Opportunistic Experiments to Constrain Aerosol Effective Radiative Forcing

Referees Comments
Point-by-Point Response

We would like to thank the referees for their time and thoughtful review of our manuscript. Through addressing their comments, we have made essential structural changes to the manuscript. We believe these changes have connected ideas together more effectively and improved the flow of the overall manuscript. The main changes include deleting the Analysis and Methods (old section 4). We agree with the reviewers that this section was a weak point of the review paper with field campaigns. Thus, we have merged the pertinent parts of it with the other sections in the manuscript. This change resulted in a reduction of approximately 2 pages in manuscript length. Section 2 became longer, and as a result, we added additional subsections to it to better guide the reader. Throughout we have fixed typos, grammatical errors, and formatting issues.

Please refer to the point-by-point response to the referee comments. Responses are followed by >> and text that was introduced into the revised manuscript is in *italics*.

Referee #1

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.

>> Thank you for your thoughtful feedback. Please see detailed responses to your comments.

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.
>> We have rewritten the first half of the introduction to better introduce the topic of aerosol-cloud interactions to a general audience and clearly state the processes. These changes are best viewed in the tracked changes file.

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.
>> We split this long winded sentence into two and clarified which ACI adjustments influence cloud fraction.

P2, L15: The first and second paragraph up to "A complication is that…" could be combined. Then, a new paragraphed started from "A complication is that…" by something like "A difficulty in understand these aerosol-cloud interactions is that…"
>> Thank you, this suggestion improved the flow of the text.

P3, L30: Change to "However, when emissions perturb aerosols…"
>> Done

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

P3, L35: Why define 'opportunistic' and then use 'natural' for both natural and anthropogenic perturbations instead of solely using 'opportunistic'?
>> Both 'natural' and 'anthropogenic' experiments offer opportunities to study the role of aerosols on clouds. Thus, by this definition they are grouped together into 'opportunistic experiments.' This definition is now more clearly stated in the manuscript and we have replaced 'natural' with 'opportunistic' where appropriate throughout the text to clarify this point. These changes are best viewed in the tracked changes file.

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?
>> This sentence has been moved to the front of the introduction (last sentence in paragraph 1) to focus on a theoretical discussion of ACI as they pertain to warm clouds.

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.
>> This is an excellent suggestion. We now include a summary statement for all of the different 'laboratories.' We have added concluding remarks which include a summary of strengths and limitations to each of the following sections:

Section 2.1.3 (Ship emissions tracks & corridors): *Overall, ship emissions provide a useful laboratory to study process-level physics of ACI in ship tracks as well as for quantifying the radiative effects on shallow marine cloud systems more broadly over entire shipping corridors and even the globe. Unique changes in policy and regulations directly influence ship emissions and these changes are currently creating an interesting experiment to examine, but it may take several years for a clear signal to emerge from the radical emissions changes in 2020 due to the COVID pandemic (see section 2.8.2).*

Section 2.2 (Industrial Sources): *Like ship emissions, industrial sources provide unique opportunities to study ACI but with the added advantage of having more information with regards to the source and characteristics of the emitted aerosol. While these cloud systems are commonly found over land areas and are less of a direct analog for anthropogenic forcing over the oceans, there is also the potential to have greater coverage of ground-based observations, and a greater range of particle types and background conditions, to aid in quantifying ACI. In addition, industrial sources have fixed locations and often emit continuously, enabling analysis of cloud perturbations for various cloud types and meteorological conditions characteristic to the specific location.*

Section 2.3 (Volcanoes): *The last major volcanic eruption globally occurred at Mount Pinatubo in 1991. Satellite and modeling capabilities to observe and model such events have greatly improved since, and a future major eruption would offer a unique natural experiment for further ACI studies. The eruption of Pinatubo and the associated suite of measurements proved a catalyst for improving our knowledge and understanding and modelling of stratospheric aerosol. Even after 25 years, studies into Pinatubo show no sign of abating indicating the longevity of such important natural analogues to the science community. In much the same way, opportunistic experiments found in large degassing events such as those that occurred in Iceland and Hawaii provide a similarly compelling case study for aerosol-cloud interactions. Volcanoes thus serve as another useful laboratory to study ACI because they can emit significantly more aerosols and SO_2 than typical ships or industrial plants (see section 4.3) but their episodic nature and uncertain emissions, can make interpretation and quantification of ACI relationships challenging.*

Section 2.4 (Fires and Biomass burning): These points are expressed in the last two paragraphs.

