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Referee comment on 'Opportunistic Experiments to Constrain Aerosol Effective Radiative Forcing' by Christensen et al.

Anonymous Referee #1

Referee comment on "Opportunistic Experiments to Constrain Aerosol Effective Radiative Forcing" by Matthew Christensen et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-559-RC1>, 2021

This paper begins by reviewing the literature on a range of aerosol perturbation events ('opportunistic experiments') in which aerosol-cloud interactions can be observationally explored. The paper also provides a table of references for the 'opportunistic experiments', with the observation/modelling type, cloud regime and location of each, along with a summary table of the available observational databases for these experiments. The review then summarises the satellite observations, field campaigns and modelling studies used to target these experiments. The review synthesises figures summarising the change in cloud properties across the range of experiments included. The review finishes by noting the challenges in establishing causality in these observed relationships, including factors that control the cloud response, and the representativeness of these opportunistic experiments.

Overall, the review paper does a good job of summarising the research within this area, and is a useful contribution to the field. I think the review is suited to publication in ACP following some modifications.

Specific comments:

I found the first half of the introduction quite difficult reading, and I think this needs some restructuring or additions for improvement. I would like to see a few more sentences clearly introducing the topic of aerosol-cloud interactions, their importance and why/what observational constraint is required so that the review begins more accessible to readers from a wider background and can be put into context. I think the following suggestions to the current text may also help improve the flow of the introduction.

P2, L20: The sentence starting with "A reduction in precipitation..." is long, and it could be made clearer which adjustments increase cloudiness and reduce cloudiness.

P2, L15: The first and second paragraph up to "A complication is that..." could be combined. Then, a new paragraph started from "A complication is that..." by something like "A difficulty in understand these aerosol-cloud interactions is that..."

P3, L30: Change to "However, when emissions perturb aerosols..."

P3, L35: Change to "In this review, we will use the term 'opportunistic'" rather than "So..."

P3, L35: Why define 'opportunistic' and then use 'natural' for both natural and anthropogenic perturbations instead of solely using 'opportunistic'?

P3, L40: The last sentence of this paragraph explains why warm liquid clouds are the focus of the review, but currently the first sentence of this introduction mentions warm liquid clouds. Could that be introduced at the same point?

The strengths and limitations of each 'laboratory' could be more clearly defined at the end of some of the subsections in Section 2. For example, for the longer subsections a summary at the end of the section drawing on what has been discussed would be useful. Particular events (Section 2.8) is missing the strength and limitations.

In Section 4, I think it could be useful to first briefly describe what types of observations can be obtained from satellites and flight campaigns respectively, before going into the methodology and summarising the literature.

In Section 5.7.1, Perturbation Concentration, the second paragraph discusses the over-representation of ship track studies in the literature. As noted, this is an over representation and I don't think it relates to perturbation concentrations. Could this over representation to be presented elsewhere or in its own sub-section instead?

Section 5.7.3 describes that models can be used to extrapolate from specific situations to climate more broadly. I think more focus is needed on how representative opportunistic experiments are to larger scale climate when applying an observed constraint to a different location/time/scenario etc.?

The title of this review paper is "Opportunistic Experiments to Constrain Aerosol Effective Radiative Forcing", yet not much is mentioned about how the opportunistic experiments follow through to constraint on aerosol ERF. For the title to be appropriate more needs to be discussed on this, at least in the summary.

P29: The summary section mentions R_{Faci} in a few places, why is this not ERF_{Faci}?

P29, L915. The paragraph about the potential changes of DSD comes in a bit out of the blue in the summary section. I think it would help here to have a clearer section in the summary that suggests such future directions.

Figure 3a: Figure caption says the wind is blowing from the North, but plumes look to be travelling South-West not just South?

Technical corrections

P3, L35: Change to (e.g. volcanoes) (e.g. industrial plumes, ship tracks)

P4, L70: "Although modelling studies..." this sentence is a bit contradicting, and needs better defining

P14, L90: Define what "cloud reductions around circulations" means

P9, L250: Should it be "Ship tracks and volcanic plume both show variable cloud adjustments depending on..." rather than "that"?

P12, L345: Include reference in sentence "This is true of the LWP trend from UKESM1..."

P4, L420: It's not clear that the sentence "Systematic changes in anthropogenic emissions..." relates to the Spring Festival

P16, L475: Include reference for "see AeroCOM ACI experiment", or does this relate to AEROCOM – VolcACI in table S2?

P16, L480: For the sentence "Shipping perturbation results are from..." all references include the type of perturbation apart from Peters et al. 2013. Include perturbation type here too

P17, L495: Include references in this paragraph

P17, L510: Delete 'because' from the sentence starting with "As the cross-section for scattering..."

P18, L550: Define the "SECA" acronym again here, it was a long way up the paper that this was mentioned

P18, L555-560: Is there a reference for the ACRUISE flights and the future plans?

P20, L625: Specify if "these two approaches" refers to different scale modelling, or to modelling and observations

P24, L730: Should "Like industry" be "Like volcanoes"? Diversity in industry emission rates have not been mentioned in that paragraph

P24, L750: Is the latter part of the first sentence in the dilution paragraph missing? "From local-scales to..."? Otherwise tens to hundreds of kms is a bit confusing.

P27, Section 5.7.2 Timescales: The point about timescales is made within the first paragraph of this subsection, I think the second paragraph could therefore be more concise

Double check references - some have strange characters

Figure 10: I don't think the caption is clear enough on whether the numbers in parenthesis refer to the number of studies averaged over, it could easily be mistaken for reference number or relating to a table. I'm also not clear on why some studies are referenced in the caption and others are not.

SI, Text S1, L5: Figures S2 should be S3

SI, Figure S4 Caption: The number of studies are not shown in the parenthesis as indicated by the caption. Same comment regarding references also applies to here as Figure 10 in main text.

SI, Table S3: There's not any numbers in parenthesis in the laboratory in this table as the caption suggests.

