Radiation physics constraints on global warming: CO2 increase has little effect

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Radiation physics constraints on global warming: CO2 increase has little effect

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Abstract – I describe the basic physics of planetary radiation balance and surface temperature, using the simplest model possible that is sufficiently realistic for correct evaluations of predicted surface temperature response sensitivities to the key Earth parameters. The model is constrained by satellite absolute integrated intensity and spectroscopic measurements and the known longwave absorption cross section of CO2 gas. I show the predicted Earth temperature for zero atmospheric resonant absorption of longwave radiation (no greenhouse effect in the otherwise identical atmosphere) to be –46^{o}C, not –19^{o}C as often wrongly stated. Also, the net warming effect from the atmosphere, including all atmospheric processes (not just greenhouse forcing), without changing anything else (except to add the removed atmosphere) is +18^{o}C, not the incorrect textbook value of +33^{o}C. The double-layer atmosphere model with no free parameters provides: (a) a mean Earth surface temperature of +17^{o}C, (b) a post-industrial warming due only to CO2 increase of $\delta T = 0.4^{o}$C, (c) a temperature increase from doubling the present CO2 concentration alone (to 780 ppmv CO2; without water vapour feedback) equal to $\delta T = 1.4^{o}$C, and (d) surface temperature response sensitivities that are approximately two orders of magnitude greater for solar irradiance and for planetary shortwave albedo and longwave emissivity than for the atmospheric greenhouse effect from CO2. All the model predictions robustly follow from the straightforward underlying assumptions without any need for elaborate global circulation models. The same longwave optical saturation that provides such a large radiative warming of the planet surface also ensures that the warming effect from increasing CO2 concentration is minimal. I conclude with suggested implications regarding warming alarmism, errors by sceptics, research funding, and scientific ignorance regarding climate feedbacks.

Introduction

Historically, the greatest ability of the physicist has been to perform simple calculations that capture the essential features of a physical phenomenon in order to correctly elucidate the underlying principal causes. This is the ultimate "What is going on?" challenge.

Too many practicing physicists, in the many areas where physics is applied, have lost or never had this ability. Instead, they have been incorporated into the enterprise of using computers to simulate reality using questionable selections of approximate or invalid algorithms in large simulation programs.

These programs develop lives of their own, as careers and reputations are invested in their incremental development and in their predictions. A pathological optimism envelops the practitioners with the illusion that their algorithms capture complex features in some "average" or "effective" way and efforts are made to demonstrate this in so-called "validation" exercises rather than perform simple calculations that would demonstrate the algorithms themselves to be wrong for the intended application.

Physicists have largely abandoned their gadfly role of fundamentally challenging broad interpretive schemes in order to serve and benefit from career-enhancing collective enterprises, often dressed in elaborate conceptual edifices and often supported by computer simulations.

I believe this situation is playing itself out today in climate modelling science. As a physicist, if on close examination I can't understand what the CO2 warming alarmism is about and I can't get any of my colleagues to explain it – without computer-black-box magic, in published papers or elsewhere – then I am not going to believe it.

At its core, planetary surface temperature is a macroscopic radiation balance phenomenon that has been understood for one hundred years or so. If global warming alarmism is justified then it must be possible to explain why it is justified in simple terms and without appealing to faith or authority for any essential point in the argument.

I've tried to do this, as honestly and openly as possible, and I have asked my peers to find any errors. I believe the present article to be error-free and to conclusively show that we should not be focussed on CO2 if we are concerned about the planet's surface temperature. I am additionally of the opinion that we should not be concerned about the planet's surface temperature.

Regarding the sceptic-warmist debate, my conclusion is: The sceptics say many incorrect things but they are right whereas the warmists say many correct things but they are wrong. The skeptics appear to be motivated by skepticism whereas the warmists appear to be motivated by conformism. The skeptics' incorrect things have been used to discredit the skeptics and the warmists' correct things have been used to mask a lie.

Simplest models with essential features

My goal is to construct the simplest possible models of planetary radiation balance, realistic enough to capture the essential global average features using different physical assumptions about the type of atmosphere.

I take the planet to be a perfect sphere with a smooth and homogeneous surface and to have a thin (compared to the planet radius, but longwave optically thick) atmosphere. The planet is uniformly irradiated by a distant sun.

The incident intensity (in Watts per square-meter, W/m^2) of "shortwave" radiation (largely visible light) from the sun at the planet is the so-called solar constant, I_s, where for Earth $I_s = 1366$ W/m^2 (having a real seasonal variation in magnitude from 1412 to 1321 W/m^2, or 6.7% of its average value).

Different parts of the planet's surface receive different intensities of incident shortwave radiation. This is because the surfaces at different latitudes receive the incident rays at different angles and because half of the planet's surface is shielded from all incident rays (only one hemisphere is exposed to the sun at any given time).

Rather than deal with the latter complexity of non-uniform irradiation, instead, as is commonly done, we take the entire planet's surface to be uniformly irradiated with an intensity equal to the corresponding average solar constant. The correct average solar constant is $\langle I_s \rangle = (1/4)I_s = 341.5$ W/m^2, as is well known and easy to calculate.

In my models, therefore, every part of the planet's surface is identical in terms of the radiation balance conditions. Each part of the planet's surface represents what is happening on average, in terms of radiation balance, and of the planet properties which we take to be the Earth's average properties.

