

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

KT Tanaka (Referee)

tanaka.katsumasa@nies.go.jp

Received and published: 19 January 2017

The authors present a new and elegant approach to including climate-carbon cycle feedbacks consistently in the estimates of emission metrics, and more specifically, absolute metrics for non-CO₂ components. The paper makes several important points associated with the treatment of climate-carbon cycle feedbacks in the calculations of emission metrics performed for IPCC AR5. The text requires some editing (although I like the style of writing), but the argument is clear and the results are well presented. I think this paper potentially has a strong impact in the field of emission metrics and may influence the next IPCC report but can also lead to confusion among metric users as I discuss below. The paper requires a revision by reflecting the comments below before being recommended for publication in Earth System Dynamics.

C1

I start with one broad comment, followed by several minor ones. The paper begins with the issue that the treatment of climate-carbon cycle feedbacks was inconsistent in representative metric values in IPCC AR5 (i.e. Table 8.A). More precisely, such feedbacks are accounted for in the estimates of absolute metrics for CO₂ but ignored in those for non-CO₂ components, resulting in an inconsistency when they are put together to calculate relative metrics. This inconsistency is, to be sure, clearly indicated in multiple places in IPCC AR5, but my observation is that the inconsistency has created confusion among metric users. Some studies that follow (e.g. (Cherubini et al. 2016; Lévassieur et al. 2016)) support a use of alternative metric values taking climate-carbon cycle feedbacks consistently into account (i.e. Table 8.SM.15 in the Supplementary Material of IPCC AR5), even though alternative values are available only for a subset of the components of interest. Now, the paper reveals that the approach to incorporating climate-carbon cycle feedbacks for non-CO₂ components adopted in IPCC AR5 was actually wrong because the natural carbon sinks are assumed inactive for the additional CO₂ release through climate-carbon cycle feedbacks (e.g. Figure 2). This finding essentially disqualifies all the alternative metric values in IPCC AR5.

Given the situation above in the recent past, this paper may create a new confusion among metric users dealing with climate and environmental policies and assessments. I would therefore request a more detailed clarification of what has happened and what should be done for the metric values in IPCC AR5 in their view. I think that this paper is a right place to do so because some of the authors have been closely involved in the writing of the metric section of IPCC AR5.

Hopefully this comment can be taken in a constructive way, but the paper can be more explicit about why the treatment of climate-carbon cycle feedbacks ended up with being inconsistent in IPCC AR5. The paper describes how it is inconsistent in sufficient details (e.g. Page 5, Lines 3-9), but it is unclear to me why this has happened. For instance, why was it not possible to estimate an IRF for CO₂ response without climate-carbon cycle feedbacks? If this were available, this might have allowed one to estimate

C2

metrics 'consistently' without climate-carbon cycle feedbacks. This might have been an alternative solution, if not a best one, in light of the inherent linear limitation in the IRF approach that is discussed in Section 5.2. In practice, it is probably not feasible to re-do an experiment requiring many models. But, looking back, was there a lack of coordination at the beginning? Furthermore, what about the method to account for climate-carbon cycle feedbacks for non-CO2 components in AR5? This method has not been sufficiently tested before the adoption and is based just on a section of one peer-reviewed paper (Collins et al. 2013), whose main contributions lie elsewhere. How was the ad-hoc decision process leading to the adoption of this approach made? Is there anything useful that can be learned from for the next IPCC report? What are the recommendations for metric values? I noticed that the paper does contain some text recommending the new estimates (page 12, lines 15-17), but it is buried in the middle of the paper and I am not sure what are the intentions. I raised some of the questions that may arise if the paper is officially published, although not all of them may not have to be answered in this paper. Clarifications suggested here should be helpful for metric applications, and ultimately the IPCC AR6.

Minor comments

Page 1, Lines 11-14 The argument concerns only a set of works using IRF to estimate emission metrics. There are also a body of relevant works based on other approaches like simple climate models (e.g. (Tanaka et al. 2009)) and more complicated ones (e.g. (Gillett and Matthews 2010)). These particular studies do consider climate-carbon cycle feedbacks to calculate emission metrics. The statement can be revised to be more restrictive.

