

Response to David Andrews regarding the carbon balance.

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As DK points out, the logic:

- Without human emissions, CO₂ in the atmosphere would not be increasing
- It follows from 1 that human emissions are the cause of increasing CO₂ in the

atmosphere

is false. The above does look persuasive at first glance, but this is owing mainly to a bias in the selection of anthropogenic emissions from all other sources of emission and sink, and then lumping together all those other sources into one net figure, as I will illustrate below. However, the statement: “Human emissions are a significant cause of increasing CO₂ in the atmosphere”, or even “Human emissions are the most significant cause of increasing CO₂ in the atmosphere” could still be true. This would be the case if all natural sources of emission and sinking of CO₂ either remain static in the period of interest (since the beginning of anthropogenic emissions), or vary to a magnitude that is insignificant in comparison to the change in anthropogenic emission. And of course I’m only referring here to the mean changes over the entire period, not the intra-annual variations.

To illustrate why this would need to be a condition for the proposition to be true, consider the following hypothetical situation:

Over a period of 2 centuries, pre-dating anthropogenic emissions of CO₂, we observe that the sources of natural emissions, from land and oceans respectively, increase by 36.6 and 23.1 Gt/a of carbon each, giving a total flux increase to the atmosphere of 59.7Gt/a. Over the same period, the CO₂ sinks to land and ocean also increase, by 29 and 25.5 Gt/a respectively, providing a total sink of 54.5Gt/a. So we have a net increase in flux to the atmosphere of 5.2Gt/a. Suppose now that the land emissions can be split into 2 distinct sources - respiration source A and B, of 25.6 and 11Gt/a respectively.

To what do we attribute the cause of this net increase of 5.2Gt/a of carbon in the atmosphere? Of all the possible options, the most ridiculous would be to attribute the cause to land respiration source B. Isolating this source as the cause on the basis that the aggregate of all other sources and emissions would otherwise result in a change of flux direction would make absolutely no sense. Of course, if you had some leaning toward that source of emission, lumping all other sources and sinks together as a net sink of smaller magnitude might look like an attractive supportive argument. But all it would be is an illustration of a theory that you had already decided was correct, not a proof of that theory in and of itself.

Clearly the correct answer to the above question would be that ALL sources and sinks that have changed significantly during the period in question are the cause. And their individual contribution to the overall change would be in proportion to how much they had changed relative to the other changed sources of emission and sinks. Thus land respiration source B could be considered to have contributed $11 \times 100 / (25.6 + 11 + 23.1 + 29 + 25.5) = 9.6\%$ to the overall change in carbon flux.

As the data used in my example above are the very same data from the IPCC AR6 carbon balance for the anthropogenic emissions era (figure 5.12), but with the anthropogenic emission source replaced by my land respiration emission source B, it is clear that the

anthropogenic emission of CO₂, far from being the cause of the increase in carbon accumulation in the atmosphere, is instead a relatively minor contributor to it.

There does remain one possibility for anthropogenic emissions to be the cause of increasing CO₂ in the atmosphere, though this is a different argument to the carbon balance one being put forward by David Andrews (which states that the size of the anthropogenic emission with respect to the overall net natural flux is proof in itself). This remaining possibility is that the anthropogenic emissions have actually caused the changes in natural sources of flux during the modern period. The argument would be that until the commencement of anthropogenic emissions, the flux from and to each natural source and sink was relatively static, and the relatively rapid subsequent changes in those natural fluxes is only present as a response to the anthropogenic forcing. However there is no evidence to support this idea, and it seems highly unlikely that increases in natural emissions and sinks of more than 4 x the anthropogenic emission were actually caused by it.

DK's own series of papers on causality actually demonstrate that the rise in global temperatures cannot have been caused by a rise in CO₂, and therefore the reverse seems likely, and the rise in temperature, and consequent expansion of the biosphere, is a much more likely explanation for the changes in natural fluxes. Incidentally, I have yet to see a single credible challenge to those causality papers, which are based on uncontroversial data and a transparent and parsimonious mathematical framework. Most of the objections I have seen refer to the above carbon balance argument as proof that the results are incorrect. As such, we have a circular dependence - for it to be even possible that anthropogenic emissions of CO₂ are the cause of CO₂ accumulation in the atmosphere (and by implication the cause of global rises in temperature), it must be true that CO₂ emissions are the cause of the changes in natural emissions, requiring that anthropogenic emissions of CO₂ are the cause of CO₂ accumulation in the atmosphere.