Basic concepts and Earth with no atmosphere

Of all the incident shortwave solar radiation that strikes the planet a fraction is reflected back into outer space without being absorbed by any part of the planet (surface or atmosphere). This fraction (from zero to one) of the incident shortwave solar radiation energy that is reflected out from the planet is called the planet's (Bond) albedo.

The reflected outgoing shortwave radiation need not have the same spectral distribution (radiation intensity versus radiation frequency or wavelength) as the incoming incident solar shortwave radiation because the amount of absorption/reflection can be (and generally is) dependent on wavelength. The albedo is the net energy fraction that is reflected.

Modern satellite spectroscopic measurements can quantify the solar constant and the amount of out-reflected shortwave radiation, can resolve these radiations from longwave thermal radiation, and can measure continuously in orbit to obtain planet-wide averages.

Satellite measurements allow us to conclude that the average Earth albedo is <*a*> = 0.30 [1]. Arguably-more-direct and reliable Earth-based so-called "Earthshine observation" measurements give <*a*> = 0.297(5) where, using scientific error notation, the latter means 0.297 ± 0.005 [2]. There are daily changes in Earth's albedo (from large scale weather changes) of ~5% and seasonal variations of ~15% (from snow and ice cover, vegetation, and weather and cloud cover) [2].

The main source of heat on the planet is the planet's surface that absorbs shortwave solar radiation. The physical absorption process transforms the electromagnetic energy of the incident solar radiation into heat energy (vibrational energy of the surface's molecules). In the case with an atmosphere, the atmosphere also directly absorbs a fraction of the incident shortwave solar radiation.

Any opaque body at any temperature above 0 K (i.e., having vibrating rather than motionless molecules) in turn emits electromagnetic radiation. The latter so-called "thermal" or "black-body" radiation has characteristics that depend on the body's "emitting surface" temperature. The spectral distribution of such emitted thermal radiation follows Planck's Law (modified to allow a wavelength-dependent emissivity). For the temperatures of interest the surface thermal radiation is longwave (or infra-red) radiation.

The intensity I_e (in W/m^2) of the emitted thermal (here longwave) electromagnetic radiation coming from the effective emitting surface of a somewhat opaque body is given by the Stefan–Boltzmann law:

$$I_e = \varepsilon \sigma T^4 \qquad \text{(eq.1)}$$

where T is the temperature of the emitting surface in K, σ is the Stefan–Boltzmann constant $\sigma = 5.6704 \times 10^{-8}\ W/m^2K^4$, and ε is the "emissivity" of the emitting surface valid for the relevant emitted frequencies.

The emissivity has a dimensionless value between zero and one. It is the fractional energy emission from the surface compared to the surface's emission if it were an ideal black body emitter. ε = 1 for an ideal black body surface and ε = 0 for an ideally reflective surface (i.e., a surface having an albedo of exactly 1).

The global average emissivity (for the relevant longwave radiation), $\langle\varepsilon\rangle$, of Earth's surface is difficult to evaluate. It can be reasonably estimated by considering the known measured longwave emissivities of typical Earth surface materials, such as liquid water, vegetation, and sand.

Let us next describe how the planet's mean surface temperature is established.

If the net radiant energy into the planet is larger than the net radiant energy escaping from the planet then the net received energy will heat the planet and increase its temperature. Likewise, if the net radiant energy out from the planet is larger than the net energy into the planet then the net loss of energy of the planet will cause the planet to loose heat and decrease its temperature.

Therefore, in a "steady state" situation, after a certain planetary response time following any change affecting radiation balance, the temperature of the planet's longwave radiation emitting surface will stabilize at some value corresponding to the rate of energy-in being equal to the rate of energy-out and there will be planetary "radiation balance" at a stable planetary surface temperature.

The net energy-in is the incident solar radiation minus the albedo loss. With no atmosphere, the net energy-out is the longwave emission energy from the planet's surface escaping into outer space. By setting in = out we can solve for the resulting radiation-balancing planet surface temperature.

The corresponding radiation balance equation, therefore, can be written as:

$$\langle I_s \rangle (1 - \langle a \rangle) = \langle \varepsilon \rangle \sigma T^4 \qquad \text{(eq.2)}$$

Solving for the planet surface temperature T_o (in K) for no atmosphere, eq.2 gives:

$$T_o = [(1 - \langle a \rangle)\langle I_s \rangle / \langle \varepsilon \rangle \sigma]^{1/4} . \qquad \text{(eq.3)}$$

At this point, virtually all researchers and authors have used $\langle \varepsilon \rangle = 1$, usually without providing a stated justification. That is, they have assumed that the Earth's surface is an ideal black body emitter for longwave radiation.

Using the latter assumption for $\langle \varepsilon \rangle$ and (for now, wrongly) assuming that the Earth's mean albedo $\langle a \rangle$ is the same with and without its atmosphere ($\langle a \rangle = 0.30$) eq.3 gives T_o = 254.8 K or minus (–) 18.3°C. Compared to the accepted actual mean global surface temperature of 14.0°C this would imply a total global atmosphere (greenhouse) effect warming on Earth of 32.3°C – corresponding to the repeatedly stated textbook nominal value of 33°C of greenhouse effect warming [3].

