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Does CO_2 really drive global warming?

I don't believe that it does.

To the contrary, if you apply the IFF test—if-and-only-if or necessary-and-sufficient—the outcome would appear to be exactly the reverse. Rather than the rising levels of carbon dioxide driving up the temperature, the logical conclusion is that it is the rising temperature that is driving up the CO_2 level. Of course, this raises a raft of questions, but they are all answerable. What is particularly critical is distinguishing between the observed phenomenon, or the "what", from the governing mechanism, or the "why". Confusion between these two would appear to be the source of much of the noise in the global warming debate.

In applying the IFF test, we can start with the clear correlation between the global CO_2 profile and the corresponding temperature signature. There is now in the literature the report of a 400,000-year sequence clearly showing, as a phenomenon, that they go up—and down—together (*1*). The correlation is clear and accepted. But the causation, the mechanism, is something else: Which is driving which?

Logically, there are four possible explanations, but only two need serious consideration, unless they both fail.

- Case 1: CO_2 drives the temperature, as is currently most frequently asserted; and
- Case 2: Temperature drives the level of CO_2.

Both appear at first to be possible, but both then generate crucial origin and supplementary questions. For Case 1, the origin question is: What is the independent source of CO_2 that drives the CO_2 level both up and down, and which in turn, somehow, is presumed to drive the temperature up and down? For Case 2, it is: What drives the temperature, and if this then drives the CO_2, where does the CO_2 come from? For Case 2, the questions are answerable; but for Case 1, they are not.

Consider Case 2. This directly introduces global warming behavior. Is global warming, as a separate and independent phenomenon, in progress?

The answer, as I heard it in geology class 50 years ago, was "yes", and I have seen nothing since then to contradict that position. To the contrary, as further support, there is now documentation (that was only fragmentary 50 years ago) of an 850,000-year global-temperature sequence, showing that the temperature is oscillating with a period of 100,000 years, and with an amplitude that has risen, in that time, from about 5 °F at the start to about 10 °F "today" (meaning the latest 100,000-year period) (2). We are currently in a rise that started 25,000 years ago and, reasonably, can be expected to peak "very shortly".

On the shorter timescales of 1000 years and 100 years, further temperature oscillations can be seen, but of much smaller amplitude, down to 1 and 0.5 ° F in those two cases. Nevertheless, the overall trend is clearly up, even through the Little Ice Age (~1350–1900) following the Medieval Warm Period. So the global warming phenomenon is here, with a very long history, and we are in it. But what is the driver?

Arctic Ocean model
The postulated driver, or mechanism, developed some 30 years ago to account for the "million-year" temperature oscillations, is best known as the "Arctic Ocean" model (2). According to this model, the temperature variations are driven by an oscillating ice cap in the northern polar regions. The crucial element in the conceptual formulation of this mechanism was the realization that such a massive ice cap could not have developed, and then continued to expand through that development, unless there was a major source of moisture close by to supply, maintain, and extend the cap. The only possible moisture source was then identified as the Arctic Ocean, which, therefore, had to be open—not frozen over—during the development of the ice ages. It then closed again, interrupting the moisture supply by freezing over.

So the model we now have is that if the Arctic Ocean is frozen over, as is the case today, the existing ice cap is not being replenished and must shrink, as it is doing today. As it does so, the Earth can absorb more of the Sun's radiation and therefore will heat up—global warming—as it is doing today, so long as the Arctic Ocean is closed. When it is warm enough for the ocean to open, which oceanographic (and media) reports say is evidently happening right now, then the ice cap can begin to re-form.

As it expands, the ice increasingly reflects the incoming (shorter-wave) radiation from the sun, so that the atmosphere cools at first. But then, the expanding ice cap reduces the radiative (longer-wave) loss from the Earth, acting as an insulator, so that the Earth below cools more slowly and can keep the ocean open as the ice cap expands. This generates "out-of-sync" oscillations between atmosphere and Earth. The Arctic Ocean "trip" behavior at the temperature extremes, allowing essentially discontinuous change in direction of the temperature, is identified as a bifurcation system with potential for analysis as such. The suggested trip times for the change are interesting: They were originally estimated at about 500 years, then reduced to 50 years and, most recently, down to 5 years (2). So, if the ocean

is opening right now, we could possibly start to see the temperature reversal under way in about 10 years.

What we have here is a sufficient mechanistic explanation for the dominant temperature fluctuations and, particularly, for the current global warming rise—without the need for CO_2 as a driver. Given that pattern, the observed CO_2 variations then follow, as a driven outcome, mainly as the result of change in the dynamic equilibrium between the CO_2 concentration in the atmosphere and its solution in the sea. The numbers are instructive. In 1995, the Intergovernmental Panel on Climate Change (IPCC) data on the carbon balance showed ~90 gigatons (Gt) of carbon in annual quasi-equilibrium exchange between sea and atmosphere, and an additional 60-Gt exchange between vegetation and atmosphere, giving a total of ~150 Gt (*3*). This interpretation of the sea as the major source is also in line with the famous Mauna Loa CO_2 profile for the past 40 years, which shows the consistent season-dependent variation of 5–6 ppm, up and down, throughout the year—when the average global rise is only 1 ppm/year.

