Reply to comments by Referee #2.

Subsequently, the Referee's comments are repeated in blue color. Our replies follow in black.

We thank the Referee for his (or her) positive review and the discussion on ICAO CAEP's new nvPM mass and number emissions information. We respond to the remarks as explained below.

This is an excellent and timely study of the climatic impact of contrails. The authors have published extensively in this technical area and are using a tool that has been well exercised in studying contrail impact. This study has addressed a key issue and taken advantage of an unfortunate, timely reduction in air traffic due to the COVID19 pandemic to perform a (somewhat) controlled experiment to determine the radiative effects of contrails. Such a specific change is a key climatic impact is rare, and while annual changes in weather must be, and have, been taken into account, this event provides a unique opportunity to try to quantify this particular impact, largely in isolation. The authors are to be commended for noting this opportunity and taking steps to acquire and process the data to evaluate the climatic impact of contrails.

At the same time, the tool has been refined and evaluated in a few key ways to further develop and improve the model (water vapor exchange between contrails and background air, and accounting for contrail overlap). These updates have been applied to both the before and after COVID19 cases, so direct comparisons are appropriate. These are useful extensions to the modeling approach.

Thus, the paper is very scientifically interesting and offers timely analysis of the aviation climatic impact, as the industry plans recovery from a significant reduction in commercial activity. The paper is well-written and clearly presents the approach and the conclusions.

Reply: We thank the reviewer for this assessment.

I only have a few comments that I hope will improve the clarity of the excellent disposition of this useful analysis.

Lines 162 et seq.: The analysis makes use of the ICAO emissions databank to obtain soot emissions indices. I presume that they performed this analysis prior to the publication of the new nvPM entries in the ICAO Edb, which were released in December 2020. Thus, they presumably used the earlier ICAO Edb entries for Smoke Number (SN) to estimate soot parameters. Given that the bulk of the work was done months before the nvPM ICAO data was released, they are unlikely to have been able to use the new nvPM data. However, for readers that are reviewing these results now and later, when the nvPM ICAO data is now available, it is probably important to point out explicitly that they have made their soot parameter estimation based on SN data in the ICAO data bank.

Reply: Thank you for this important question. It helps us to clarify the method used:

The black carbon number emissions index (EI_n) is calculated using the Fractal Aggregates (FA) model (Teoh et al., 2020): it estimates the BC EI_n from the BC mass emissions index (BC EI_m), particle size distribution (geometric mean diameter, GMD, and its standard deviation, GSD) and morphology (D_{fm}) because these parameters are more commonly measured and modelled before the ICAO CAEP's new nvPM mass and number emissions were published. For each flight, the BC EI_m is estimated using the Formation and Oxidization Method (FOX) (Stettler et al., 2013) and Improved FOX method (ImFOX)

(Abrahamson et al., 2016), which are based on the thermodynamic and physical mechanisms by which BC is formed and oxidized. More specifically, the FOX method requires the overall pressure ratio of each engine type as an input to estimate the BC EI_m, and we obtained this parameter from the ICAO EDB. No smoke number measurements are required by both the FOX and ImFOX method. The formulas and constants used to calculate the remaining parameters (GMD, GSD and D_{fm}) can be found in Teoh et al. (2020).

Teoh, R., Schumann, U., Majumdar, A. and Stettler, M.E., 2020. Mitigating the climate forcing of aircraft contrails by small-scale diversions and technology adoption. *Environmental science & technology*, *54*(5), pp.2941-2950.

Stettler, M.E., Boies, A.M., Petzold, A. and Barrett, S.R., 2013. Global civil aviation black carbon emissions. *Environmental science & technology*, *47*(18), pp.10397-10404.

Abrahamson, J.P., Zelina, J., Andac, M.G. and Vander Wal, R.L., 2016. Predictive model development for aviation black carbon mass emissions from alternative and conventional fuels at ground and cruise. *Environmental science & technology*, *50*(21), pp.12048-12055.

Lines 367 et seq.: This paragraph is an "aside" and perhaps did not receive as careful attention as the main conclusions. There are two statements in this paragraph that are not clearly stated.

The first sentence makes a point about fuel usage and aircraft types over Europe. The second sentence makes an additional point about fuel usage and aircraft types for a different case but does not explain the difference for this second set of statistics. Is it for a different geographic region (North America? The entire globe?)?

In the last sentence of this paragraph, the largest contrail contribution is noted. However, it is not clear if this is noting the largest contrail contribution for a single/individual airplane, or if it is the largest contribution to the total contrail impact of the fleet. The latter seems to not be the case, because of the prior statement about the twin-engine medium sized airliner (and presumably that was for 2020 also?), but the sentence is not clearly stated.

Reply: Apparently, the text needs some clarification. The whole paragraph refers to the same set of data, all for Europe.

We now plan to write:

As an aside, it was found that that 80 % (90 %) of fuel consumption over Europe comes from just 15 (23) aircraft types, whilst 80 % (90 %) of the contrail forcing came from 13 (19) types in 2019 and from 16 (24) types in 2020. One particular aircraft type, a twin-engine medium-sized airliner, produced nearly 20 % of total fuel consumption and 16 % of contrail forcing, in the same data set. The largest contrail contribution in 2020 came from one type of twin-engine heavy aircraft, probably as a result of the larger fraction of cargo flights in 2020 (ICAO, 2021).