This surface temperature (nominally –19°C) is also the surface temperature (with $\langle \varepsilon \rangle$ = 1) of the bare planet (no atmosphere but preserving the same albedo) that would give the same total emission of longwave radiation presently escaping from Earth into outer space.

Many authors have stated that this thus calculated nominal –19°C temperature is "the Earth's temperature as seen from outer space". The latter statement is incorrect because although the actual present integrated emission intensity would, via eq.1, give this temperature, the actual longwave emission spectrum of Earth is not a black-body emission spectrum (i.e., does not follow Planck's Law, due to significant atmospheric absorption) and only a black-body-radiation spectrum can be interpreted as corresponding to an emitter's "temperature".

Wrong textbook views of Earth warming

The above described repeatedly stated textbook [3] value of 33^{o}C of Earth greenhouse effect warming is wrong because this is not the correct predicted value of planet surface warming (or cooling) that occurs on turning on (or off) the greenhouse effect in an otherwise unchanged Earth atmosphere and otherwise unchanged Earth.

I also taught the incorrect 33^{o}C value in my university physics courses and repeated it in my 2007 critique of global warming [4]. Wikipedia is no exceptions [5]. American Geophysical Union (AGU) press releases typically announce [6]:

> *"Overall, the greenhouse effect warms the planet by about 33 °C, turning it from a frigid ice-covered ball with a global average temperature of about -17 °C, to the climate we have today. Heat-absorbing components contribute directly to that warmth by intercepting and absorbing energy passing through the atmosphere as electromagnetic waves."*

In describing the "physical science basis" the Intergovernmental Panel on Climate Change (IPCC) in its 2007 "Contribution of Working Group I to the Fourth Assessment Report" (incorrectly, see below) put it this way [7]:

> *"The energy that is not reflected back to space is absorbed by the Earth's surface and atmosphere. This amount is approximately 240 Watts per square metre (W m–2). To balance the incoming energy, the Earth itself must radiate, on average, the same amount of energy back to space. The Earth does this by emitting outgoing longwave radiation. Everything on Earth emits longwave radiation continuously. That is the heat energy one feels radiating out from a fire; the warmer an object, the more heat energy it radiates. To emit 240 W m–2, a surface would have to have a temperature of around –19°C. This is much colder than the conditions that actually exist at the Earth's surface (the global mean surface temperature is about 14°C). Instead, the necessary –19°C is found at an altitude about 5 km above the surface.*
>
> *The reason the Earth's surface is this warm is the presence of greenhouse gases, which act as a partial blanket for the longwave radiation coming from the surface. This blanketing is known as the natural greenhouse effect."*

The scientists at RealClimate.org also (incorrectly, see below) use this 33^{o}C number in their interpretations [8]:

"Since we are looking at the whole of the present-day greenhouse effect (around 33 C), it is not surprising that the radiative forcings are very large compared to those calculated for the changes in the forcing. The factor of ~2 greater importance for water vapour compared to CO2 is consistent with the first calculation."

Virtually all mainstream science and teaching has accepted and parrots this idea that the planetary greenhouse effect on Earth causes a warming of approximately 33^{o}C.

In all of these sources the assumption $\langle \varepsilon \rangle = 1$ is virtually never explicitly justified. It is important to provide a justification because, at first glance, the assumption appears to violate Kirchoff's Law of radiation physics.

Kirchoff's Law of radiation physics says generally that the larger the reflectivity the smaller the emissivity. More precisely, Kirchoff's Law is expressed for a given wavelength λ as:

$$1 - a(\lambda) = \varepsilon(\lambda). \qquad \text{(eq.4)}$$

It is essential to note that the law holds at each wavelength (and direction) of radiation but that albedo at one wavelength need not be related to emissivity at a different wavelength.

On Earth, the relevant mean (Bond) albedo is for shortwave radiation (solar radiation, largely visible) and has a value $\langle a \rangle = 0.30$ whereas the needed emissivity is for longwave radiation (infra-red or thermal Earth-emission radiation) such that $\langle \varepsilon \rangle$ can have a value significantly different from the value 0.70 incorrectly predicted by eq.4.

We must therefore appeal to measurements of ε for representative Earth surface materials. A main Earth surface material is water. The longwave emissivity of water is almost 1. This is understandable because water is almost perfectly absorbing in the infrared. Dry rocks and sand also have near-one values of their longwave emissivities, that is values of ~0.91-0.92. Any vegetation coverage of dry soil significantly increases the value of the emissivity, given the water content of vegetation. For example, green grass has emissivity in the range ~0.97-0.99 [9].

This is why it is not unreasonable to use $\langle \varepsilon \rangle \sim 1$ for our ocean, lake and vegetation-covered Earth. Therefore, the assumed value of unity for emissivity is not significantly in error for our purposes.

Similarly, note that the above calculation leading to the nominal –19^{o}C surface temperature is not for an Earth without its atmosphere but that is otherwise unchanged; because such an instantaneously bared Earth would not retain its albedo of 0.30. Indeed, a large contribution to Earth's albedo is from clouds and the atmosphere itself – it is not a purely planet-surface albedo.