Section 2.5 (Hemispheric differences): These points are expressed in the singular paragraph for this section.

Section 2.6 (Long Term Trends): *Overall, long term trends are useful for correlating observed changes in clouds and radiative effects to aerosols but are likely not suited for process understanding of ACI unless new analysis techniques can overcome the above-mentioned issues.*

Section 2.7 (Weekly Cycle): *Seven-day cycles in geophysical quantities do not typically arise by natural variability and if they can be identified with certainty this laboratory may provide a clear pathway to attributing an aerosol influence on clouds.*

Section 2.8 (Particular events): *Overall, particular events like the experiments discussed here provide potential opportunities to quantify ACI processes and response to changes in the patterns of anthropogenic emissions. They work best if the emissions changes are known, and if sufficient observations are available before and/or after the event to establish a good baseline. One challenge with particular events, especially one-off events that are not repeated, is that meteorological effects may be difficult to disentangle from emissions-related changes and cannot be mitigated by averaging over multiple realizations (as can be done with repeating holidays or within a climate model ensemble). Moreover, care must be taken in selecting a baseline for comparison, as other factors such as long-term policy-driven emission trends or unrelated holiday or weekday effects may have influenced the "no event" counterfactual. Nonetheless, because the emissions perturbations are independent of meteorology and reasonably knowable, these events still hold promise for improving our understanding of causality in aerosol-cloud interactions as long as meteorological and other sources variability can be addressed.*

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.
>> Section 4 (prior version) on 'Analysis and Methods' was deleted because it lacked focus and the pertinent parts were integrated into sections 2 & 5. See response to referee #2 for details. We have pointed out which types of observations from satellite and flight campaigns are useful in the different opportunistic experiments.

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?
>> Agreed, this paragraph does not fit the theme and deserves its own subsection now entitled: *Sampling and Over-representation*.

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.?

>> We have tightened the focus of this section by clarifying how to extrapolate from natural experiments to climate more broadly and replaced our previous argument with the following: *The spatial extrapolation of opportunistic experiments requires a good understanding of the dependence of cloud response not only to cloud regime (stratocumulus, shallow cumulus, etc) and dominant microscopic processes (rain- or entrainment-dominated; warm, ice, or mixed-phase) but also to external, cloud controlling factors like above-cloud humidity, and the typical persistence time of the perturbation. Climate model intercomparisons in specific geographic and meteorological natural experiment settings (Malavelle et al. 2017) could help to overcome the limited representativeness of natural experiments.*

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.

>> Thank you for your feedback regarding the title of the manuscript. We now make the point clearer in the manuscript that the quantitative analysis (Figure 10) summarizing the literature is helpful for developing constraints to estimate aerosol effective radiative forcing. Throughout, it is clarified which studies estimate ERF and how this information is useful for constraining the terms in equation 2.

These experiments can provide useful observational constraints on ERF_{ACI} through the quantification of key terms represented in equation 2.

P29: The summary section mentions RFaci in a few places, why is this not ERFaci?

>> We have correctly replaced ERFaci for RFaci in all locations of the manuscript except section 2.5 (Hemispheric Differences). Here, the RFaci constraint discussed in the hemispheric differences section from McCoy et al. 2020 is applied to the PPE which does *not* include rapid adjustments. However, constraining RFaci helps to constrain ERFaci since RFaci in liquid clouds is contributing significantly to the overall uncertainty (Bellouin et al. 2020). This is now mentioned explicitly.

