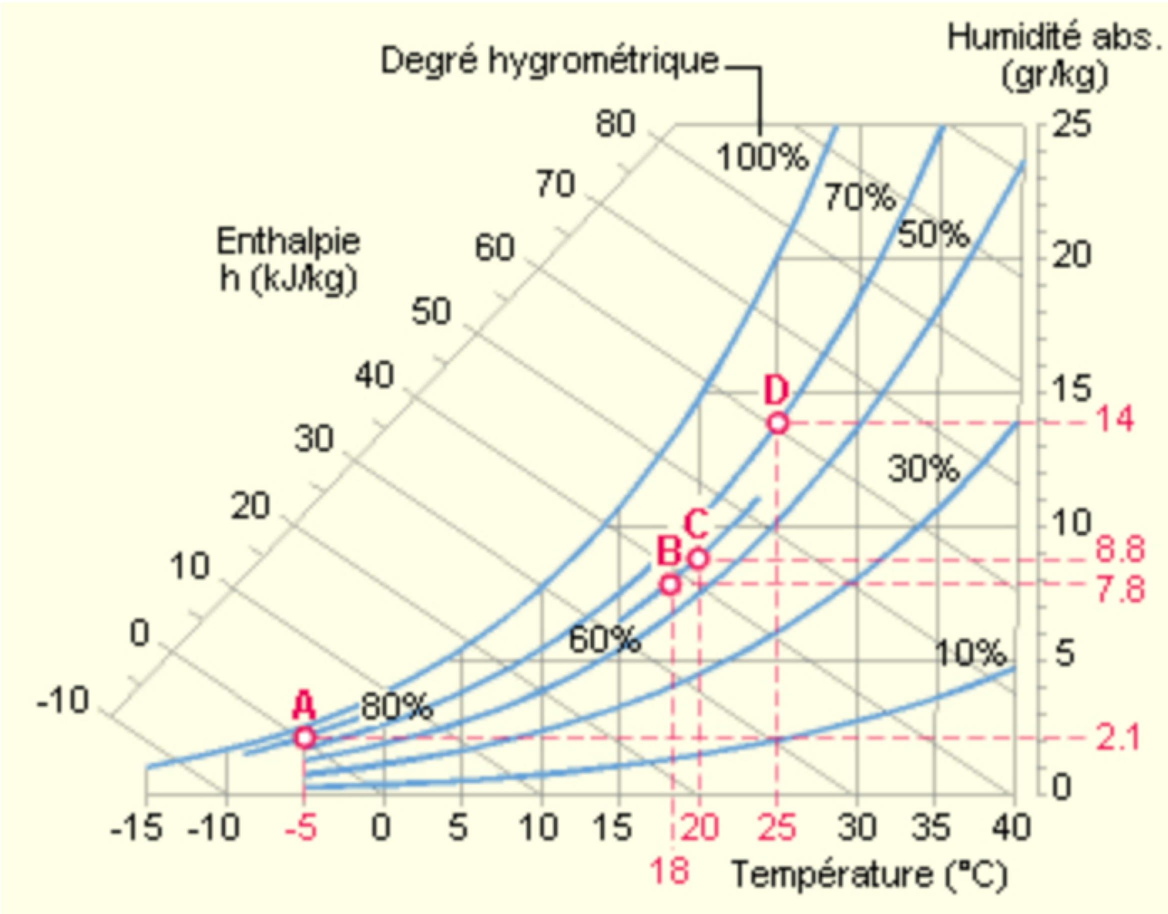
Data reminder (2019):

§ Definition in physics: a greenhouse effect is the overall result of the behavior in radiation, of gases re-emitting part of the energy received, in all directions; this is called radiative forcing. The greenhouse effect of CO2 in the troposphere would therefore be the reflection of a semi-transparent mirror, returning part of the energy to the emitter, to its source.

NB: We can compare the real process in the troposphere to that of a multi-layer insulation, a eiderdown: in fact there cannot be an IR mirror effect in a gas at such density, which transforms (the scientific discipline concerned is quantum physics) with very high probability the IR absorbed in heat, because being part of the spectra of the molecules present in the air ... It is then necessary to apply to this heat the laws of thermodynamics, which is classic physics.