With no atmosphere we should use the albedo of the Earth's present solid surface, in its present state. The latter shortwave albedo <a_s> has been measured by satellite and is 23/(23+161) = 0.125 ([1]: Fig.1). This gives (eq.3) the significantly higher no-atmosphere mean surface temperature of T_o = 269.4 K (or –3.7°C), for a total atmosphere warming effect without changing anything else on the present Earth of +18°C, not +33°C. The correct predicted surface temperature of an Earth with no atmosphere but otherwise unchanged is –4°C.

Of course without an atmosphere there would be no vegetation, etc., and significantly more snow and ice cover, thereby increasing the surface albedo. The latter changes are difficult to predict and obviously have not been measured by satellite. In any case, the relevant question for the present discussion is "What is the net warming effect from the atmosphere, including all its processes, without changing anything else?" The answer is +18°C, not +33°C.

It should be clear therefore that the oft-repeated nominal –19°C surface temperature both is not the Earth temperature without an atmosphere (but otherwise unchanged) and is not "the temperature of Earth as seen from outer space". It is a nonsense number arising from an incorrect application of eq.1.

But error in most warming establishment spin is even larger than that because the presence or absence of the atmosphere is not equivalent (in terms of global radiation balance) to the presence or absence of an atmospheric greenhouse forcing, by any means. In other words, in terms of the planetary radiation balance, removing the atmosphere and removing the greenhouse action of the greenhouse gases in the atmosphere have dramatically different effects.

This is shown below and is because the atmosphere impacts surface temperature by much more than only via greenhouse forcing. And the other impacts cause surface cooling rather than warming. These other impacts are: (1) direct absorption by the atmosphere of incident shortwave solar radiation (78 W/m^2; [1]), (2) increased albedo from clouds and atmosphere (0.30 vs. 0.125), (3) surface cooling via atmospheric thermals (17 W/m^2; [1]), and (4) surface cooling via the evaporation/condensation via the water cycle (80 W/m^2; [1]).

I show below that, as a result, the correct Earth surface temperature in the absence of greenhouse forcing but with an otherwise unchanged atmosphere is a freezing –46°C. This means that "global warming" from atmospheric resonant scattering of infrared radiation on Earth is +60°C, from –46°C to +14°C, not +33°C.

Note that despite the large (~60°C) predicted atmospheric greenhouse warming on Earth this includes the total planet greenhouse effect whereas CO2 absorption is presently saturated (see below), such that a large CO2 change impact is not implied. It is essential to recognize that a large overall planetary greenhouse warming does not imply a significant warming from increasing the concentration of CO2. Indeed only a much smaller overall planetary greenhouse warming could give rise to a large warming effect from increasing the CO_2 concentration in the atmosphere. The two factors (total warming versus sensitivity to CO_2 increase) are anti-correlated via the phenomenon of optical saturation (see below).

Earth with homogeneous atmosphere

Consider first the simplest atmosphere; an atmosphere which is uniform in its temperature, composition and density and that attains its own steady state temperature by balancing its own net in and out radiative and other fluxes of energy. Let the temperature of the atmosphere (in K) be denoted T_β and the temperature of the planet surface be denoted T_α.

In this case, the longwave emission of the atmosphere (eq.1) up and out is equal to its longwave emission down and in (which is fully absorbed by the planet surface, $<\varepsilon> \sim 1$). In addition, since the atmosphere layer emits both up and down, it has a thermal emission surface of $2\mathscr{A}$ in area for every surface of area $\mathscr{A}$ of the planet surface.

In our homogeneous atmosphere model we include convective and air-mass thermals heating and water latent heat heating of the atmosphere, and evaporation and thermals cooling of the planet surface.

Consequently, the following energy flux balance equation must hold for the planet's surface:

$A + \beta - \alpha - C - D = 0$ ... (eq.5)

where

- "A" is the average intensity of incident shortwave solar radiation directly absorbed by the Earth's surface, 161 W/m^2 [1]

- $\beta = \varepsilon_{at}\, \sigma\, T_\beta^4$ is the average longwave emission intensity from the atmosphere to the Earth and ε_{at} is the longwave emissivity of the atmosphere

- $\alpha = <\varepsilon>\, \sigma\, T_\alpha^4$ is the average longwave emission intensity from the Earth surface and $<\varepsilon>$ is the longwave emissivity of Earth's surface, as defined above

- "C" is the (mean global) upward energy flux intensity from thermals, taking heat from the surface and delivering it into the atmosphere, 17 W/m^2 [1]

- "D" is the (mean global) upward energy flux intensity from the water cycle (evaporation and latent heat condensation/freezing), taking heat from the surface and delivering it into the atmosphere, 80 W/m^2 [1]

Eq.5 represents all the radiation and other energies absorbed by and emitted by the planet surface. If the atmospheric temperature (of the assumed homogeneous atmosphere) was known, eq.5 would lead to a predicted surface temperature.

Likewise, the following energy flux balance equation must hold for the planet's atmosphere:

$B + (1 - a_{at})\alpha - 2\beta + C + D = 0$ ... (eq.6)

where

- "B" is the intensity of incident shortwave solar radiation directly absorbed by the atmosphere, 78 W/m^2 [1]

- a_{at} is the longwave "albedo" of the atmosphere, the fraction (from zero to one) of longwave radiation intensity incident on the atmosphere that is not absorbed by the atmosphere, referred to elsewhere as the atmosphere's transmission coefficient $<t_e>$ [10]

The global average value of a_{at} is known from satellite measurements to be a_{at} = 40 W/m^2 / 396 W/m^2 = 0.10 [1]. In addition, eq.4 implies $\varepsilon_{at} = 1 - a_{at} = 0.90$ (both are longwave values for the atmosphere).

