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The Root Cause of Atmospheric CO_2 Rise

More Clear Thinking

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Abstract

This paper continues the debate sponsored by Science of Climate Change on the root causes of atmospheric CO_2 rise during the last century. A little progress has been made in finding common ground, but not very much. A suggestion is made to make the discussion more productive.

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1. Introduction and a Proposal

In an earlier paper (Andrews 2023), three primary points were made:

(1) Data show that land and sea reservoirs have been net sinks, not sources, of carbon from the atmosphere during the Industrial Age.

(2) Mixing of carbon between reservoirs, which happens on a time scale of about one decade, precludes making inferences on the cause of atmospheric carbon increases from the present composition of the atmosphere.

(3) The attempt of (Harde and Salby 2021) to reconcile their model with correctly interpreted radiocarbon data was unsuccessful (despite their claim to the contrary) as it required postulating unrealistically large new sources of ^{14}C.

(Harde 2023a) and (Berry 2023) contested these points, while (Engelbeen 2023) supported and elaborated on the first two. Now (Harde 2023b) in a response to Engelbeen, has agreed that the basic argument in support of point (1) is correct, though he continues to dispute the consequences.

Often "responses" by author A to author B's "comments" have been restatements of author A's previous articulated positions, without addressing in any meaningful way concerns raised by author B's comments. Further productive discussion is difficult if arguments perceived by author B to be critical have been ignored. Author B's only recourse is to find another way to make his point which likely includes yelling a little louder the second time. (Harde 2023b) is an exception, since with his Equation (1) and (2) he endorsed the concept of "Net Global Uptake", the concept that carbon conservation can be used to infer trends in land/sea reservoirs, though he did not concede the full consequences laid out in (Engelbeen 2023).

In an in-person debate, Author B could cross examine Author A to ensure his concern was considered. As our remote debate format does not allow this, this note will conclude with two focused questions each for Berry and Harde. The questions will underscore this author's opinion of the most critical flaws in each of their analyses. They can choose to answer them or not. But if they ignore them, their evasion will be obvious. Of course, Harde and Berry can choose to respond with one or two focused questions of their own but should expect answers only if they have been responsive to questions to them. Let us stop talking past each other.

2. Net Global Natural Emissions

Equation 2 in (Harde 2023b) describing the rate of change of atmospheric CO_2 concentration is one all now accept. It is based simply on carbon conservation and the absence of significant anthropogenic absorption processes. Other than that, it is model independent with the two emission and one absorption variables independent and unconstrained. It treats natural and anthropogenic emissions on an equal footing. There is not a shred of circular reasoning in its derivation. We reproduce it here:

$$\frac{\delta c_{CO_2}}{\delta t} - e_A = e_N - a_N \qquad (1)$$

As Harde notes, the quantities on the left-hand side (average rate of change in atmospheric carbon in a year, average anthropogenic emission rates) are well measured. Those on the right-hand side (absorption and emission rates of carbon to and from natural land/sea reservoirs) are poorly known. But this equation allows the *difference* between emissions and absorption ("Net Global Natural Emissions") to be known with some precision. (Andrews 2023) discussed the negative analogue of this quantity for carbon rather than CO_2, called "Net Global Uptake" by (Ballantyne 2012) who found it to be +192 $\pm$ 29 PgC. for the period 1960 to 2010, making Net Global Natural Carbon Emissions -192 $\pm$ 29 PgC . We are on the same page except for sign conventions and whether we are tracking CO_2 or carbon. Note that ALL natural sources of carbon emissions are included in e_N including volcanoes, outgassing freshwater ponds, etc., or else the logic of its derivation would be violated. As we said, e_N itself is poorly known.

After noting Engelbeen's conclusions from this equation, (Harde 2023b) criticizes three models for allegedly making further unwarranted assumptions about, for example, the constancy of e_N. He accuses *those models* of circular reasoning. We will not pursue that accusation but note only that Harde does not apply his claim of circular reasoning to his own Equation 2. He continues to dispute some of Engelbeen's inferences, but significantly (Harde 2023b) no longer disputes that land/sea reservoirs are sinks, not sources, as he had in (Harde 2023a).

(Harde and Salby 2021) modeled the relationship between absorption and atmospheric concentration. (The supposed confirmation of this model with ^{14}C data is not credible, but we defer that discussion.) This allows (Harde 2023b) to determine a value of a_N from data, and then use it to get an e_N . Unsurprisingly this is higher than e_A by about a factor of six from his calculation. The two-way natural exchanges have always been described as larger than the one-way anthropogenic one. So we have the situation that while the natural reservoirs are undoubtedly net sinks, the gross emissions from them are higher than anthropogenic emissions. $a_N > e_N > e_A$. The disagreement between camps boils down to arguing about which inequality is more important: is it $a_N > e_N$ making natural reservoirs sinks, or $e_N > e_A$ making natural emissions dominate anthropogenic ones? The standard argument of course is that a pre-Industrial Age balance when $a_N = e_N$ was upset by the addition of e_A,. Plots in (Ballantyne 2012) of the changing Net Global Uptake support this, as does Figure 1. Perhaps the question *"do natural sources contribute anything at all to the CO_2 rise?"* is not the right one to ask. In Ballantyne's analysis, temporarily reduced (but still positive) Net Global Uptake during the 1990's is attributed to a volcanic eruption. Should that count as a contribution to the rise? But claiming that natural processes dominate the rise in CO_2, just because gross natural emission rates exceed anthropogenic ones, when Net Global Natural Emissions are negative is untenable. .

