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Interactive comment on "Significant climate impacts of aerosol changes driven by growth in energy use and advances in emissions control technology" *by* Alcide Zhao et al.

Anonymous Referee #3

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The study uses the CESM global climate model to quantify the impact on effective radiative forcing, surface temperature, and precipitation rates of increases in aerosol emissions due to energy generation and decreases in emissions due to technological advances over the period 1970-2010. The authors find that technological advances only partly offset impacts of energy generation. They also highlight the non-linearity of effective radiative forcing and diversity in temperature sensitivities.

The paper is well written, and the figures support the discussion well. Figure 5 is perhaps the most novel aspect of the study and acts as a very efficient summary of the main findings. There are however results I do not understand, and the discussion

could be improved in places. For these reasons, I recommend minor revisions.

1 Main comment

- I understand why temperature sensitivities, as defined in the study, could be negative (i.e. located in the top left corner of Figure 5) locally because (i) albedo and circulation feedbacks mean that temperature responses are not collocated with ERF and (ii) both ERF and surface temperature distributions are inherently noisy. But I cannot understand how temperature sensitivities can be negative globally, as stated for the best estimate (Page 7 line 16). Is that really the case? According to Fig 3 and 4, ERF is +0.1 W m^{-2} and DeltaT is +0.09, so the sensitivity should be positive. If there are negative global sensitivities, I would be concerned that the model does not conserve energy...

2 Other comments

- Abstract, page 1, line 19: " must be interpreted in the context of experiment designs" is a cryptic statement that is in some way true of all experiments. I would suggest rewriting, perhaps to something like "must be interpreted in the context of the reference baseline".
- Page 3, lines 3–4: That statement could be toned down – improving air quality is getting harder, and climate feedbacks (e.g. this year's record Arctic wildfires) may negate parts of the decreases.
- Page 3, line 10: The reason why the impact of future changes in aerosols have not been looked in isolation before is that (i) uncertainties in emission pathways

also affect other forcings, so aerosols are not alone in that respect, and (ii) considering all forcings together makes sense because sectors emit a cocktail of gaseous and particulate species. So the authors should make a better case for what we really gain at considering aerosols in isolation.

- Page 3, lines 19–21: What did the Turnock study find?
- Section 2.2: Which aerosol radiative forcing mechanisms does the model represent?
- Page 5, line 5 : permutations -> perturbations
- Page 5, line 29: Technically speaking, a decrease of -4 is an increase!
- Captions of Fig 2 and 3: "raised up" is unnecessarily ambiguous. Simply say "multiplied"
- Page 6, line 15 : Why is there an increase over Southern Africa? It looks statistically significant. Are there technological advances that increase emissions?
- Page 6, lines 22–24: That statement is not obvious to me. The area of strongest cooling, in Siberia, looks to be to the north of where emissions changes are probably located, in China. (It would really help to see maps of emission changes.)
- Page 6, line 31: Is the enhancement again due to sea-ice albedo?
- Caption of Fig 5: "error bars represent model uncertainty" – how is that calculated?
- Section 4.1: An alternative conclusion of that section is that trying to decompose ERFs and response into component-based estimates is misleading in an internal mixture context. Doing so is just not as informative as it first appears. Source-based decomposition would be more useful and, perhaps, less subject to non-linearities.

- Page 11, line 11: "Despite the global mean negative forcing from 1970-2010 aerosol changes" – but according to Fig 3, your best estimate ERF is positive.
- Page 11, line 21–24: Beyond model dependence, being critical of one's model is also useful. CAM is not the best-behaved model in Malavelle et al. 2017 doi:10.1038/nature22974, strongly overestimating rapid adjustments to aerosol-cloud interactions. But then even the best-behaved model gets the wrong rapid adjustments compared to observations Toll et al. 2017 doi: 10.1002/2017GL075280. That would imply that ERFs, and the subsequent temperature and precipitation responses, are too strong in that model.

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