This system of two equations (eqs.5 and 6) is immediately solved for the two unknowns (α and β) such as:

$\alpha = (1 + a_{at})^{-1}[2A + B - C - D]$ ... (eq.7)

And gives:

T_α = 264 K (or –9°C) and ... (eq.8a)
T_β = 254 K (or –19°C). ... (eq.8b)

It is also possible to "turn off" all greenhouse effect forcing by setting $a_{at} = 1$ (i.e., letting a_{at} approach a value of one). This gives a zero-greenhouse-warming Earth surface temperature of

T_α = 227 K (or –46°C) ... in the absence of greenhouse effect warming ... (eq.9)

The latter value for the surface temperature of a non-greenhouse Earth is maintained for all multi-layer atmosphere models, with any number of atmosphere layers and with any distributions of energy deliveries to the different layers (energies B, C, and D partitioned to the different atmosphere layers). This is shown below, for all models using equally opaque (sufficiently optically thick) layers sharing the same value of a_{at}.

Interpreting the homogeneous atmosphere prediction

The above predicted Earth surface temperature T_α = 264 K (or –9°C) is low compared to the accepted measured average of 14°C [11] and the predicted difference with the homogeneous atmosphere temperature T_β = 254 K (or –19°C) is only 10°C.

This occurs because a single-layer homogeneous atmosphere does not allow the air closer to the surface to be warmer than air of higher altitude. Energy transport from the surface via thermals and the water cycle is considered to occur towards the full atmosphere rather than be concentrated near the surface.

We can consider that the near-surface air is part of an effective surface and that the thermal and water cycle energy deliveries occur near the surface (e.g., fog, wind-mixing of thermal transport, etc.) and are cyclically confined to a near-surface region by simply setting C = D = 0. This implies that no thermal and water cycle energy exchanges occur with the atmosphere-proper that is taken to be distinct from a near-surface atmosphere layer considered to be part of the effective surface.

When, in this way, only radiative heating and cooling are considered we obtain: T_α = 283 K (or +10°C) and T_β = 239 K (or –34°C). These values are close to actual values for Earth. This suggests that multi-layer atmosphere models are needed for sufficient realism.

Earth with double-layer atmosphere

Let the planet surface be denoted α, the inner atmosphere layer be denoted β and the outer atmosphere layer be denoted γ. For simplicity, let the direct incident solar, thermals, and water cycle energy inputs to the atmosphere be divided between and delivered equally to the two atmosphere layers.

Therefore, the energy flux balance condition for α is:

$A - C - D - \alpha + \beta + a_{at}\gamma = 0$ ... (eq.10)

where

- $\gamma = \varepsilon_{at}\, \sigma\, T_\gamma^4$ is the longwave emission intensity from the γ-layer of the atmosphere to the Earth and T_γ is the uniform temperature of the γ-layer

Each atmosphere layer emits equal longwave emission intensities both up (towards space) and down (towards Earth). Each atmosphere layer is equally optically opaque, with the same values of a_{at}. The latter arises because of the high degree of longwave optical opaqueness (high degree of resonant absorption over saturation, ~4 orders of magnitude or so) of the total atmosphere.

And, the energy flux balance equations for β and γ are, respectively:

$B/2 + C/2 + D/2 + (1 - a_{at})\alpha - 2\beta + (1 - a_{at})\gamma = 0$ ... (eq.11)

and

$B/2 + C/2 + D/2 + a_{at}(1 - a_{at})\alpha + (1 - a_{at})\beta - 2\gamma = 0$ ... (eq.12)

These equations (eqs.9, 10, 11) give:

$\alpha = (1/2)(3 + 2a_{at} - a_{at}^2)(1 + a_{at})^{-2}[2A + B - C - D]$ ... (eq.13)

and

$T_\alpha = 290$ K (or +17^{o}C), ... (eq.14a)
$T_\beta = 280$ K (or +7^{o}C), and ... (eq.14b)
$T_\gamma = 251$ K (or –22^{o}C). ... (eq.14c)

These temperature values are close to actual values for Earth despite the remarkable simplicity of the model with no free parameters. This suggests that a radiation balance approach is correct despite ancillary complications related surface roughness, lapse rate constraints, Earth's rotation, non-uniform irradiation, thermal response times, an inhomogeneous atmosphere, and an inhomogeneous surface. It also suggests that the model is sufficiently realistic to calculate response sensitivities to changing its key parameters.

We note that the only difference between eq.13 and eq.7 is in the prefactor to the intensity terms and that eq.13 gives the same no-greenhouse-effect ($a_{at} = 1$) prediction as eq.7:

$\alpha = [A + B/2 - C/2 - D/2]$ ... (eq.15)

giving T_α ($a_{at} = 1$) = 227 K (or –46^{o}C) (same as eq.8). Indeed, the structure of the equations show that this is a robust result that would be the same for any number of optically opaque layers and using any division or distribution of direct incident solar, thermals, and water cycle energy inputs to the atmosphere layers.

