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Earth System Dynamics Discussions

Interactive comment on "Accounting for the climate-carbon feedback in emission metrics" *by* Thomas Gasser et al.

Anonymous Referee #1

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This manuscript presents a methodology to better assess the greenhouse-gases emission metrics, by considering and removing the "climate-carbon" feedback that is implicitly used in previous estimations and in previous IPCC recommendations. The methodology is well exposed and rather straightforward, the scientific discussion is clear and well written. Therefore, I have no comment on the technical content of this paper. In contrast, I have some major comments on the overall presentation, introduction and conclusion : these critical comments must be accounted for by the authors before considering publication. Indeed, greenhouse-gases emission metrics is a very "subjective" tool that should be presented as such. It is possible to build a very accurate subjective methodology, but this certainly does not help to provide an objective one. I therefore strongly disagree with the general tone of the paper, given in the introduction:

page 1, line 20 : "However, including carbon-climate feedbacks, particularly in absolute

metrics or for short time horizons, gives a more realistic representation of the response"

I also strongly disagree with the conclusion that:

page 15, line 15: "To avoid potential biases in metric values, we suggest to include the climate-carbon feedback in metric estimates".

The very concept of a unique simple metric for GHG is both UNREALISTIC and BIASED. Refining this concept will not change this fundamental fact.

The purpose of GWPs or GTPs is to provide a unique simple metric to compare the "climatic impact" of the many different anthropogenic greenhouse gases (GHG). Obviously, from a scientific perspective, this amounts to comparing oranges and apples. I understand that such an exercise is necessary from a policy perspective, and that scientists should help and provide numbers. Still, I am not convinced that comparing "very accurately" oranges and apples is either necessary or desirable. At the very least, when comparing them, scientists should keep insisting on the differences.

The most important (and arbitrary) parameter is the chosen time horizon : do we value more the current generation (20 years from now) or future generations (500 years from now) ? This is a moral question, not a scientific one. Therefore, in the 2001 IPCC report, we read, for instance concerning methane (CH4), a range of values: GWP20 = 62 ; GWP100 = 23 ; GWP500 = 7 (IPCC 2001, page 388, Table 6.7) Interestingly, the range given in the 2014 IPCC report (AR5) is "narrower": GWP20 = 84 ; GWP100 = 28 (IPCC 2014, page 731, Table 8.A.1) which does not reflect scientific advances or a more accurate assessment of the metric, but simply a different a priori choice, with the 500-year horizon not being discussed anymore in the last AR5 report. Similarly, using the GTP metric (the effect at final time t) instead of GWP (the effect integrated between gas injection and time t) is a rather arbitrary choice. The use of the global mean temperature (in GTPs), or global mean radiative forcing (in GWPs), is also quite arbitrary, since local impacts do not necessary scale linearly to such global averages. Of course, all these points have been discussed in the literature many times and are

well known to specialists. Still, I believe they are so critical and so often overlooked by non-specialists (policymakers, BUT also many climate scientists), than they need to be heavily stressed in papers on GHG metrics like the current manuscript. In particular, the reassessment of GWPs (or GTPs) performed in this manuscript, in order to "remove the carbon-cycle feedback in the denominator", does change the numerical values by, typically, a few percent or less, something very much smaller than, for instance, the arbitrary choice of a time horizon. This needs to be explicitly stated and probably strongly emphasized in the manuscript : comparing GHGs is much more a moral and subjective choice (eg. long-term versus short-term) than a scientific question. Providing accurate estimations of a subjective metric does not lead to an objective metric.

The very concept of GWPs/GTPs is based on a simple linear view of the climate system (impulse response functions, transfer functions, Laplace transforms, ...). In order to be physically relevant, it requires the quite strong assumption that there is NO feedback at all in the system (ie. GWPs are fully independent on climate or other GHG levels). Of course, GWPs/GTPs can be diagnosed from complex non-linear systems, but their use as a simple metric is based on the assumption that the climate responds linearly to each individual forcing. The aim of the paper is therefore to remove the feedbacks in the carbon cycle to better "fit" into the concept of linear systems and therefore provide a more "accurate" quantification of GWPs/GTPs. But at the same time, climatologists usually insist in describing climate as a complex non-linear system, with many feedbacks (in particular between climate and the carbon cycle, precisely the one discussed in the paper). This is a point that deserves some extended discussion: To what extent GWPs/GTPs are sound concepts for climate? And to what extent are they simply imperfect tools designed to answer the heavy policy requirement for a metric ?

I have also a more specific problem with the IRF for temperature. The impulse response functions for carbon (Appendix C.1) have all the same structure: a constant term (= percent carbon staying in the atmosphere "forever") and several decreasing exponentials

(= capture of carbon by vegetation and ocean). In contrast, the impulse response functions used for temperature (Appendix C.2) have no constant term. In other words, a basic fundamental ASSUMPTION in the GTP computations is that climate change is fully reversible: whatever the size of the initial radiative "spike" forcing at time zero, climate recovers to its initial conditions after a few centuries. I have some major difficulties to admit such a strong HYPOTHESIS, which stands against all my knowledge in climate science... These response functions are obtained from atmosphere-ocean only GCMs simulations (without feedbacks from the surface vegetation changes, land ice cover, deep ocean changes, etc...) by fitting one-way experiments (abrupt or gradual 4xCO2 experiments with stabilization). Is this supposed to be realistic? Interestingly, there are no reversed experiments, even though the IRF functional form assumes reversibility: is this climate reversibility assumption based on something else than just simple convenience?

Again, I understand the requirement for a metric to compare GHG. Obviously, this implies some arbitrary choices and some drastic simplifications of the climate system. Still, I have difficulties with the logic of "fitting" the climate system into a simple linear fully reversible system. I certainly do not share the scientific concept behind. At the very least, these fundamental assumptions should be explicitly stated and discussed in the manuscript.

There is a real danger to misrepresent the response of the climatic system, in a "very accurate" BUT certainly not "objective" fashion, as a linear response to the superposition of independent GHG forcings that are not allowed to interact with each other, nor with climate. I am not sure that scientists should blindly misrepresent the real world, only to fit policy requirements of a simple metric. At least, they should be extremely cautious and stress the limitations of the GWPs/GTPs concept.

I am not a specialist of GHG metrics. I am writing this review just after the interactive comment from M. Sarofim et al. was posted online, and I strongly agree with it. The added value of a more "accurate" assessment of GWPs/GTPs, as presented in this

manuscript, comes at the cost of simplicity and reproducibility. Though the scientific methodology presented in this paper is sound and well presented, I am not sure this is the best way to fulfill the requirements of GHG metrics. Fundamentally, GHG metrics are only a "rule of thumb" to decide which GHG is "better" or "worse", from some subjective perspective. Scientists should not try to disguise this "rule of thumb" into an objective, quantified, assessment.

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