Earth Syst. Dynam. Discuss., 3, C92–C95, 2012
www.earth-syst-dynam-discuss.net/3/C92/2012/

Earth System Dynamics Discussions

Interactive comment on "Comparison of physically- and economically-based CO_2-equivalences for methane" *by* O. Boucher

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Received and published: 19 March 2012

I would like to thank Dr. Glen Peters for his thoughts and comments. I reply to the specific comments raised here but the reader may please refer to my other replies as well.

1. Dr. Peters is right that the variable t is the starting time as indicated on page 6, lines 17 and 20. The variable and the text can easily be modified as suggested to make this clearer.

2 and 3. I certainly agree that the GWP and GTP depend on the background atmosphere and climate. This is partly discussed on page 12, line 18 to page 13, line 4. I also agree that there is subtle difference between calculating the GWP / GTP at dif-

ferent but constant background levels and allowing the background levels to change according to a scenario. There are various reasons why the methane GWP and GTP depend on the background concentrations levels: i) the CO_2 radiative efficiency decreases with increasing CO_2 concentration, ii) the CO_2 impulse response function changes with climate and atmospheric CO_2 concentration, iii) the CH_4 lifetime varies with climate change, iv) the CH_4 radiative efficiency depends on the CH_4 and N_2O atmospheric concentrations, and v) the climate impulse response function depends on the state of the climate (e.g., through the carbon-climate feedback). Taken individually these effects are not necessarily insignificant (see references cited in Section 3.2 of the discussion paper and those in item 2 of Dr. Peters' comment). However some of these effects are of opposite signs, e.g. effects i) and ii) partly compensate for each other for the CO_2 AGWP, effects iii) and iv) can partly compensate for effects i) and ii) for the methane CO_2-equivalences, effect v) could affect the GTP and GDP metrics but in ways that may change over time and there would also be some compensation between the effects on CO_2 and CH_4. Overall it is not clear that such changes in the background atmosphere and climate do induce a systematic change in the methane GWP and GTP as it is the case for the GDP with a non-linear damage function. For instance results by Reisinger et al. (2011) suggest that the 100-year CH_4 GWP can either increase or decrease according to the climate scenario. Similar results would be expected if the background levels are allowed to change over the time horizon.The discussion paper deliberately makes simplifying assumptions and our goal was to study the time evolution of the metrics under this set of simplifying assumptions rather than look at the details of how individual metrics may vary with the details of emission pathways and climate response. I agree though that the issue of varying backgrounds can be emphasised further but I think this represents a level of sophistication that is not required here.

4. I agree that discounting can be introduced into a GWP-type of metric (but it should not be called GWP anymore). I am not sure however how discounting can be in-

troduced into the GTP metric. I also agree that a time horizon has some similarity to discounting (this was mentioned on page 18, lines 26-27 of the discussion paper by the way). Time horizon is a timescale while a discount rate is the inverse of a timescale, so there is indeed a connection between the two quantities. A discount function that is unity before TH and zero beyond TH would correspond to a zero discount rate before TH and an infinity discount rate beyond TH, so it is stretching the concept a bit. Thank you for pointing out Figure 5 in Fuglestvedt et al. (2003). This can be referred to in a revised version.

5. I believe the text in Section 2.5 is factually correct. The GWP and GTP are not straightforward cases of the simplified GDP the way it is defined by Equation (3). It does not mean that GWP and GTP cannot be folded under a more generalised GDP as suggested by Dr. Peters. It is useful to find a unifying equation and link the metrics, but one should also question the meaning of it. A discount function that is a Dirac function is difficult to interpret in terms of discounting (it corresponds to a discount rate that is infinity up to the TH, zero at the TH and infinity beyond the TH, why sort of discounting philosophy would result in a discount rate that looks like that?). The damage function could instead be seen as a Dirac function, but again it is difficult to interpret why a damage function would be zero before and after the TH. In conclusion I would not push the connections too far as the different metrics correspond to different logics (although it does not imply in my opinion that they are equally good).

6. As this comment is common to a series of comments made by referee # 1, it is addressed in my reply to that review. I only address one specific aspect of the comment here. I think it is somewhat flawed to say that the GTP only requires one additional parameter (the target year) to be time-varying. The target year itself is a function of the target temperature change, the chosen concentration pathway and the climate sensitivity parameters. Moreover there is an issue on what to do as the target year is approached or passed unless some more sophisticated metric is introduced as done in Johansson (2012).

7. Again I agree that the instantaneous response to a sustained emissions is equivalent to the integrated response of a pulse emission, but it does not mean that a pulse emission metric should be interpreted as a sustained emission metric or vice versa when it comes to using the metric. What would be the meaning of a "double" sustained emission metric? The text in the discussion paper should read "...even if a different (pulse) climate metric had been used".

8. These comments essentially repeat previous comments 1 to 7. Please refer to my replies above and to the reply to referee #1on what is a good metric. The conclusions were not meant to be critical of the GWP and GTP metrics but the text can certainly be adjusted to eliminate any ambiguity.

9. I am not sure to understand the point on Figure 4, but please refer to the reply to referee #1 on what a good metric is.

References

Johansson, D. J. A., Economics- and physical-based metrics for comparing greenhouse gases, *Climatic Change*, 110, 123-141, doi:10.1007/s10584-011-0072-2, 2012.

Interactive comment on Earth Syst. Dynam. Discuss., 3, 1, 2012.