Eq.15 shows that under no-greenhouse-effect conditions half of B and of C and of D are longwave re-radiated back to Earth by the emitting atmosphere, irrespective of its vertically inhomogeneous structure. The other halves of B, C, and D are radiated out to space.

Temperature change scenarios and sensitivity predictions

In this section we use our double-layer atmosphere model to predict surface temperature responses to various CO2 scenarios and to other changes in key physical parameters.

First we consider the model (eq.13) predictions for doubling the present atmospheric CO2 concentration and for the post-industrial increase in atmospheric CO2 concentration, without changing anything else. That is, in the absence of any water vapour feedback or any other such positive or negative feedback.

For these calculations we must develop an equation that relates changes in atmospheric CO2 concentration to corresponding changes in atmosphere albedo a_{at}, equavalent to net longwave forward transmission through the atmosphere (denoted $<t_e>$ in a previous paper [10]). A given atmospheric CO2 concentration (in ppmv, parts per million per volume) is denoted C_{co2}.

The present known value of a_{at} (~0.10) is significantly smaller than 1 and CO2 longwave absorption predominantly occurs in a limited wavelength range (from ~600 to ~800 wavenumber, 1/cm) centered on ~15 μm (micro-meter wavelength), such that absorption saturation occurs in this main relevant CO2 absorption band [12].

This implies that the induced change in a_{at} is not simply (anti-)proportional to the considered change in CO2 concentration (change in C_{co2}) but instead is highly attenuated. Indeed, the decrease in a_{at} from an increase in C_{co2} arises not from an increased absorption at resonance but instead from increased absorption on the outer edges of the absorption band, thereby increasing the wavenumber-width of the absorption region corresponding to saturation absorption conditions (e.g., [12]: Fig.2).

Here, we derive the needed relation between a_{at} and C_{co2} as follows.

We take the main relevant CO2 longwave absorption band to be mathematically represented by a Gaussian function having a height and width equal to the height and width of the actual (non-saturated) absorption cross section for the CO2 band centered at the radiation frequency (ν_o) corresponding to 15 μm wavelength.

This choice is mathematically convenient, is motivated by the fact that a single motion-broadened resonance line in a gas atmosphere has a near-Gaussian shape, and gives a fair though approximate representation of the actual resonant absorption cross section for CO2 in the atmosphere.

The Gaussian cross section is written:

$$G(\nu) = \sigma_m \exp[- (\nu - \nu_o)^2 / 2\omega^2] \quad \text{... (eq.16)}$$

where σ_m is the (maximum) absorption cross section at resonance (at ν_o) and ω is the Gaussian width of the cross section function. Note: I am using total sample (atmosphere) intrinsic cross section, not specific cross section on a per-molecule or per-mass of gas basis. The Gaussian function is such that the half width at half maximum (HWHM) of the cross section function (intrinsic absorption band) is related to ω as:

$HWHM = (2\, ln(2))^{1/2}\, \omega$ ... (eq.17)

Next, we find the needed frequency-width of the region of absorption saturation by setting $G(\nu)$ equal to the cross section σ_e defined to be the cross section at which the CO2 longwave absorption becomes effectively saturated in the atmosphere. That is, we set $G(\nu) = \sigma_e$ and we solve for the two absorption band edge positions in frequency ν, on either side of the central resonance frequency ν_o.

This gives a saturation band full width as:

$\Delta\nu \;=\; 2\omega\, [2\, ln(\sigma_m/\sigma_e)]^{1/2}$ ... (eq.18)

Here, σ_e is a constant property of a CO2-bearing Earth atmosphere and σ_m, by definition, is directly proportional to the atmospheric concentration of CO2. Also $\sigma_m/\sigma_e \sim 10^4$ for CO2 at Earth concentrations ([12]: Fig.2, using intrinsic specific not total cross section). The precise value of the latter ratio does not significantly impact our calculations because it appears as the argument of the logarithmic function.

We then examine the variation ($\delta(\Delta\nu)$) of $\Delta\nu$ (eq.18) with σ_m and obtain:

$\delta(\Delta\nu) / \Delta\nu \;=\; [\, 2\, ln(\sigma_m/\sigma_e)\,]^{-1}\, \delta(\sigma_m)/\sigma_m$ ... (eq.19)

where $\delta(\sigma_m)$ is the considered variation or change in σ_m. Next, we note that:

$\delta(\Delta\nu) / \Delta\nu \;=\; -\delta(a_{at}) / (1 - a_{at})$ ... (eq.20)

since the saturation band width, by definition, negatively and proportionally affects the relevant CO2 longwave absorption through the atmosphere (nothing within the saturation width escapes through any thick layer of atmosphere in our simplified approach), and

$\delta(\sigma_m)/\sigma_m \;=\; F_{co2}\, \delta(C_{co2})/C_{co2}$ ... (eq.21)

where F_{co2} is the present fraction (from 0 to 1) of all greenhouse effects that arise from CO2. Eq.21 follows from the linear proportionality of cross section with greenhouse effect gas concentration for a given gas.

Therefore we need F_{co2}. It can most reliably be obtained from satellite spectral measurements. This was done in [13] where $F_{co2} \sim 0.26$ (for clear sky conditions).

