

Estimates of non-traditional secondary organic aerosols from aircraft SVOC and IVOC emissions using CMAQ

Responses to Reviewer #2

We thank the reviewer for providing thoughtful comments. We have responded to each comment below, and have noted the section number for each revision to the manuscript. Each comment by the reviewer is reproduced below, in bold type. Our responses appear below each comment, indented.

Page 8: If I understand correctly the authors used the 1.5x NTSOA yields for CMAQ simulations. By doing so, does the author apply this factor to all power settings of the aircraft? If not, can the authors comment about how these simulations are expected to differ (if at all) during periods of higher engine power?

The 1.5x increase in yields used in the CMAQ simulations were applied to all power settings. We have revised the text in Section 2 as follows:

“Given the better agreement at 4% and 7% power settings, our CMAQ simulations were conducted using the higher (1.5x) yields for all four power settings.”

Page 9: The authors state that ATL is the world’s busiest airport with 2400 flights/day. One would think that the aircraft performing these flights would represent a cross section of engine types. However, the emission dataset is from a single engine type. Can the authors comment on the expected differences in emissions based on engine and aircraft type? Furthermore, the CFM56-2B engine from which the emissions data is generated is an older model engine and becoming obsolete. How might the lowered emissions from newer engines impact the study findings?

We agree that our approach to normalize SVOC and IVOC emission factors (EF) by ICAO reported hydrocarbon EF is meant to, at least, partially, mitigate the differences in engine and aircraft type. By calculating S/IVOC emissions for engines using their ICAO-reported hydrocarbon EF multiplied by the ratio of S/IVOC EF to ICAO hydrocarbon EF for the CFM56-2B engine (rather than directly using the CFM56-2B S/IVOC EF), we would expect our approach to account for lower emissions (assuming their ICAO reported hydrocarbon emission factor is lower) from newer engine technologies. That said, further research is needed to determine if this approach biases the emission inventory high or low, as no information is currently available to indicate if the same SVOC and IVOC to VOC emission ratio for the CFM56-2B engine is similar for newer (or older) engines. To address this comment, we have revised the text in Section 2 as follows:

“It should be noted that applying a normalized EF for SVOC and IVOC emissions from all aircraft based on a single engine type introduces some uncertainty as the CFM56-2B engine is primarily used for military aircraft and represents older technology with higher emissions than newer, more efficient engines. That said, the CFM56 engine family (which includes ~80 different types)

was used on approximately 20% of commercial U.S. flights in 2006 and normalizing SVOC and IVOC emission factors based on ICAO reported hydrocarbon emission factors is meant to, at least partially, account for differences in engine type and technology. Without the normalization, we would expect the SVOC and IVOC emission estimates to be biased high and future work is needed to test if a bias, either high or low, remains after normalization. At this time, limited data currently exist on SVOC and IVOC emissions from other engines and therefore we consider this an acceptable means to approximate emissions for this work.”

Page 13: By stating CMAQ results indicating elevated PM as low as 1 ng/m³, the authors are implicitly stating that model inputs have the accuracy and resolution to realize this value. I have serious doubts that about that. The authors themselves state multiple times about areas of uncertainty in the model inputs (see their discussion on extrapolation of ICAO idle emissions from 7% to 4% power settings).

We report values as low as 1 ng m⁻³ similar to other studies examining single source impacts both specific to aircraft emissions (Rissman et al., 2013; Yim et al., 2015), as well as from other source sectors (Baker and Foley, 2011; Kwok et al., 2013; Kelly et al., 2015). While we agree that model uncertainty reduces confidence in reporting values this low, we would like to emphasize that these values are not absolute predictions (which would have more uncertainty), but rather differences of two model scenarios, where aviation air quality impacts are calculated as the delta between model scenarios with and without aircraft emissions. This approach to apply the model in a relative sense has been extensively used in grid-based model applications for scientific and regulatory purposes for studying source contributions, and in fact an approach that has been recommended by the U.S. EPA (U.S. EPA, 2014). By using this delta approach, we are able to take into account all non-linearities associated with the complex chemical interactions between emissions from aircraft and all other non-aircraft related sources. Furthermore, from the spatial patterns we show, the modeled impacts have a clear spatial pattern around the airport study region, again supporting the contribution of the emissions sources to the modeled impacts. And finally, these values are indicative of the general magnitude of incremental contributions of aviation at the modeled (as well as measured) scales on a monthly average basis (while hourly concentrations – the time scales at which CMAQ is run – are at least 1 – 2 orders of magnitude higher), not meant to represent an absolute concentration but instead to provide context adequate to make informed inferences about aviation-attributable PM_{2.5}. To address this comment, we have revised the text in Section 3.1 as follows:

“Impacts on PM_{2.5} in January and July were highest near the airport, although impacts as high as 10 ng m⁻³ extended up to 100 km away from the airport in July (Fig. 4a and b). NTSOA contributions were generally confined to grid cells surrounding the airport, similar to primary PM species, though impacts of 1 ng m⁻³ or higher were located 50 km away from the airport (Fig. 4c and d). Given uncertainty in model inputs and outputs, values at these low concentrations are not meant to represent absolute concentrations, but are, however, indicative of the general magnitude of incremental contributions of aviation at the modeled scales and provide context adequate to make informed inferences about aviation-attributable PM_{2.5}.”

References:

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