

## Reply on RC2

Kalle Nordling et al.

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Author comment on "Understanding the surface temperature response and its uncertainty to CO<sub>2</sub>, CH<sub>4</sub>, black carbon, and sulfate" by Kalle Nordling et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-401-AC2>, 2021

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We would like to thank Review 2 for valuable comments and suggestions. We have revised the manuscript according to the suggestions. All changes are marked with red color to revised manuscript

- It would be useful if panel a) of figure 1 could be labelled with all the terms used in section 2.1. Or if this panel is too small, a separate schematic of showing all the terms would be useful.
  - The panel is too small for this. Furthermore, all terms used in section 2.1 are local changes, whereas panel a) shows an atmospheric column without perturbations. Hence the terms in section 2.1 are not present in panel a.
- Line 105: This could clarify at the start that all these fluxes are net, I first interpreted the arrows as meaning upwards and downwards components until I realised they were net.
  - This is done as suggested
- Line 105: You use the term "cloud radiative fluxes" here, rather than "cloudy-sky radiative fluxes", I presume this is deliberate and part of the APRP decomposition. If so, this should be more explicit at this point.
  - This line text is changed to namely to changes in local longwave fluxes associated with changes in clear-sky and cloud emissivity ( LWclr and LWcld , respectively, with the arrow indicating the vector direction towards space) at TOA, changes in shortwave fluxes due to changes in clear-sky absorption and reflection as well changes in cloudiness and cloud radiative properties ( SWclr , and SWcld),
- Line 120: This is defined (eqn 2) as the change in OLR associated with the change in the local effective emissivity of the planet (not atmosphere). It might also be worth clarifying that changes in the effective emissivity of the planet and changes in the atmospheric emissivity have opposite signs.
  - Emissivity of the atmosphere is here changed to planetary emissivity
- Equation 3: It might make more sense for the arrow on C to be leftward rather than rightward since it is inward flux.
  - Changed as suggested.
- Line 144: Some brief explanation of how the CS and CRE decomposition is done would be helpful. Is CRE just the cloudy-sky component?
  - Here CRE is just the cloudy-sky component. A short text is added to line 150 where we say that these terms are calculated using Equation 2
- Equation 11: I found the terminology on the second line of this equation confusing since DeltaLW and DeltaSW have units of K rather than W/m<sup>2</sup>. Couldn't you use DeltaT with different subscripts?

- We found that using  $\Delta T$ 's with suffixes in the text became too messy. To Clarify that the terms in the last line of Eq. 11 are in units of temperature, we added a text to the end of the paragraph: "In the last line of Eq. (11) the terms without TOA suffix, that is the radiative components divided by  $D$ , are in units of temperature. Hereafter, we will use these terms as shorthand notations when discussing the various temperature responses in the text."
- Line 169: I think there should be a minus sign rather than a plus before the  $\lambda_{LW\_cld} \Delta T$  term? Or at least it should have the opposite sign to all the downward terms.
  - Fixed
- Line 204: I think it is better to say the semi-indirect effect is "inherent" in all models since it is not something that can be explicitly included or excluded. It would be better to use "meteorological adjustments" rather than semi-direct.
  - Done as suggested
- Section 2.4: Why do you not include land-warming corrections? Tang et al. and Richardson et al. show they are important for CO<sub>2</sub>.
  - This is included as suggested in Figure S5.
- Line 246: The relationship might be stronger if you remove the land component from the ERF<sub>fsst</sub>.
  - This is partly true, for CO<sub>2</sub> and black carbon the correlations are higher, however, for sulfate and methane correlations are smaller than for any other method. A new figure (S5) is added to the supplementary material to show ERF with land warming correction. Due to the small number of models, the sensitivity of the relationship to different methods of estimating ERF is difficult to assess..
- Line 309: This seems to imply that all the feedback processes are manifesting themselves in the LW and in the clear-sky which is slightly surprising. It might be worth signalling that you will discuss why this differs with Zelinka in the discussion section.
  - Line 323 includes now The large model to model spread compared to other terms is discussed more in section 3.3. In section 4 we discuss why these differs from example values presented by Zelinka et al. (2020). The somewhat large spread in LW clearsky terms is probably due to small number of models
- Line 314: The feedbacks however should appear in  $\Delta T_{LWclr}$ . Zelinka suggest the WV+LR feedback is around half the Planck feedback ( $\Delta T$  in your figure). Does this imply the feedbacks are different for aerosols and not simply a function of surface temperature change?
  - This is not implying that feedback are different for greenhouse gases and aerosols. With aerosols, the forcing is more on SW side than on LW, whereas  $\Delta T_{LWclr}$  for greenhouse gases includes a substantial contribution from forcing. The temperature response depends both on forcing and the feedback, as discussed at the end of section 2.1.
- Line 325: Presumably this the offsetting cloud adjustment found in earlier PDRMIP papers (Stjern et al.).?
  - This is true, Stjern et al. (2017) shows that rapid adjustments for BC are dominated by the cloud response, and the rapid adjustments dampen the overall temperature response. Line 338 includes now: . With the bcx10 the net cloud effect is cooling across different latitudes, despite variations between  $\Delta LW_{cld}$  and  $\Delta SW_{cld}$ . The increase of low level clouds over the Arctic regions and reductions of clouds in upper troposphere (see fig. S4) due to BC forcing is typical cloud response and these dominates the rapid adjustments and leads dampening of the surface response (Stjern et al. 2017).
- Line 329: For models with an indirect effect I would expect  $\Delta T_{SW_{cld}}$  to be as large (or larger) than the direct effect. Does this imply that there is a negative  $SW_{cld}$  feedback that adds (negatively) to the indirect effect?
  - Yes it does. The changes in cloud cover dominate the overall response.
- Figure 5: needs units
  - Units added.

- Line 387: Can you explain more how the temperature distribution changes in bcx10 and why that means a negative DeltaLWclr? Is it greater LR than WV feedback, or is the initial adjustment?
  - The following line is added: The top-heavy warming in bcx10 experiment results from fast adjustments as shown in Smith et.al 2018.
- Line 404: Could you separate the DeltaSWcld for the models with and without indirect effects?
  - SWcld terms for each model are now added to the supplementary
- Figure 7: Needs unit
  - Units added.
- Figure S2: This would be easier to interpret if it were divided by ERF
  - Done as suggested. Figures S2 to S4 includes now both absolute values and values normalized by ERF.