Given equations such as eq.7 and eq.13 for α where α is defined as $\alpha = \langle\varepsilon\rangle\, \sigma\, T_\alpha^{\,4}$, it follows that changes in Earth surface temperature T_α are related to changes in α (arising from changes in a_{at}) as:

$\delta(T_\alpha) \;=\; (1/4)\, T_\alpha\, \delta(\alpha)/\alpha$ ... (eq.22)

Using the fact that a_{at} is much smaller than one, it follows that for our double-layer atmosphere model (eq.13) that changes in surface temperature are related to changes in CO2 concentration as:

$\delta(T_\alpha) = (1/4)\ T_\alpha\ [(2 - 2a_{at})/(3 - 4a_{at})]\ [\ 2\ ln(\sigma_m/\sigma_e)\ ]^{-1}\ F_{co2}\ \delta(C_{co2})/C_{co2}$ ... (eq.23)

where $T_\alpha = 290$ K, $a_{at} = 0.10$, $\sigma_m/\sigma_e \sim 10^4$, and $F_{co2} \sim 0.26$. In addition, $\delta(C_{co2})/C_{co2} = 1$ for a doubling of the CO2 concentration from the present values and $\delta(C_{co2})/C_{co2} = -0.28$ for a rolling back of the CO2 concentration to the pre-industrial value (from 390 ppmv to 280 ppmv).

This immediately gives:

$\delta(T_\alpha)$ (doubling CO2) = +1.4 K ... (eq.24a)
$\delta(T_\alpha)$ (pre-industrial CO2) = 0.4 K ... (eq.24b)

Regarding relative temperature change sensitivities of the various parameters, since the solar constant itself varies by 6.7% of its mean value over the course of the seasons, let 6.7% variations be our standard of variation, for the sake of comparisons.

For our double-layer atmosphere model (eq.13), the temperature change sensitivities for 6.7% changes in solar constant, etc., are as follows:

$\delta(T_\alpha)$ (+6.7% CO2) = +0.09 K ... (eq.25a)
$\delta(T_\alpha)$ (+6.7% solar constant) = +4.9 K ... (eq.25b)
$\delta(T_\alpha)$ (+6.7% Earth albedo) = –1.5 K ... (eq.25c)

The latter calculations assume the terms C and D in eq.13 (thermals and water cycle) to be proportional to the intensity of solar radiant energy absorbed by Earth.

The radiation balance steady state temperature of Earth's surface is approximately two orders of magnitude more sensitive to changes in solar constant and planetary albedo than to changes of atmospheric concentration of greenhouse effect CO2.

Virtually the same results (as eqs.24 and 25) are obtained for our single-layer atmosphere model (eq.7) and the same results were previously obtained for a model where the atmosphere was treated as an inert (non-thermalizing and non-radiative) infra-red greenhouse filter (i.e., like a pane of greenhouse glass that acts only to transmit or reflect back some fraction of the longwave emissions from the planet surface) [10].

CONCLUDING REMARKS

Implications for climate science funding and practice

In view of the above model sensitivity calculations and given the physical simplicity of the model with no free parameters and based on established physical principles it is clear that many factors will have a larger effect on surface-temperature-determining radiation balance than CO_2 concentration in the atmosphere. For example, such factors as changes in albedo from aerial mineral dust variations due to land use changes, changes affecting cloud dynamics (albedo), effective solar irradiance variations, and many more, are expected to have larger impacts than CO_2 concentration under present saturation absorption conditions.

Anyone wishing to focuss on CO_2 concentration as a climate driver should have the onus to explain ignoring the above straightforward demonstration of an approximately two order of magnitude irrelevance of CO_2 relative to solar irradiance (of known seasonal variation) and albedo and emissivity (both under-studied and significantly more complicated than the effect of CO_2).

Regarding the above relative sensitivities, it stands to reason, if reason matters and if we are concerned about the global mean surface temperature, that more research funding should go into studying solar irradiation variations, regional/planetary shortwave planet albedo and regional longwave surface emissivity (dependent on water-contents) rather than trying to deduce the relatively subtle effects of changes in “longwave radiative forcing” from CO_2. After all, large scale human land use changes can have dramatic effects on both surface radiative properties and colloidal atmospheric particle pollution concentrations and depositions, not to mention clouds, clouds, and clouds.

Likewise, land use practices should be subject to much more scrutiny, if radiation warming is our concern, than CO_2 fluxes into and out of the atmosphere.

In addition, the tenuous practice of assuming a positive water vapour feedback in models would need rigorous validation, despite recent overly optimistic opinionating [14]. See section below: “On climate feedbacks and ignorance”.

I have extensively argued from both the social science and climate science perspectives that global warming should not be our concern regarding environmental destruction and social injustice [4][15].

Relevance to the dominant climate science narrative

Recently, I critically reviewed the dominant narrative of climate science on several of its central points [16]: That the post-industrial atmospheric CO_2 concentration increase is directly a result of fossil fuel burning production of CO_2, that the post-industrial increase in atmospheric CO_2 concentration causes a greenhouse warming, that a measurable global mean surface warming has occurred in the post-industrial period, and that anthropogenic global warming radiative forcing drives “climate chaos” and produces extreme weather events.

The considerations of the present model are mostly consistent with the critical review of reference [16].