In conclusion, it is extremely unlikely that human emissions of CO₂ are more than a relatively small contributor to the increase of CO₂ in the atmosphere. For even a starting point to demonstrate otherwise, it is necessary to demonstrate scientifically how causality in the direction from CO₂ to temperature is possible, as it has been shown by DK et al, in a truly scientific framework, not to be.

An additional final note regarding David Andrews comments. There is nothing in the essay (or any of the published papers by DK on this topic) that requires the synthesis of new CO₂. All his arguments are fully compliant with the total carbon budget. The expansion of the biosphere to which he refers does not require the creation of mass - it merely changes the rate of flux between the notional natural reservoirs.

If I understand him correctly, David Andrews' argument seems to be that the net natural carbon sink requires an external source of carbon to allow the simultaneous expansion of the biosphere and accumulation of CO₂ in the atmosphere. Is he saying that the biosphere can only expand without human intervention if carbon on balance is being transferred to the atmosphere by natural processes?

This argument seems to point towards a sequential process, whereby net carbon accumulation in the atmosphere is required to drive expansion of the biosphere via photosynthesis, which then drives increased respiration due to plant decay, leading to a further increase in the atmospheric inventory.

But the fluxes between the reservoirs of carbon in the oceans, land and atmosphere, year over year, operate simultaneously, not sequentially and it is the simultaneous increase in all elements of the carbon fluxes (including the relatively small fossil fuel origin flux) that allows the biosphere to expand whilst at the same time increasing the amount of carbon in the atmosphere. The only place that the carbon required to effect these increased flux levels can come from is the oceans, the land and the atmosphere, with the vast majority coming from the first two. Clearly there is nowhere near enough carbon from fossil fuels to drive the huge increases in natural carbon flux estimated by the IPCC during the human era.

Again, on the numerous other occasions in pre-human history when the biosphere underwent an expansive phase, the planet managed to bring it about without human intervention. Or does David believe that prior to humans, there were no such expansion phases?

To clarify, I do not dispute that extra carbon has been added to the overall inventory of the carbon cycle by the burning of fossil fuels, nor that it plays a part in the modern carbon cycle. However, the lack of a human absorption process to offset the human emission process can only imply that human emissions are the sole or primary contributor to the rise in atmospheric CO₂ concentration if the natural processes themselves remain static or relatively so when compared with the anthropogenic emission. David's comments suggest that he denies this, but he hasn't addressed either the argument put forward by DK using the rules of logic, nor my attempt to illustrate them by an example.

If he does not deny it, his conclusion cannot in any case be true, since we know that the natural fluxes have been subject to significant change throughout history. We know that natural processes have resulted in the accumulation (and de-cummulation) of CO₂ in the atmosphere prior to the modern era, before the release of the carbon previously trapped in fossil fuels into the carbon cycle. This must have resulted from significant changes in the natural carbon fluxes, changes in which the IPCC's own estimates show also exist in the modern era.

As I also pointed out in my previous comments, the only other possibility for anthropogenic CO₂ emissions to be the primary cause of the increased CO₂ concentration in the atmosphere, is that the anthropogenic emissions have forced the changes in natural flux estimated by the IPCC for the modern era. But David is not appealing to this argument - and rightly so, as it is rather ridiculous.

In addition, his statement 'Obviously it is a logical fallacy to conclude that therefore there are only natural processes at work today' is a distortion of my argument. On the contrary, I state that the addition of the anthropogenic carbon to the carbon cycle is a contributor to the accumulation of CO₂ in the atmosphere. The point I make is that it is neither the sole nor primary contributor*.

David, in his final paragraph, states that I've been 'duped' 'by DK's assertion that the year over year increase in atmospheric CO₂ in recent decades is caused by temperature, and his ludicrous claim that statistical confidence levels don't matter'.

Taking the second of these statements first, 'his ludicrous claim that statistical confidence levels don't matter', is a distortion of what DK stated in his comprehensive response to the challenge to his paper's results concerning the lack of statement of a significance level.

Though DK doesn't argue this, my own understanding is that the statement of results in relation to processes that are stochastic by nature without an accompanying calculation of significance levels does not invalidate those results. It merely omits any quantification of the likelihood that they are not valid, which of course is a different thing. David's earlier comments suggest he believes otherwise.

