**Atmospheric
Chemistry
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Discussions**

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Interactive comment on "Quantifying immediate radiative forcing by black carbon and organic matter with the Specific Forcing Pulse" *by* T. C. Bond et al.

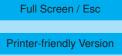**T. C. Bond et al.**

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Reviewer's original text appears in italics; our responses are in normal font.

This manuscript introduces a new metric for quantifying and comparing the climate impact of short-lived climate forcers (SLFCs) called specific forcing pulse (SFP). I think this a very useful matrix, but the manuscript has many issues.

Thank you for your hopeful statement and for your engagement.

I agree with reviewer 1 that the manuscript is overstating the difference between SFP and AGWP, i.e., that some of the "alleged advantages of the SFP over the AGWP

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are because SFP is restricted to short-lived species, rather than an intrinsic property of the SFP." The main advantage of SFP I see is that SFP can refer to forcing within a specific region, but the difference in time horizon is the nature of the short-lived species, not SFP. I think Section 2 would be easier to understand if the manuscript introduces AGWP first, and then introduce the definition of SFP as a refinement of AGWP that is applicable for short-lived species only.

Please see our comment, "Metric or measure?" posted on 5 Sept 2010. At no time did we suggest that SFP should replace AGWP. We did argue that SFP has some uses that AGWP does not allow. This reviewer and reviewer 1 argue that we "overstate" the difference, yet they have not disagreed with the differences we identify. Our presentation flow was meant to show the uses of SFP first, rather than forcing the proverbial square peg (AGWP) into the round hole that does not suit it. We then draw a connection with AGWP. We have revised the presentation of SFP and hope that its uses and connection with AGWP have been clarified.

I disagree with setting the minimum value of one year for the time horizon. Precisely because there are seasonal variations in forcing, SFP should also be subdivided into seasons or months. To achieve a policy goal of a certain reduction in forcing, we need to know not only how much emissions reduction is needed from where, but also when (seasons or months).

The reviewer is confusing the time horizon with the timing of emission. Time horizon is the period over which forcing is integrated after emission occurs. Forcing after a pulse emission in spring could be integrated over one year. Forcing after a pulse emission in winter could also be integrated over one year. In this paper we provide calculations based on annual-average emissions, but our definition does not preclude SFP of emissions at particular times.

Equation (4) assumes that climate response is linear. This is not a trivial assumption as many studies have indicated that climate response is non-linear.

We agree with this statement and the original manuscript addresses this issue: "Although Eq. (4) may not capture nonlinearities, we suggest that it is better than ignoring regional differences."

The reviewer did not specify what sort of nonlinearity would be of concern: temperature response to forcing? Many equations in simple climate models, including those used to produce global temperature potentials, assume that climate response is linear. Integrated assessment models may also assume such linearity. These models assume linearity, not because it is fully valid, but because such an assumption allows a useful study. Our goal is to allow similarly useful explorations. We also note that some "nonlinearity" that appears in the study of climate response may result from regional differences in forcing. Therefore, representing these regional differences might render the response more linear.

One important distinction is that SFP and all responses are calculated for the current system state. SFP (and in fact, published GWPs for all substances) might change for a different system, introducing nonlinearities. Since short-lived climate forcers are thought of as a solution to be applied within the next 2-3 decades, we did not worry very much about this dependence. We have added a note about this in the text.

Starting from Equation (4), I simply do not understand Section 4 "Ensemble-adjusted models". (Sloppy section title: models are not ensemble-adjusted; forcing estimates are ensemble-adjusted.) In Equation (4), is SFPfull from baseline model results or "enhanced" model results? Does the index i indicate processes or models? Is Eproc based on the median or average of the ensemble?

Equations have been added to this section so that the final equation (which is the Some of the terminology has been changed, including the indexing, to clarify which estimates come from models.

Section 2 "Impact Measures" is very difficult to understand. Reviewers 1, 2, and3 all have listed a few examples of sloppy sentence constructions. There are more ex-

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amples. In Section 2 the symbol τ sometimes refers to lifetime of a species in the atmosphere while other times the symbol τ refers to the time horizon. This is another example of the sloppy writing that makes comprehending the manuscript more difficult than necessary for the reader.

We have altered all the equations to ensure that no symbol is used twice. In some cases this means that we have had to introduce symbols that are not consistent with previous literature. This desire for consistency was the reason for the choice of symbols in the first version.

Equation (1) is more than a bit sloppy. The use of symbols A and a implies all regions with the same physical area (as in meter2) have the same SFPs; further, it implies that forcing in a given region is impacted only by emissions in the same region. fS and SPF both should depend on the region in which forcing is manifested and the region of emissions.

This section has been rewritten, and also figures given, to demonstrate the intent more clearly.

Equation (4) is also sloppy. First, the term e should not be there because the climate response matrix R includes forcing efficacy/efficiency impact.

We disagree with the reviewer. Inclusion or exclusion of the efficacy term depends on whether **R** is response to the forcing of a particular substance, or the response to forcing of a substance that behaves like CO2. If it's the latter, the efficacy term must be included, because it represents additional responses that are particular to a given substance. If **R** is just the response to the forcing of the substance, then of course the efficacy term should be excluded. However, the second formulation– where **R** is species-specificâĂŤ- allows only the use of **R** values that have been developed for that species. We wish to allow the use of **R** that has been determined for general forcings (e.g. Hansen et al. 1997, although that reference provided **R** for equilibrium response)

Second, the indexing of columns and rows are not consistent: the statement "l and e are vectors in which the n-th element..." should be "l and e are vectors in which the m-th element"

It is true that we could have used *n* to indicate rows only. For the equation as written, *n* was used to indicate the region where the effect of greatest interest for each term was occurring (emission, then forcing, then response). The equation in the paper was accurate as given. The reviewer's statement that this equation is "sloppy" in this case means that we did not conform to the reviewer's desired conventions, which are not universal.

Nevertheless, to clarify this equation, we first wrote it with subscripts in the revised paper. Subscripts *i, j, k* now indicate the region of emission, forcing or response, respectively. The matrix equation is given next.

We note that this still does not conform to the reviewer's convention of always using the same subscript for matrix rows.

I agree with reviewer 1 that the use of "rejected" is sloppy language. Instead of 're-jected" or "rejection", I think "reflected back to space" is a better phrasing.

We disagree that "rejected" is "sloppy" (which we take here to mean "inaccurate.") Re-jected, in thermodynamics, can mean re-emitted. In English, it can also mean refused entry, or reflected. This term covers both reflection and re-emission, and that was the reason for our original choice of wording. None of the terms suggested by the re-viewers have this general sense. Furthermore, this word appears only in a drawing that presents the general idea of a box model. Such diagrams are usually intended to convey generalities, and this one is no exception.

Reference

Hansen, J., Sato, M., and Ruedy, R.: Radiative forcing and climate response, J. Geo-phys. Res.-Atmos., 102, 6831-6864, 1997.

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