The global inter-carbon-pool flux dynamics of exchanges with the atmosphere and the factors affecting these inter-compartment fluxes remain the dominant determinants of the resulting atmospheric CO2 concentration value [16] (and references therein).

There remains a vehement debate among atmospheric physicists on the question of whether or not a planetary greenhouse effect can occur on a real planet having a greenhouse effect gas bearing atmosphere [16][17][18][19][20]. However, the simplicity and robustness of the models developed in the present paper imply that scientists claiming an absence of a planetary greenhouse effect mechanism are probably wrong and should have the onus to provide a simple physical explanation regarding their proposed absence of a planetary greenhouse effect in models of the radiation balance with a realistic atmosphere.

The physical-measurement and mathematical-statistics difficulties in obtaining a mean global surface temperature and in estimating the uncertainty error in this mean global surface temperature remain [4][16][21].

The reality of a post-industrial increase in extreme weather events remains undemonstrated and highly contested by climatologists and the physical mechanism whereby "climate chaos" would result from extra-CO2 "greenhouse radiative forcing" is at the level of a tenuous theoretical fantasy [16].

Sceptics need to correct many of their statements

Sceptics are correct that warming alarmism has not been justified from scientific principles or from empirical facts. Sceptics are correct that warming alarmism seems to be motivated by careerism and corporate/finance opportunism [4][22]. How else can one understand the climate warming feeding frenzy that has too long dominated the climate modellers and their entourage of proxy data masseurs, given the straightforward physics of the actual temperature sensitivity calculations?

However, given this same straightforward physics, sceptics (including me) need to stop saying things like:

- "CO2 is only a trace gas." Yes, but that is not relevant. What is relevant is CO2's contribution to the atmosphere's longwave absorption. It is a question of actual cross section, not absolute concentration. Satelite spectroscopic measurements are unambiguous that CO2 contributes 1/4 to 1/3 of all longwave absorption by the atmosphere (the rest being due to water vapour and clouds, depending on sky conditions) and that CO2 absorption is saturated in its main absorption band.

- "It's not principally a radiation balance effect." Turn off the Sun and calculate Earth's temperature!

- "Heating the surface by a greenhouse effect violates thermodynamics." No it does not. Energy is not lost or created anywhere and local temperatures adjust towards steady state to balance energy fluxes. Period.

- "There is no such thing as a greenhouse effect." While it is true that a "greenhouse" with longwave-transparent glass would heat up by retaining the air heated by shortwave absorption inside the "greenhouse" it is also true that it heats up faster and to greater temperatures if the glass is longwave-opaque. A planet's surface (and atmosphere) heats up without any greenhouse gas present but it heats up faster and reaches higher temperatures with greenhouse gases.

And, well, warmists on the other hand need to simply stop and look for intellectual honesty. The group think is frightening and needs a serious injection of loss of funding, or at least diversification of funding. No one should be allowed to publish anything more without making public all the raw data, all the data manipulations, and all the computer codes, with manuals and explanations. Science needs to be verifiable. It must never be based on authority and protected access.

On climate feedbacks and ignorance

It has been shown that one-dimensional dynamical models (vertical dimension only with average horizontal layers) of the Earth climate system are as good as three-dimensional global circulation models (GCMs) for making sensitivity and climate scenario calculations [23]. In many regards they are better because changes in underlying physical assumptions are more easily implemented and calculated [23]. Similarly, the present calculations show that simple steady state energy balance models also provide the same global mean climate predictions and climate sensitivity estimates as one-dimensional dynamical models and GCMs; as they should, given the correctly relevant underlying physics.

In all cases, non-negligible surface temperature increases from doubling CO_2 concentration are only predicted if some "positive feedback" or amplifying assumption is arbitrarily added to the calculations (to "make it work").

The warmist scientists have coalesced around the idea and practice of a "positive water vapour feedback" in order to resolve the "problem" of small calculated warming impacts from increased CO_2. In my view, the arguments and most heartfelt opinions in support of the positive water vapour feedback artifice are tenuous and overly optimistic, typical of an edifice seeking to justify itself [14].

Regarding such a water vapour feedback, consider the following. More humidity is highly correlated to more clouds. Compare winter and summer skies at mid-latitudes, look at the skies over large deserts, etc. Clouds in turn are a major cause of Earth's high albedo. As shown above, without clouds and without the atmosphere Earth's mean albedo would be ~60% less: 0.125 instead of 0.30. This albedo-cloud relation represents a large *negative* feedback potential that has not been sufficiently studied and about which geoscientists are mostly ignorant.

Indeed, geoscientists are mostly ignorant about the mechanisms and geostatistics of virtually all the potential feedbacks that could play dominant roles given the dominant physical impacts of shortwave Bond albedo and longwave surface and atmosphere emissivities. [24]

What emboldens warmist scientists and modellers, beyond institutional backing and the advantages of groupthink, is the fact that the atmosphere's uniform CO2 concentration is easy to work with – both in modelling and conceptually – but they should aquire humility before indulging their CO2 fetish and advancing their tenuous doomsday predictions given geoscience's overwhelming ignorance about climate feedbacks. [24]

And, of course:

> *"I argue that by far the most destructive force on the planet is power-driven financiers and profit-driven corporations and their cartels backed by military might; and that the global warming myth is a red herring that contributes to hiding this truth."* [4][25]

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