23 March 2017

To:
Dr Olaf Morgenstern, Editor GMD, olaf.morgenstern@niwa.co.nz

Re: Manuscript GMD-2016-169

Dear Olaf, dear Copernicus editorial team,

Thank you for your acceptance "with corrections" of our CMIP6 historical GHG concentrations paper.

I provide here a brief reply to the editing suggestions.

Editor suggestion: I suggest to make the following corrections: p7l12 and elsewhere: I'm fine with using "dry air mole fraction" and "mixing ratio" interchangeably, using your phrase for clarification. They reduce to the same thing in the limit of ideal gases. However, the term "concentration" is patently a different quantity. "Concentration" is not conserved under transport and is not suitable to force a climate model with. It would come in units of mol/m^3, whereas mole fractions are dimensionless. So I suggest to remove all occurrences of "concentration" from the text.

Reply: After the previous discussions about the units (ppmv versus mole fractions), we had extensive discussions in the author team on the correct terms. Given that the CMIP6 panel asked us to provide the GHG CONCENTRATIONS, and given that this is the generally used term, we feel obliged to use "concentrations" both in the title as well as in the manuscript. We do however clearly define that we use this term interchangeably with "mole fractions". The respective paragraph reads now:

"All concentrations given here are dry air mole fractions and we use 'mole fractions' and 'concentrations' interchangeably and synonymously with 'molar mixing ratios'. For simplicity, we denote the dry air mole fractions 'μmol mol-1', 'nmol mol-1' and

'pmol mol-1' as parts per million (ppm), parts per billion (ppb) and parts per trillion (ppt), respectively. Note that dry air mole fractions are independent of temperature and pressure, while volume mixing ratios (e.g. ppmv) for mixtures of non-ideal real gases are not, and at standard temperature and pressure conditions can differ significantly from their corresponding mole ratios."

Furthermore, we agree with the Editor that "mole per volume" is not a conserved quantity. However, we would argue that concentrations are not ubiquitously understood as a "mole per volume" unit. In the general usage of the words, e.g. CO_2 concentrations are not considered to be lowering throughout the atmospheric column because of a height / thinning of atmosphere reason. In the specific modelling community, concentrations are clearly associated with mole fractions, as it is denoted in the CMIP6 modelling protocols; the RCPs "Reference Concentration Pathways" are used to denote the concentrations as mole fractions or mole mixing ratios (e.g. ppm), and not as a non-preserved quantity.

We hence suggest to keep a wording throughout the article for simplicity reasons, that is consistent with the CMIP6 panels' request to provide GHG CONCENTRATIONS and hope that the provided clarifications within the ms are sufficient.

Editor's comment - p6l6: The list of 43 gases considered in the paper include quite a few with negligible or zero GWP; they are there because they are ozone-depleting substances. Calling them all "GHGs" is therefore inaccurate. I suggest to replace "GHGs" with "GHGs/ODSs" or to find another way of consistently addressing this concern.

Reply: All the considered substances were chosen because they do have a (sometimes rather small) radiative forcing effect. Thus, none of the substances was considered in this CMIP6 exercise merely because it constitutes an ODS (although that property might be of primary importance for the stratospheric ozone community). We are hence not sure which substances are referred to as not having a GWP. We list all the 43 substances radiative forcing efficacies and lifetimes in the top right corners of the 43 factsheets. The convolution of atmospheric residence and radiative forcing efficacies builds the foundation for deriving GWPs, and hence is not strictly zero for any of the considered gases as neither lifetimes nor radiative forcing efficiencies are zero. We do agree (and discuss in the paper) that some species have negligible radiative forcing effects – which hence gives rise to

calculating equivalence species. Again, none of the substances were considered simply because they are ODS. We hence would argue to keep the current naming as purely referring to GHGs.

p9l16: An EOF is an "empirical orthogonal function" not field, as far as I know.

Thanks. Corrected.

p9l20: Capitalize "Gram".

Thanks. Corrected.

p20l22: Some ODSs are indeed also GHGs, but not all, see above. I suggest to insert "Some" at the start of the sentence.

See above. All ODS's have a climate effect indirectly via ozone destruction (as the Editor points out, also via dynamically induced changes). Thus, the introduction of the word 'some' would render the sentence incorrect in our view.

p20l27: The cooling effect of ozone depletion is substantially complicated by its dynamical impact (effect on circulation) which is the real reason people have identified ozone depletion as the leading cause of recent climate change in the Southern Hemisphere.

Thanks. We adapted the sentence that now reads:

"The impact of ODSs on climate is somewhat complicated by their destruction of stratospheric ozone, which induces dynamical effects on circulation patterns, and has a net cooling effect on the global climate."

There is one additional issue. In the course of compiling the latest version of the manuscript, we noticed a small error. We hence suggest to introduce the following "known issues" section in the limitations section:

"6.8 Known issues

There is one known issue in the historical dataseries before the year 2002 for CF_4, C_2F_6 and C_3F_8. We use the Trudinger et al. {, 2016 #4733} datasets and our algorithm categorised them as mid-year values, but the data were estimates for start-of-year values. Thus, while Trudinger et al. {, 2016 #4733} is well aligned with the Mühle et al. {, 2010 #4551} over that time period (given that the same in-situ and archive data was used), our historical timeseries suggest half a year's growth rate, i.e. up to maximally 0.63 ppt, 0.065 and 0.015 ppt, too low mole fractions for CF_4, C_2F_6, C_3F_8, respectively for the pre-2002 timeframe. In terms of radiative forcing, this difference amounts to approximately 0.00022 Wm-2, 0.000016 Wm-2 and 0.0000043 Wm-2 in the years with the maximal growth rates (1980, 1999 and 2002, respectively). Given that some CMIP6 models had started using the historical data by the time of discovering this error (which will have no significant effect on CMIP6 outputs), we opted for not revising this study's CMIP6 datasets."

Thank you very much for your time and effort and guidance. The final manuscript and figures are uploaded separately.

Sincerely,

A/Prof. Malte Meinshausen
Director of the Australian-German Climate & Energy College