§ Air contains about 413 ppmv (parts per million in volume) of CO2, or about one in 2,400 molecules, in 2020; the annual rate of increase is in the order of 2.2 ppmv / year. Each CO2 molecule can emit / absorb hundreds of thousands of IR lines.

§ About humidity, water H2O: 1 m3 of air weighs 1,292 kg (international standard at sea level). Air at 15 ° C can experimentally contain (at 100% relative humidity) no more than 10.5 g of water vapor per kg of air, which is absolute humidity under these conditions; documentation:



Belgian source, link: Energie + in the chapter: Absolute humidity

Proportion of the maximum water vapor trace, estimated by calculation at 15 ° C and 100% relative humidity: in the first approximation assumption, that all the molecules (air and water vapor) each occupy the same volume - we have approximately (mass ratio) * (inverse molar mass ratio) i.e. at most (10.5 g / 1'292 g) * (28.965 / 18) = 0.013078 = ~ 13'000 ppmv . Each molecule of H_2O in vapor can emit / absorb more than 18,000 IR lines.

§ Air contains approximately 1.9 ppmv of methane (CH_4). Each CH_4 molecule can emit / absorb hundreds of thousands of IR lines.

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§ Let's do physics experiments with a recovered bottle: we fill it with a coolant (the temperature of which can be measured), to ensure great inertia during the measurements; then we arrange to bring the whole to 288 K; it has become an experimental hot water bottle, of which cooling devices - in the case of hot surrounding gas - or heating - in the case of cold surrounding gas - will be essential to ensure stability at 288 K.

What you fabricated here is a little chilly to be a hot water bottle in a bed - but is a pretty good average thermal model for the rock surface of the continents.

§ Please note that in the following study, **it is about IR in gases**, and not about the behavior in these gases of drops, crystals or dust, evaporation, sublimation, condensation, in a word clouds, where the mechanisms of radiation and heat exchange are very different and lead to a much greater complexity of observable behavior.

§ **If all the heat present on the surface of the hot water bottle were supplied by radiation**, according to Stefan-Boltzmann's law, we would find as the power to be supplied (or emitted) in a vacuum to ensure this temperature to the black body 390.0794 W / m2 ; the black body is in physics the best emitter / absorber possible; the local heat (alias thermal agitation of molecules) is evacuated by the gases in the ambient air, which are poor heat conductors, but also emitters of IR, the spectrum of which is then that of the gases composing the air at 288 K; therefore it is because of this relative thermal insulation property of air that the discharge (other than IRs) to space is slow.

§ By measuring its IR, you will confirm that this 288 K hot water bottle, bathing in air at current atmospheric pressure, is an IR emitter: the radiation in W / m2, can be measured closely with a photometer or better with a spectrophotometer IR.

We can also observe with a thermal camera: by determining how the hot water bottle dissipates its heat other than by radiation (in cold laboratory air, for example at 0 ° C), we discover that it leaves by conduction (air is heated in the boundary layer) and by convection (air warmer than that of the environment rises, which amplifies the contact at the boundary layer). The temperature of the air surrounding the hot water bottle can be modified for tests, while remaining at laboratory pressure: for example at 45 ° C or at -52 ° C; to keep the hot water bottle its 288 K, it will be necessary to cool or heat the liquid it contains; we can thus test whether there are IRs that are part of the CO_2 spectrum (emitted by the hot water bottle) and measure which IRs re-emitted by the gas in all directions exist.; with a concentration of 2,400 molecules of air relative to the tested gas CO_2 (this is ~ the current concentration), there will be one, microscopic; indeed, each time an IR photon touches a CO_2 molecule and is absorbed, it will therefore be excited - but it will generally not be able to re-emit anything at a same frequency or higher, because its energy will be taken immediately partly by collisions with the crowd of neighboring molecules (mainly nitrogen N_2, oxygen O_2, argon Ar)… the density of the laboratory atmosphere is indeed very high. In addition, using spectrophotometers, it is possible to determine, either in the direction of the hot water bottle, or on the opposite side, the spectrum of the IRs physically present: a difference will come from the fact that the heat in a gas at almost 15 ° C will nor have exactly the same behavior of IR emissions as at the surface of a solid (clearly of another chemical composition); but a gas at 15 °C will not be able in this exchange to modify the 15 °C of the gas-solid boundary layer: this is elementary thermodynamics; the quantities measured under these conditions, of a possible "greenhouse effect" (radiative forcing), are in the order of magnitude of the uncertainty ...