In the literature, this oscillation is attributed to seasonal growing behavior on the "mainland" (*4*), which is mostly China, >2000 mi away, but no such profile with that amplitude is known to have been reported at any mainland location. Also, the amplitude would have to fall because of turbulent diffusive exchange during transport over the 2000 mi from the mainland to Hawaii, but again there is lack of evidence for such behavior. The fluctuation can, however, be explained simply from study of solution equilibria of CO_2 in water as due to emission of CO_2 from and return to the sea around Hawaii governed by a ±10 °F seasonal variation in the sea temperature.

Impact of industrialization
The next matter is the impact of fossil fuel combustion. Returning to the IPCC data and putting a rational variation as noise of ~5 Gt on those numbers, this float is on the order of the additional—almost trivial (<5%)—annual contribution of 5–6 Gt from combustion of fossil fuels. This means that fossil fuel combustion cannot be expected to have any significant influence on the system unless, to introduce the next point of focus, the radiative balance is at some extreme or bifurcation point that can be tripped by "small" concentration changes in the radiation-absorbing–emitting gases in the atmosphere. Can that include CO_2?

This now starts to address the necessity or "only-if" elements of the problem. The question focuses on whether CO_2 in the atmosphere can be a dominant, or "only-if" radiative-balance gas, and the answer to that is rather clearly "no". The detailed support for that statement takes the argument into some largely esoteric areas of radiative behavior, including the analytical solution of the Schuster–Schwarzschild Integral Equation of Transfer that governs radiative exchange (*5–7*), but the outcome is clear.

The central point is that the major absorbing gas in the atmosphere is water, not CO_2, and although CO_2 is the only other significant atmospheric absorbing gas, it is still only a minor contributor because of its relatively low concentration. The radiative absorption "cross sections" for water and CO_2 are so similar that their relative influence depends primarily on their relative concentrations. Indeed, although water actually absorbs more strongly, for many engineering calculations the concentrations of the two gases are added, and the mixture is treated as a single gas.

In the atmosphere, the molar concentration of CO_2 is in the range of 350–400 ppm. Water, on the other hand, has a very large variation but, using the "60/60" (60% relative humidity [RH] at 60 °F) value as an average, then from the American Society of Heating, Refrigerating and Air-Conditioning Engineers standard psychrometric chart, the weight ratio of water to (dry) air is ~0.0065, or roughly 10,500 ppm. Compared with CO_2, this puts water, on average, at 25–30 times the (molar) concentration of the CO_2, but it can range from a 1:1 ratio to >100:1.

Even closer focus on water is given by solution of the Schuster–Schwarzschild equation applied to the U.S. Standard Atmosphere profiles for the variation of temperature, pressure, and air density with elevation ([8]). The results show that the average absorption coefficient obtained for the atmosphere closely corresponds to that for the 5.6–7.6-µm water radiation band, when water is in the concentration range 60–80% RH—on target for atmospheric conditions. The absorption coefficient is 1–2 orders of magnitude higher than the coefficient values for the CO_2 bands at a concentration of 400 ppm. This would seem to eliminate CO_2 and thus provide closure to that argument.

This overall position can be summarized by saying that water accounts, on average, for >95% of the radiative absorption. And, because of the variation in the absorption due to water variation, anything future increases in CO_2 might do, water will already have done. The common objection to this argument is that the wide fluctuations in water concentration make an averaging (for some reason) impermissible. Yet such averaging is applied without objection to global temperatures, when the actual temperature variation across the Earth from poles to equator is roughly –100 to +100 °F, and a change on the average of ±1 °F is considered major and significant. If this averaging procedure can be applied to the atmospheric temperature, it can be applied to the atmospheric water content; and if it is denied for water, it must, likewise, be denied for temperature—in that case we don't have an identified problem!

What the evidence shows
So what we have on the best current evidence is that

- global temperatures are currently rising;
- the rise is part of a nearly million-year oscillation with the current rise

- beginning some 25,000 years ago;
- the "trip" or bifurcation behavior at the temperature extremes is attributable to the "opening" and "closing" of the Arctic Ocean;
- there is no need to invoke CO_2 as the source of the current temperature rise;
- the dominant source and sink for CO_2 are the oceans, accounting for about two-thirds of the exchange, with vegetation as the major secondary source and sink;
- if CO_2 were the temperature–oscillation source, no mechanism— other than the separately driven temperature (which would then be a circular argument)—has been proposed to account independently for the CO_2 rise and fall over a 400,000-year period;
- the CO_2 contribution to the atmosphere from combustion is within the statistical noise of the major sea and vegetation exchanges, so a priori, it cannot be expected to be statistically significant;
- water—as a gas, not a condensate or cloud—is the major radiative absorbing–emitting gas (averaging 95%) in the atmosphere, and not CO_2;
- determination of the radiation absorption coefficients identifies water as the primary absorber in the 5.6–7.6-µm water band in the 60–80% RH range; and
- the absorption coefficients for the CO_2 bands at a concentration of 400 ppm are 1 to 2 orders of magnitude too small to be significant even if the CO_2 concentrations were doubled.

The outcome is that the conclusions of advocates of the CO_2-driver theory are evidently back to front: It's the temperature that is driving the CO_2. If there are flaws in these propositions, I'm listening; but if there are objections, let's have them with the numbers.

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