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.

>> Agreed, the DSD paragraph comes out the blue and has been moved to "Methodology and observing system" subsection.

Figure 3a: Figure caption says the wind is blowing from the North, but plumes look to be travelling South-West not just South?
>> Good point. Upon further inspection we find that *The near-surface wind is blowing from the northeast based on MERRA reanalysis.* The figure caption has been modified accordingly.

Technical corrections

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

P4, L70: "Although modelling studies…" this sentence is a bit contradicting, and needs better defining
>> Introducing modeling here without context detracts from the clarity of the manuscript. We have deleted this sentence to tighten the focus.

P14, L90: Define what "cloud reductions around circulations" means
>> "cloud reductions around circulations" has been changed to "cloud reductions along the edges of ship tracks from local-scale circulations"

P9, L250: Should it be "Ship tracks and volcanic plume both show variable cloud adjustments depending on…" rather than "that"?
>> Thank you for catching this mistake. The word "that" was replaced with "both."

P12, L345: Include reference in sentence "This is true of the LWP trend from UKESM1…"
>> The reference supporting this statement is not yet published. This sentence has been removed to increase clarity.

P4, L420: It's not clear that the sentence "Systematic changes in anthropogenic emissions…" relates to the Spring Festival
>> This sentence has been shortened as well as replacing "Systematic changes in" with "This events results in" to increase clarity.

P16, L475: Include reference for "see AeroCOM ACI experiment", or does this relate to AEROCOM – VolcACI in table S2?
>> This line in the main manuscript does indeed refer to Table 2 which this reference as https ://wiki.met.no/aerocom/phase3-experiments (Malavelle et al., 2017). We explicitly mention *Table S2* in the main text to refer interested readers to this reference.

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

>> Good point. The Peters et al. (2013) values are part of the GCM estimate. The sentence has been changed to "Shipping corridor perturbation results are from Diamond et al. (2020), effusive volcanic eruption is from Malevelle et al. (2017) and the global shipping model is from Lauer et al. (2007) and Peters et al. (2013)."

P17, L495: Include references in this paragraph
>> This paragraph was in the Analysis and Methods section that was dropped from the paper.

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

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

P18, L555-560: Is there a reference for the ACRUISE flights and the future plans?
>> The ACRUISE 2019 flights are described in Yu et al. (2020) which is already in the reference list. We have changed "future flights" to "flights which took place in the summer of 2021" as these flights were recently carried out. Unfortunately, there is not currently a public document that outlines the details of these most recent flights but they were carried out in slightly different regions (primarily off the coast of France in 2021 instead of off the coast of Portugal as in 2019 has been noted in the text).

P20, L625: Specify if "these two approaches" refers to different scale modelling, or to modelling and observations
>> This sentence was in the Analysis and Methods section which was dropped from the paper. Although, we have retained this part and moved the "different scale modelling" LES simulation papers on ship tracks to section 2.

P24, L730: Should "Like industry" be "Like volcanoes"? Diversity in industry emission rates have not been mentioned in that paragraph
>> You are correct. The previous sentence discusses "volcanoes" not "industry." The sentence has been modified accordingly.

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.
>> We have made changes to this sentence to increase clarity. It has been rewritten as "Aerosol plumes from ship stacks can overwhelm the ambient CCN at local-scales ranging from tens to hundreds of kilometers."

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
>> While some elements of the second paragraph deal with the "Timescales" it mostly discusses satellite retrieval uncertainty and various methods to constrain dlnLWP/dlnNd and therefore this paragraph has largely been moved to *Methodology and observing system*.

Note, we have also added another subsection (Sampling and Over-representation) to provide more focus to this section.

Double check references – some have strange characters
>> The characters in several references have been corrected.

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.
>> Numbers in parenthesis have been removed from the figure and added to the caption to increase clarity. We have also removed specific papers referenced in the caption and instead point interested readers to Table S1 for details.