Repeat the experiments with the surface of the restructured hot water bottle (color, texture), or with a hot water bottle that is partly very cold (and very hot for the rest), but with an average temperature of 288 K.

§ Having finished a series of experiments with the hot water bottle, it will obviously also be necessary to measure at 288 K what a seawater surface does in IR. This means that we will have to be able to work in the laboratory with an apparatus measuring a horizontal surface (the air being therefore measured above, in the vertical axis).

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§ Calculations at all scales, using computers.

We can apply the simple Beer-Lambert law and use the HITRAN database to do the calculations in quantum physics; all of this can be treated with precision, which is what Prof. Reinhart did to estimate a maximum of this absorption of IR, by atmospheric CO2 in increasing traces, near the surface of the Globe. The chosen IR lamp is the best physically possible, the black body heated to 288 K: the real IR lamp represented by the Globe is obviously less intense. Towards the surface (the place where the IR flux is maximum, assumed to come from an ideal 390 W / m2 IR lamp), the increase in IR absorption by CO2 from 280 ppmv at 400 ppmv of concentration results in a local (calculated) air temperature increase of less than 0.12 K; this is the maximorum of the contribution of the hot water IRs to the transfer of energy between the hot water bottle and the surrounding air, by interaction of the IRs with the CO2 currently present in the atmosphere; since the actual IR lamp is less intense than the blackbody, the interaction that causes this local temperature rise is even smaller.

Going from 400 ppmv to 800 ppmv, Prof. Reinhart found that the calculated temperature rise would be less than 0.24 K; that by pushing the concentration from 400 ppmv to 4,000 ppmv of CO2 in the atmosphere - at the current rate of our emissions it would take more than 1,600 years and we would have to assume that no natural mechanism would absorb the additional CO2 - the calculated heating would be less than 0.8 K.

Finally, we can calculate what awaits us in 10, 30, 70 or 100 years; in 100 years and at the current rate of increase, we will have reached just over 630 ppmv of CO2 in the atmosphere; the expected temperature rise is estimated to be less than 0.2 ° C.

Faith of an experimenter and faith of a physicist at the end of these calculations, with the best possible IR lamp at 288 K, there is not the conditions met to obtain, with air containing the current trace of CO_2 or in a century, a greenhouse effect by radiative forcing… a fortiori, with the real IRs of the ground or the sea, they are even less obtained.

§ **Conclusions of observations and small-scale calculations**; heat evacuation is made up of the energy sum of three mechanisms: conduction (heat transmission by contact in the solid-gas boundary layer, then departure while respecting the ideal gas law, in still air), convection (moving air) and IR; the local effect on the air of IRs - less than 0.1 K of heating (by absorption by CO_2, therefore order of magnitude 0.1 °C) - is weak enough so that we can in practice exclude a greenhouse effect such as it is defined, measurable and which would be directly due to CO_2 locally. The same reasoning applies to other even smaller traces of gases with molecules of more than two atoms (with very rich IR spectra, such as, for example, methane gas CH_4).

§ The temperature at the surface of the Globe is determined by the speed of evacuation of the incident energy: the IRs go at the speed of light, but they are absorbed by the lower atmosphere and transformed into heat, which will prevent a significant return of radiation of the same energy level to the emitting Globe; mixed with other heat sources, its escape towards space is slow (poor conduction of heat by gases: it is simply an insulator) and therefore the local temperature is on average much higher than without an atmosphere (for example like on the Moon). It is the low conduction of the air that will determine the low rate of heat removal and this parameter may be calculated, knowing the conduction factor of each gas; but it is currently very weakly influenced, by the concentration of traces of the order of 1 / 2'400 of CO_2, or 1 / 526'000 of CH_4 in the atmosphere, for example. Increasing the CO_2 trace twice will only change by about 0.4 ‰ its influence on air conduction.

