

# Reply to referee # 1

April 10, 2019

Dear Christopher Smith,

thank you very much for such positive comments on our manuscript. We feel particularly honoured for your recommendation to AR6. In the following we reply to your comments point-by-point. The indicated pages of the answers relate to the discussion paper.

## 1 Specific comments

The authors prefer to use "radiative impact" rather than (effective) radiative forcing, and on page 11 discuss the fact that they are equivalent. Is there a good reason to use RI rather than ERF? Perhaps it is because the reference experiment is present-day rather than pre-industrial.

Indeed we chose to use "radiative impact" over ERF, since ERF is (e.g. in the IPCC) commonly used for the change in radiative forcing from pre-industrial. Since we compare to present-day we decided to use a different notation to avoid confusion.

It would make slightly more sense to me for the perturbation experiments to be called S2 and S5 (for 2x and 5x methane respectively). In this context Figure 3 could be understood without reading the paper.

Thank you, we decided to follow your suggestion, as we agree that this change makes the text more reader-friendly.

page 2, line 32: The way this currently reads implies that in Smith et al. we only used one model. It would be good to highlight that this was a 10-model intercomparison study.

Thank you for this note. It was not our intention to suggest this and are happy to change the text to stress that it is a model intercomparison.

Text added to the manuscript:

**Old** Smith et al. (2018) investigated the fast radiative feedbacks (adjustments) in a 3×methane (CH<sub>4</sub>) simulation without considering the chemical feedback effects.

**New** Smith et al. (2018) investigated the fast radiative feedbacks (adjustments) in a model-intercomparison using simulations with 3×CH<sub>4</sub> mixing ratio without considering the chemical feedback effects.

page 5, line 10 (near the bottom): "any possible feedback on tropospheric temperature is largely suppressed...": you mean that climate feedbacks (from increasing global mean surface temperatures) are suppressed. There may be some tropospheric temperature change unrelated to surface temperature, due

to changes in tropospheric heating rates in the 2xCH4 and 5xCH4 experiments.

You are right that there are nevertheless some temperature changes. Actually, the feedback on tropospheric temperature is only suppressed concerning the sea surface temperature. There are indeed minor temperature changes over land and in the free atmosphere. In Figure 6, a small but mostly significant tropospheric temperature increase is apparent. However, fixing the SST leads to a stable temperature in the troposphere and the influence on dynamical processes is largely suppressed (e.g. Brewer-Dobson circulation (BDC)).

Text changed in the manuscript:

**Old** Since SST and SIC are prescribed, any possible feedback on tropospheric temperature is largely suppressed in the present simulations.

**New** Since SST and SIC are prescribed, the larger part of the feedback on tropospheric temperature is suppressed in the present simulations.

The low direct forcing from methane in ECHAM5, mentioned on page 12: is SW absorption of methane included in ECHAM5? This would account for some of the underestimate if not. See Etminan et al., 2016; <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL071930>. Also, there is a difference between models that include SW absorption of methane in their radiation C2 schemes and those that do not in Smith et al. (see Figure S6 in the supplement to that paper).

We indeed found a shortwave contribution close to zero for the radiative impact directly contributed by CH<sub>4</sub>, so this information has been added to the paper together with the reference indicated by the referee. Unfortunately, we could not identify the reason for the longwave part of the underestimation.

Text added to the manuscript:

**New** Part (but only part) of the underestimation can be attributed to a near zero shortwave absorption contribution that is known from radiation schemes used in other climate models (Etminan et al., 2016; Smith et al., 2018).

The separation of the methane ERF into the "direct" component and the chemistry-driven adjustments (table 1) I like. Stratospheric water vapour and O<sub>3</sub> include stratospheric temperature adjustments, so technically these would include a component of physical adjustment as well as the direct radiative effect of the water vapour and ozone (O<sub>3</sub>). The authors are correct that these interactive effects are not present in the participating models in Smith et al.

That is an interesting comment. There are most likely secondary effects due to the changes in stratospheric water vapor (SWV) and O<sub>3</sub> as well as feedbacks on those components. The stratospheric adjusted temperature shown in den supplemental Figures S6 and S7 indicates the expected temperature changes of the chemical species, which are probably the cause of the variations in the meridional transport discussed on page 11. We, for example, also discussed changes in O<sub>3</sub> production and depletion due to stratospheric cooling.

For now, we separated in physical and chemical components based on the intuitive order that "chemical" refers to CH<sub>4</sub>, SWV and O<sub>3</sub>, including the associated stratospheric temperature adjustment. These are the most important radiatively active species that are directly affected by CH<sub>4</sub> through interactive chemistry, but their radiative impact cannot be quantified reasonably without the temperature adjustment (Hansen et al., 1997; Dessler et al., 2013).

## 2 Technical corrections

**Abstract, line 1** would read better as: Methane (CH<sub>4</sub>) is the second most important directly emitted greenhouse gas, the atmospheric concentration of which is influenced by human activities.

**Page 3, line 1:** "result" ⇒ "resulted"

**page 5, line 14:** "a large part" ⇒ "some"

**Page 11, last line:** "(see 2 for a detailed explanation..." not clear what "2" is a reference to here.

**Page 14, line 14:** "antarctic" ⇒ "Antarctic"

Thank you for these suggestions and corrections. We fully agree and changed the manuscript accordingly. The 2 in the fourth comment refers to the Section 2.