SI, Text S1, L5: Figures S2 should be S3
>> Thanks for this catch! It has been corrected.

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.
>> Captions for Figure 10 and Figure S4 have been synchronized.

SI, Table S3: There's not any numbers in parenthesis in the laboratory in this table as the caption suggests.
>> Numbers for each laboratory have been added to Table S3. Captions for Tables S3 & S4 have also been made more concise and synchronized.

Referee #2

This paper aims at reviewing the advantages and limitations of various kinds of "opportunistic experiments" that nature and/or mankind offer to those studying aerosol radiative forcing of climate change. The paper is focused on aerosol-cloud interactions and their rapid adjustments. The authors highlight the important scientific findings that the "opportunistic experiments" have allowed, but caution that scaling those findings to the global scale remains difficult.

The paper is well written and its aim of providing a "common footing" in which to understand and interpret the opportunistic experiments is laudable. However, the paper could fulfil that aim more sharply. For that reason, I recommend revisions to address the weaknesses listed below. This could involve a sizeable restructuring of the paper, so major revisions may be needed.
>> Thank you for your time and effort to provide a comprehensive review. We have restructured the text to increase the flow and clarity of the overall manuscript. Please see detailed responses below.

Main comments:
The paper does not give a tight definition of what an "opportunistic experiment" is. There is an attempt at lines 34-35, but it is unclear whether that definition covers all the types of experiments that are discussed in the paper. Some types do not allow to "know the unperturbed state", for example – more on that below. In addition, that definition is immediately thrown away "for convenience" in lines 38-39. It should be possible to use a consistent vocabulary throughout.
>> Both 'natural' and 'anthropogenic' experiments offer opportunities to study the role of aerosols on clouds. Thus, by this definition they are grouped together into 'opportunistic experiments.' This definition is now more clearly stated in the manuscript and we have replaced 'natural' with 'opportunistic' where appropriate throughout the text to clarify this point.

The paper presents two main types of opportunistic experiments. The first type is essentially based on in-plume/out-of-plume comparisons (sections 2.1, 2.2, and to some extent 2.3 and 2.4). The second type covers events that are either much larger or comparing situations that are very distant in time (sections 2.5, 2.6, 2.7, 2.8). But the two types sit uneasily together. There is a clear tension between ability to determine the unperturbed state (that would favour the first type) and relevance to climate scales (that would favour the second type). Figure 10, the only figure that attempts to mix the two types of results, illustrates the tension well. But the paper never attempts to resolve that tension. Tellingly, the very good section 5 is mostly based on the first type of experiments – it is the ability to determine the unperturbed state that has brought the best insights. Are some experiments too large in scope? Is there a sweet spot somewhere? The paper could offer guidance there.
>> Thank you for your insightful comment. We agree that more discussion on the tension between small and large scale experiments should be raised here. It is true that it is difficult to

determine simultaneously the unperturbed state (which is possible only in small scale perturbations) and the climatic relevance (which is more appropriate in large scale perturbations experiments). This is a great point to add particularly as an introduction to the topic of opportunistic experiments in section 2. We have added the following to section 2:

The review is organized around two main types of opportunistic experiments covering different spatial scales. The first type is based on relatively small scale perturbations in which "in-plume/out-of-plume" comparisons are possible (sections 2.1, 2.2, and to some extent 2.3 and 2.4). These cases provide opportunities to determine the unperturbed case ("out of plume" conditions), and thus, directly evaluating the response of clouds to aerosol perturbation under similar meteorological conditions. The second type of opportunistic experiments cover events with much larger spatial scales or comparing situations that are very distant in time (sections 2.5, 2.6, 2.7, 2.8). In these cases the relevance to the climate scale is easier to establish but it is much more difficult to determine the unperturbed/reference conditions. Then we provide a linked summary database of different experiments that have been used in previous studies (Section 3). Section 4 brings together the different experiment types to synthesize qualitative and quantitative aerosol effects across methods and experiment types. In this section we examine the factors controlling the cloud response to aerosol perturbations and the challenges of using type 1 experiments to constrain ACI across spatio-temporal scales. Section 5 provides a synthesis of these findings and their conclusions.