Page 2, Line 2 Another area that I could think of is the ecosystem community (e.g. (Neubauer and Magonigal 2015)).

Page 2, Line 13 If there is any reference to support this statement for the last century, please add.

C3

Page 2, Line 21 "whose" instead of "which"?

Page 3, Line 9 I don't think the underlying models exhibit a hysteresis within the range of IRF calibrations.

Page 4, Line 6 In practice, this pulse emission is large. As in Appendix A, it is 100 GtC in the case of CO2.

Page 5, Line 26 Should it be $a(t')$ instead of $a(t)$ in the integral?

Page 7, Line 16 It would be helpful if the authors provide a few sentences on how climate-carbon cycle feedbacks are modeled in OSCAR, rather than just a reference. Do the feedbacks act only on soil carbon? What about NPP? Do they directly affect the ocean carbon uptake?

Page 10, Line 3 Please elaborate on how this equation was derived.

Page 10, Lines 9-10 There are many earth system processes that are nonlinear. As something that has been discussed intensively before, I would point out the buffering of ocean CO2 uptake under rising atmospheric CO2 concentration. But this nonlinearity can be modeled by a revised IRF approach that treats the atmosphere and the mixed layer as one box (Hooss et al. 2001).

Page 11, Lines 4-5 Related to the comment above, the authors should refer to the relevant debate on the linear limitation of IRF (Joos et al. 1996; Hooss et al. 2001). A detailed biogeochemical discussion is given in Section 2.1.2 of (Tanaka et al. 2007).

Page 12, Line 2 This should be "figures 5 and 6" because there is no figure 7 in the current manuscript.

Page 12, Lines 15-17 Related to my major comment, if this is really a recommendation for metric users, this needs to be more highlighted in the text. Metric users would otherwise be left wonder what are the values that should be used for applications.

Page 13, Line 20 This is just a minor note, but TOTEM (Ver et al. 1999; Mackenzie et

C4

al. 2011), which is one of the models used to derive the IPCC AR5 IRF (Joos et al. 2013), accounts for nitrogen and phosphorus limitations.

Page 14, Lines 29-30 I fully agree with this statement.

Page 15, Lines 16-17 I am coming back to the first minor comment. Although I somewhat hesitate to repeat this point because of the conflict of interest, the paper should discuss studies that estimate emission metrics based on models other than IRFs at least at some length. Examples are (Manne and Richels 2001; Tanaka et al. 2009; Gillett and Matthews 2010; Reisinger et al. 2010; Johansson 2012; Smith et al. 2012; Tanaka et al. 2013; Sterner et al. 2014), and there are many more. The current manuscript narrowly focuses on IRF-based studies. I believe that adding more relevant studies should enrich the discussion in this paper and make the argument more convincing.

Page 27 Figure 4 is not discussed in the paper.

References

Cherubini F, Fuglestvedt J, Gasser T, Reisinger A, Cavalett O, Huijbregts MAJ, Johansson DJA, Jørgensen SV, Raugei M, Schivley G, Strømman AH, Tanaka K, Levasseur A (2016) Bridging the gap between impact assessment methods and climate science. *Environmental Science & Policy* 64:129-140. doi:10.1016/j.envsci.2016.06.019

Collins WJ, Fry MM, Yu H, Fuglestvedt JS, Shindell DT, West JJ (2013) Global and regional temperature-change potentials for near-term climate forcers. *Atmos Chem Phys* 13 (5):2471-2485. doi:10.5194/acp-13-2471-2013

Gillett NP, Matthews HD (2010) Accounting for carbon cycle feedbacks in a comparison of the global warming effects of greenhouse gases. *Environ Res Lett* 5 (3):034011. doi:10.1088/1748-9326/5/3/034011

Hooss G, Voss R, Hasselmann K, Maier-Reimer E, Joos F (2001) A nonlinear impulse response model of the coupled carbon cycle-climate system (NICCS). *Clim Dyn* 18