What DK does point out in response to the question of significance levels is that they are often mis-used in Hydrology and in science in general, providing numerous references in support of his claim, including the following:

"Part of the statistician community argues against the concept of significance testing (Nuzzo, 2014 [19]; Wasserstein and Lazar, 2016 [20]; Amrhein and Greenland, 2018 [21]; Trafimow et al., 2018 [22]; Wasserstein et al., 2019 [23]), with the main critique summarized in the statement of the American Statistical Association that "the widespread use of 'statistical significance' (generally interpreted as ' $p \leq 0.05$ ') as a license for making a claim of a scientific finding (or implied truth) leads to considerable distortion of the scientific process" (Wasserstein and Lazar, 2016 [20])."

This, however, is a very long way from saying that 'confidence levels don't matter'.

Concerning the first statement, I don't believe that I've been duped at all. I came across DK et al's series of papers on causality by chance, and read them with a healthy skepticism, particularly considering the weight of opinion against their conclusions. Having followed the arguments, which I repeat are based on a transparent and parsimonious mathematical framework using uncontroversial data, I could not find any fault in them. In order to understand the arguments fully, I worked through all the derivations, coded them in R and applied the same uncontroversial data, from which I was able to replicate all the results stated in the papers.

I don't expect everyone who challenges DK et al's conclusions to go to the same ends of analysis and assessment - we all have lives outside this discussion - but please do not tell me that I've been duped without at least showing me where the work in those papers is wrong. Should you choose to do so, I would welcome an argument with the same scientific rigour used in those papers.

As a newcomer to this whole subject area, what baffles me is that if such a lot of work by so many scientists has brought about the "settled science" of human-caused climate change [not quoting David here, I hasten to add], why is none of it brought forward to challenge ideas to the contrary in a mathematical, and thereby unambiguous, framework? Despite the alleged mountains of evidence available, a scientific response to the papers regarding causality remains outstanding. Does David really think the reason for this is that the papers are 'not serious'? The Royal Society, as I understand it, is not given to the publication of papers that are not serious. And from what I've been reading, they appear to be considered seriously enough to generate a lot of anger among the climate crisis faithful, including efforts to prevent and then retract their publication.

The reason I not only believe that I have not been duped, but rather that David himself has been, is that I trust in the very scientific method that DK applies and is so far lacking in the responses to DK's work.

**[I did, however, quote the anthropogenic emissions contribution as a percentage of all the changes of flux, which is misleading in terms of this discussion. Better to instead quote it as the percentage of only the sources of emission - the contribution proportion to the total emission change is $11/(11+25.6+23.1) = 18.4\%$. My apologies for this, which was not intended to exaggerate my argument]*

David's pool analogy is a favoured one used in this argument, so let's take a look at it.

The pool analogy as described by David provides us with a constant amount of water being circulated via the filter, so that the level is in equilibrium, other than for the 1 gal/min leak from the filter. This represents the natural carbon cycle. The level in the pool would therefore be decreasing were it not for the 2 gal/min we add with the hose, which represents the carbon added to the atmosphere by humans.

But this analogy doesn't very well model the situation with the carbon balance, because it assumes we have a single reservoir containing the water (made up of the pool itself and the volume of the filtration/circulation system, which is assumed full, and that therefore contains a constant volume of water), and (an implied) constant rate of circulation. However, in the case of the atmosphere we know that we have 3 main reservoirs of carbon (atmosphere, oceans, land) and the volume of carbon stored in each is continually changing, as are the flow rates between them.

So let's modify our pool analogy in a simple way to more accurately model what's going on.

Now we install a large header tank above the pool which feeds the pool with water, and we have a control valve that allows us to set the rate at which the tank feeds water to the pool. We also have a variable speed pump at the discharge of the filter that allows the water to be fed back up to the header tank at a variable rate.

Occasionally, we manually change the settings of the control valve opening and pump speed and notice that the level of the pool increases and decreases accordingly. One day we decide to measure the flow rates in and out, and note that the header tank is feeding 49 gal/min of water to the pool, and the pump is removing 50 gal/min from the pool and sending it up to the header tank. The level in the pool is falling at a rate of 1 gal/min.

We then turn on the hose to add 2 gal/min of water to the pool, and note that the pool level is now increasing by 1 gal/min.

What's causing the pool level to rise? We know that if we turned off the hose the level would be dropping, so we conclude that the 2 gal/min we are adding with the hose is the cause of the rising level of water in the pool. It clearly has nothing to do with the much higher, variable flows represented by the header tank and circulation pump, since they are currently providing a net sink. In addition, the volume of water in the pool and header tank without the hose is constant, so that confirms that the new source of water must be the cause of the rising pool level.

This is a more accurate analogy of what David is saying is happening in the atmosphere with CO₂. Is the water from the hose causing the pool level to rise, or is it just a minor contributor?