We have also added more explanation to the summary on the utility of using different types of laboratories and the different time and space scales involved. This refers back to the meta-analysis of figure 10, which we think also addresses the point of scales (in time as well as in space) and what processes are dominating.

Section 4 on Methods is the weak point of the paper and compares poorly to the very good sections 2 and 5. I think that is because it lacks a clear focus and too often reads like an advert for upcoming campaigns/instruments/models. I am not sure that the section is needed. Pointing to key datasets is the role of section 3. Listing key insights brought about by specific campaigns or models should be done within the context of sections 2 and 5.
>> We agree. Section 4 (prior version) on 'Analysis and Methods' lacked focus. Therefore, this section was removed, and the pertinent parts were integrated into sections 2 & 5. Key insights from campaigns, satellite observations, and models were integrated into section 2 and aspects dealing with controlling factors or issues on interpretation of results were primarily integrated into methodology and observing system subsection. Refer to the tracked changes file for the detailed changes.

Other comments:

Lines 11-12: I would move that sentence before the previous one, to have the statement on instantaneous forcing preceding that on rapid adjustment.
>> Done

Line 83: I would replace "as evident in" to "according to", because EDGAR is not an observational dataset.
>> Done

Line 122: Missing word between evolution and several.
>> Done

Line 145: I do not understand the "therefore". Is a large fraction of the ship tracks simulated by Peter et al. undetectable?
>> No, Peter et al. (2013) did not simulate "ship tracks." This sentence implied so, and was thus changed to: "In a global modeling study, Peters et al. (2013) showed significant radiative (0.3 W m^{-2}) effects from the net emissions of global shipping. Contrasting their results to the satellite observations suggests that the integrated radiative effect from isolated ship tracks make up a small contribution to the total aerosol indirect radiative effect from shipping.

Lines 161-180: This paragraph lacks a clear conclusion. The difficulty of model-data comparison is one thing, but how does that relate to the use of corridors as opportunistic experiments?
>> Agreed. The following concluding remarks on the use of corridors and model-data comparison as an opportunistic experiment has been added. Note, this paragraph was also split into two; moving the role of black carbon impacts to the biomass burning aerosol section.
Climate model studies focused on comparing output to observed corridor perturbations may need to restrict emission reductions to the region of interest only, as opposed to reducing emissions worldwide, due to the non-negligible contributions from longer-range transport.

Lines 238-239: That statement does not add much and could be deleted.
>> Agreed, it has been deleted.

Lines 253-257: Are those two sentences in the right place? The section would end better without them. (And the sentence on lines 254-255 is grammatically incorrect.)
>> These sentences were replaced using text from deleted section 4 (Previously Analysis and Methods) describing radiative forcing estimates from the Holuhraun eruption.

Lines 266-267: That statement seems to miss the point that ships increase aerosol loading over a normally low baseline.
>> We removed "characterized by generally low aerosol loading" as this was repeated in this sentence as well as modified the following sentence to point out the issue of causality between

lower aerosol concentration levels and precipitation scavenging by more vigorous deep convection.

Lines 273-274: Could refer to section g3 of the Global Climate section of the BAMS State of the Climate 2020 report https://doi.org/10.1175/BAMS-D-21-0098.1 to support that statement.
>> Thank you for this useful reference. We have referred to this work in the manuscript.

Line 312: It would help readers to clarify the link between economic restructuring and cloud reflectance.
>> We have clarified by adding "that caused decreased emissions of aerosols and their precursors" after "...following political changes…" in this sentence of the manuscript.