The history of atmospheric CO_2 concentration over the last 800,000 years per the UN EPA is shown in Figure 1. We can also read it as a history of Net Global Uptake since anthropogenic emissions were 0 except at the very end of the plot. During eras in the geological past when natural emissions exceeded natural absorption, dC/dt was positive making Net Global Uptake negative. Whenever Net Global Uptake was positive, that meant that dC/dt was negative. But in the present era, Net Global Uptake is positive, *yet dC/dt has never been more positive*. The current excursion in atmospheric CO_2 concentration is not like previous ones.

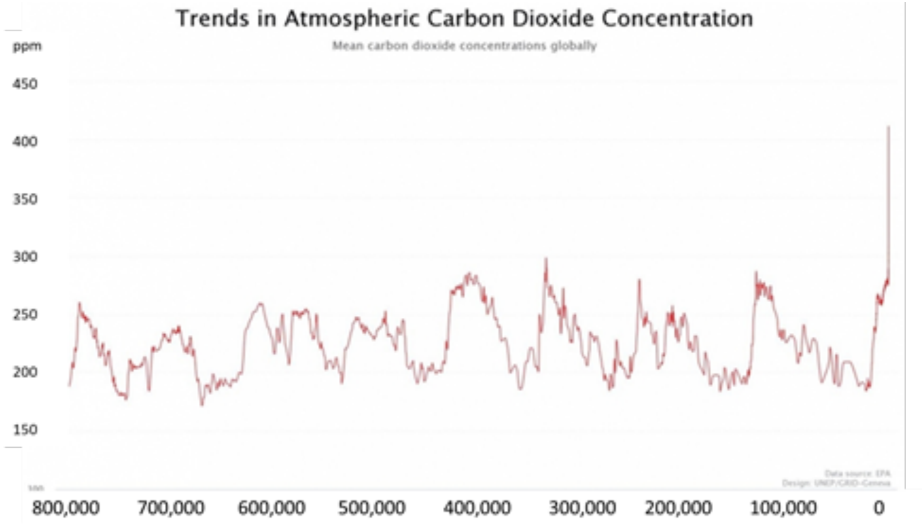

Figure 1 Atmospheric CO_2 concentration for the last 800,000 years. Only on the far right of this graph have Net Global Uptake and dC_{CO2}/dt been positive at the same time.

2. Two questions for Berry

2.1 You have argued in (Berry 2023) without giving detail that analyses using data and carbon conservation to show that natural reservoirs have been net sinks throughout the last century used circular reasoning. Do you still believe that, and if so can you elaborate?

2.2 (Berry 2023) reiterates your model of the human carbon cycle. (Andrews 2023) argued that you have been calculating an unimportant quantity: the amount of carbon in the present atmosphere that was once contained in a fossil fuel. Because of mixing on a decade time scale the statement *"Human carbon in the present atmosphere is only 30% of the Industrial Age increase"* is not the same as *"Human emissions caused only 30% of the increase."* Let us assume your calculation of human carbon in the present atmosphere is correct. How can you justify making inferences about the cause of CO_2 rise from it, given the mixing?

3. Two questions for Harde

3.1 In (Harde and Salby 2021) you set out to establish your model of carbon exchanges by fitting atmospheric ^{14}C concentration curves which, since about 2000, have shown steady increases. Your model required them to decrease exponentially. You therefore made a fit with a growing background, and published the parameters of that fit, ascribing the background to new nuclear power plants, nuclear testing, and increases in cosmic ray flux. Figure 3 in (Andrews 2023) used your parameters and argued they were unreasonably high. You say in (Harde 2023a) *"the artificially constructed background in Andrews' Fig 3 has nothing to do with our calculation and explanation, which unambiguously confirms our previous conclusion"*. Have you reconciled the parameters you found from the fit to other estimates of ^{14}C sources, or found an error in Andrews' use of your parameters and produced another plot to correct it?

3.2 In (Harde 2023a) you write *"Radiocarbon is an ideal tracer, which obeys the same rules as the other isotopologus, and thus can be well used to study temporal carbon mixing and exchange processes."* You didn't like the alcohol water mixing analogy, but no doubt can see that balanced mixing between two carbon reservoirs with initially different isotopic composition can lead to equilibration in the isotopic composition of each without changes in the total carbon content. That means that total carbon flows do NOT necessarily follow ^{14}C flows. While you dismissed isofluxes, might they help you understand the rise in ^{14}C this century?

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