C5

(3):189-202. doi:10.1007/s003820100170

Johansson D (2012) Economics- and physical-based metrics for comparing greenhouse gases. *Clim Change* 110 (1):123-141. doi:10.1007/s10584-011-0072-2

Joos F, Bruno M, Fink R, Siegenthaler U, Stocker TF, Le Quélé C, Sarmiento JL (1996) An efficient and accurate representation of complex oceanic and biospheric models of anthropogenic carbon uptake. *Tellus B* 48:397-417. doi:10.1034/j.1600-0889.1996.t01-2-00006.x

Joos F, Roth R, Fuglestvedt JS, Peters GP, Enting IG, von Bloh W, Brovkin V, Burke EJ, Eby M, Edwards NR, Friedrich T, Frölicher TL, Halloran PR, Holden PB, Jones C, Kleinen T, Mackenzie FT, Matsumoto K, Meinshausen M, Plattner G-K, Reisinger A, Segsneider J, Shaffer G, Steinacher M, Strassmann K, Tanaka K, Timmermann A, Weaver AJ (2013) Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: a multi-model analysis. *Atmospheric Chemistry and Physics* 13 (5):2793-2825. doi:10.5194/acp-13-2793-2013

Levasseur A, Cavalett O, Fuglestvedt JS, Gasser T, Johansson DJA, Jørgensen SV, Raugei M, Reisinger A, Schivley G, Strømman A, Tanaka K, Cherubini F (2016) Enhancing life cycle impact assessment from climate science: Review of recent findings and recommendations for application to LCA. *Ecol Indicators* 71:163-174. doi:10.1016/j.ecolind.2016.06.049

Mackenzie FT, De Carlo EH, Lerman A (2011) Coupled C, N, P, and O biogeochemical cycling at the land-ocean interface. In: Wolanski E, McLusky DS (eds) *Treatise on Estuarine and Coastal Science*, vol 5. Academic Press, Waltham, pp 317-342

Manne AS, Richels RG (2001) An alternative approach to establishing trade-offs among greenhouse gases. *Nature* 410 (6829):675-677

Neubauer SC, Megonigal JP (2015) Moving Beyond Global Warming Potentials to Quantify the Climatic Role of Ecosystems. *Ecosystems* 18 (6):1000-1013.

C6

doi:10.1007/s10021-015-9879-4

Reisinger A, Meinshausen M, Manning M, Bodeker G (2010) Uncertainties of global warming metrics: CO₂ and CH₄. *Geophys Res Lett* 37 (14):L14707. doi:10.1029/2010gl043803

Smith SM, Lowe JA, Bowerman NHA, Gohar LK, Huntingford C, Allen MR (2012) Equivalence of greenhouse-gas emissions for peak temperature limits. *Nature Clim Change* 2 (7):535-538. doi:org/10.1038/nclimate1496

Sterner E, Johansson DJA, Azar C (2014) Emission metrics and sea level rise. *Clim Change* 127 (2):335-351. doi:10.1007/s10584-014-1258-1

Tanaka K, Johansson DJA, O'Neill BC, Fuglestedt JS (2013) Emission metrics under the 2°C climate stabilization target. *Clim Change* 117:933-941. doi:10.1007/s10584-013-0693-8

Tanaka K, Kriegler E, Bruckner T, Hooss G, Knorr W, Raddatz T (2007) Aggregated Carbon Cycle, Atmospheric Chemistry, and Climate Model (ACC2) – description of the forward and inverse modes. Reports on Earth System Science, vol 40. Max Planck Institute for Meteorology, Hamburg

Tanaka K, O'Neill BC, Rokityanskiy D, Obersteiner M, Tol R (2009) Evaluating Global Warming Potentials with historical temperature. *Clim Change* 96 (4):443-466. doi:10.1007/s10584-009-9566-6

Ver LMB, Mackenzie FT, Lerman A (1999) Biogeochemical responses of the carbon cycle to natural and human perturbations: Past, present, and future. *Am J Sci* 299 (7-9):762-801

Interactive comment on Earth Syst. Dynam. Discuss., doi:10.5194/esd-2016-55, 2016.