Line 312: "co-incident upward trend" combined with the previous sentence suggests that changes in cloud reflectance caused the trend in surface radiation. That is not so sure. Trends in surface radiation are much more robust in cloud-free sky than in all sky conditions.
>> We have fixed two problems in this sentence. The first is that the co-incident upward trend in surface solar radiation is caused by *both ACI and clear-sky aerosol radiative interactions (ARI)* and that this was found to be useful as an emergent constraint on simulated total aerosol effective radiative forcing (ERF).

Line 316: "CMIP6 emissions database" needs a reference, especially as different versions of CMIP6 emissions have very different histories for sulfur dioxide.
>> We have added the following (most current) reference to describe the CMIP6 emissions database.

Mulcahy, J. P., Johnson, C., Jones, C. G., Povey, A. C., Scott, C. E., Sellar, A., Turnock, S. T., Woodhouse, M. T., Abraham, N. L., Andrews, M. B., Bellouin, N., Browse, J., Carslaw, K. S., Dalvi, M., Folberth, G. A., Glover, M., Grosvenor, D. P., Hardacre, C., Hill, R., Johnson, B., Jones, A., Kipling, Z., Mann, G., Mollard, J., O'Connor, F. M., Palmiéri, J., Reddington, C., Rumbold, S. T., Richardson, M., Schutgens, N. A. J., Stier, P., Stringer, M., Tang, Y., Walton, J., Woodward, S., and Yool, A.: Description and evaluation of aerosol in UKESM1 and HadGEM3-GC3.1 CMIP6 historical simulations, Geoscientific Model Development, 13, 6383–6423, https://doi.org/10.5194/gmd-13-6383-2020, 2020.

Lines 381-383: Would need references that attempted such approaches to support the claim that they hold promise. They sound very hard to do in practice.
>> While we are not aware of any studies in the published literature, we are aware of ongoing work which seeks to address this challenge.

Lines 439-440: What caused that shallowing? Anomalous meteorology?
>> The Shallowing of PBL for this episode was mainly driven by meteorology, although there were studies showing the general decline in the PBL in China at least priori to the peak of air

pollution due presumably to increases in absorbing aerosols. We have added: *In China, the reduction in emissions during the pandemic may have been offset by the shallowing of the planetary boundary layer (PBL) caused primarily by anomalous meteorology Su et al. (2020).*

Su, T., Li, Z., Zheng, Y., Luan, Q., and Guo, J.: Abnormally Shallow Boundary Layer Associated With Severe Air Pollution During the COVID-19 Lockdown in China, Geophysical Research Letters, 47, e2020GL090 041, https://doi.org/https://doi.org/10.1029/2020GL090041, e2020GL090041 2020GL090041, 2020.

Lines 447-449: Is that result linked to previous discussions that variability in cloudiness can "hide" substantial radiative forcings?
>> Yes. We have noted this now explicitly in the text

Line 458: It would be useful to link contrail reductions to the subject matter of the paper, aerosol ERF. Perhaps a short reminder of the mechanisms of contrail formation?
>> Good idea. We have noted the contrail formation mechanism and how they create an ERF.

Lines 471-475: Aren't there ship track databases for the Southeast Atlantic stratocumulus deck? There are a few studies that focused on that region and some of that data seems to be used in Figure 10.
>> Yes, they were analyzed in Christensen and Stephens, 2011, 2012 work. This additional information (time periods and locations of the ship track databases) has been added to the text.

Line 522: "can be performed" – reference needed there.
>> Added Minnis et al. (2008) which describes the radiative transfer retrieval approach for cloud properties derived from geostationary satellite observations in the VISST product.

Line 576-577: What are the implications of these findings for aerosol ERF?
>> This line was from the Analysis and Methods section which was dropped from the paper. We did not retain the subsection field campaigns targeting continental outflow since this material was sufficiently covered in section 2.4 Fires and Biomass burning natural experiments.

Technical comments:
Page 3, line 48: human -> human-caused
>> Done

Line 512: Delete "because"
>> Done

Lines 586 and 656: Character encoding problems.

>> Fixed the characters.