The role of water, in the form of vapor up to ~ 31 times more abundant than CO_2, is separate, with its ability to easily produce clouds of drops or crystals and therefore to disappear (by condensation) or appear in vapor form (by evaporation or sublimation), with enormous heat transfers at each conversion.

Conclusion: the general temperature of the gas is in practice not physically modified by the presence of traces of CO_2, CH_4 or other gases with more than 2 atoms / molecule in the dense atmosphere; these traces are important for trapping the IRs in the mass of the atmosphere over Km (regardless of their direction of origin), but their local influence is microscopic ... bordering on measurable.

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§ **In the stratosphere and above**, it's a different story: the energy which has reached the surface of the Globe and absorbed (transformed into heat) will be almost totally returned there to space, where there is in practice no more gas allowing to define a temperature, therefore no more heat support material:

- The energy, evacuated in the troposphere in the form of heat, is thus transformed at very high altitude in the stratosphere, and propagates in the vacuum even further, in the form of IR of very low frequencies (their speed is that of light), whose spectrum makes it possible to recognize all the chemical bodies present in the atmosphere and having participated to their emission ...

- Greenhouse effect from or above the stratosphere; most IR radiation (which is not part of the optical window, as physicists interested in IR in astrophysics have found to their dismay) will be intercepted by the atmosphere at higher density - just like those coming from space - so in practice no measurable effect on temperature in the lower troposphere.

Final conclusion

By calculation, we discover that the radiative forcing, obtained by the presence of gas with more than two atoms per molecule and provided with a very rich IR spectrum, is diluted throughout the volume of the atmosphere at high density (troposphere) and that at the internationally accepted average temperature of the Globe of 288 K (alias 15 °C) the local heating at the surface of the Globe thus obtained is minuscule. Along with the other gases in the atmosphere, they participate in slowing down the escape of heat to space, but to a much lower extent than previously believed: the variation of the radiative forcing for which they are responsible by their variation in concentration must be revised, using computerized calculations in quantum physics and measurements in classical physics in the laboratory.

Considering the orders of magnitude already highlighted at that date by calculations in quantum physics: **the influence of a greenhouse effect far beyond 0.1 ° C is unlikely,** which would have been caused by anthropogenic CO2 emissions of the past 150 years.

30.6.2020, Rev. 9.9.2020

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Author's acknowledgment
I would like to express my gratitude to the top scientists - Dr. Christophe De Reyff, Prof. Franz-Karl Reinhart and Prof. Pierre

Jacquot - for many very interesting discussions, as well as for the critical reading of the manuscript.

Bibliography

§ Pr. F. K. Reinhart, **Infrared absorption of atmospheric carbon dioxide** 2014, Rev. 2017

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§ **Suggestion to the IPCC: calculations to (re) do on CO2 and CH4** - it is advisable to read all the documentation links, if only from a historical point of view.

§ Original text in French: http://www.entrelemanetjura.ch/BLOG_WP_351/une-bouillotte-a-288-k-induit-elle-un-effet-de-serre-mesurable/

Comments.

§ August 31, 2020 at 2:36 pm

"… Basically, the experimental hot water bottle that you imagine is in line with the experiences of Eunice Foote, John Tyndall or Robert

Wood, but, unlike them, you pose the problem correctly and you rely on adequate instrumentation. The tour de force is that you offer real experiences, the outcome of which is so obvious that it doesn't even make you want to be done. So André Bovay-Rohr's hot water bottle is akin to a *Gedankenexperiment*, just like Archimedes' bath, Newton's apple, Maxwell's demon, or Schrödinger's cat - a physicist's faith!

In my opinion, you are making a relevant analysis of what comes under thermodynamics in this question of CO2, and what relates to quantum physics: the quantum emission-absorption activity of this gas is certainly considerable, but does not result in significant warming of the atmosphere; so it remains thermodynamics, which excludes any particular role of CO2 in relation to air. It's crystal clear! … ”

Prof. Pierre Jacquot

End of comments