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Discussions

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Interactive comment

Interactive comment on "Characteristics of sub-10 nm particle emissions from in-use commercial aircraft observed at Narita International Airport" *by* Nobuyuki Takegawa et al.

Anonymous Referee #2

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This paper reports the characteristics of sub-10nm particle emissions from field measurements at the Narita International Airport in Tokyo, Japan. Total and non-volatile particle emissions were measured using particle counting and size distribution instruments.

The paper is well written, and includes relevant details and analysis. I found some of the observations and results presented were not put into proper context with previous findings from earlier studies reported in the literature. Recent studies were cited, but their relevance to the current work was not well stated or in some cases was overstated. There are also some inconsistencies in the description of the results which requires clarification. I have several comments that I hope will help the authors in addressing the gaps identified.

General comments:

The introduction section needs to better state the motivation for this study. The authors provide good background and context for the study, but the motivation for investigating sub-10nm particles is lacking.

The difference between the total PM and non-volatile PM is the attributable to volatile PM. The formation of volatile PM is due to a number factors including ambient conditions, fuel used, etc. The authors while presenting data for total PM and non-volatile PM haven't made any observations about the volatile PM, which is some cases dominates.

The study reports that the sub-10nm particles are non-volatile. Why is this different from earlier studies of aircraft engine emissions at airports? Is it because lower cut-off instruments were used or the mix of aircraft compared with previous studies is different, i.e. more newer engines in the fleet with different emissions characteristics or the fuel composition was different? The authors have not discussed the key finding from the current study in the context of previous observations.

References: Include the weblink or doi for each for the references included in this paper.

Specific comments:

Lns 32-34: It is not clear how aircraft emissions are unique in this aspect compared to other transportation or emission sources. Are the authors referring to aircraft emissions during cruise? Rephrase this sentence.

Lns 38-44: I think it is important to state that direct health impacts of UFP emitted from aircraft have not been currently established.

Lns 49-51: Ambient conditions also play an important role in the formation of volatile particles. Update the text accordingly.

Lns 72-73: A specific date for the measurements is stated in the introduction, however the next section (Ln 80) lists a range. Please be consistent.

Lns 86-88: The authors state that the instruments used during the measurement at NRT have previously been used for airborne measurements. More pertinent to the discussion is how the instruments used in this study varied from earlier studies of aircraft emissions at airports.

Ln 91: Specify the make and model of the NOx detector.

Ln 131-132: The location of the EEPS was not indicated in Figure 2. Was the sample provided to the EEPS from the same inlet as that for the CPCs and SMPS? This should be stated in the manuscript.

Lns 141-142: If the scanning time of the SMPS was set to 3 minutes, it is likely that the measured size distribution would be a combination of multiple plumes and not a single event. Other studies (Herndon et al., 2008; Lobo et al., 2012; Moore et al., 2017) have shown that plumes from an individual aircraft activity/movement are on the order of less than 1 minute.

Lns 187-189: What size ranges did the different sources cover?

Ln 190: "non-volatile propane soot particles supplied from the CAST" – What were the set points? Previous studies have shown a high volatile/organic content for certain the miniCAST set points, especially with pre-mixed nitrogen (e.g. Maricq, 2014; Durdina et al., 2016).

Lns 194-195: Instead of using qualitative phrases like "somewhat longer", be specific in terms of the parameters.

Lns 218-220: It's not clear why the penetration efficiency curve at room temperature

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was scaled. This should be explained and it should be noted in Figure 4 b) that these data are scaled.

Lns 233-234: This is not a fair comparison. The enhancement level for CO2 for individual plumes is not an indicator of similarity. For example, how would you compare if an air parcel has higher emissions closer to the engine but heavily diluted with ambient air vs. lower emissions closer to the engine but the plume is not as diluted? Both these cases could give the same CO2 enhancement, however, the residence time in the plume, and hence the opportunity for particles to nucleate, would be different in these two cases. Do you have any data to present this in the context of residence time in the plume?

Lns 245-252: What is the main message of this plot? Is it supposed to indicate what fraction of particles heated to 350C are below 10nm? A bar chart would be more relevant to illustrate this point.

Lns 256-257: What was the lower size cut-off for the EEPS? Was it also 10nm? Is the data in Fig 7a from the SMPS or the CPC? The text indicates CPC but the figure heading has SMPS (unheated).

Lns 270-275: This enhancement has been previously reported for measurements of exhaust plumes in the near field (Lobo et al., 2012; Timko et al., 2013; Beyersdorf et al., 2014; Trueblood et al., 2018). Based on the number and volume distributions, can any inferences be made with respect to the type of plume being sampled, i.e. idle, take-off?

Ln 293: What does “artificial nucleation mode” mean?

Lns 314-316: The SAE standard system for aircraft engine emissions measurements consists of several sections (diluter, 25m sampling line, etc) that were not included in this study. I don’t think it’s fair to say that the difference is between real-world conditions and regulatory measurements. The difference is between measured total particle number and non-volatile particle number, which gives a measure of the volatile particle number emissions.

Lns 316-318: It's not clear what is meant by "standard engine tests". The SAE standard system is used for the emissions certification testing of aircraft engine emissions. The engines used in these tests do not have the wear and tear associated with in-use commercial aircraft engines. Also, the data on the nvPM emissions from the certification tests is not publicly available.

Lns 324-337: Can any inferences be drawn between the previous studies and the current one, other than the emissions being in the same range? The ambient conditions, background PM, fuel, airport operations, etc during all of these studies are different. However, the particle number emissions all fall into a similar range.

Lns 337-342: Zhang et al., 2019 did not perform any measurements themselves but used the data from previous studies in their analysis. This reference should not be included in the comparison of measurement data. Also, Zhang et al. 2019 excluded certain datasets in their analysis, and thus limits the conclusions that can be drawn from their analysis. As stated previously, there are other measurements reported from previous studies that can be used to compare and quantify the differences or similarities with the current study.

Lns 353-354: The three studies referenced here all reported bi-modal distributions. When referring to the mode diameter of particle number EIs measured downstream of the engine in the near field, a distinction between the nucleation and accumulation modes should be made. For the case here, the nucleation mode should be specified.

Lns 354-360: This discussion does not follow from the previous comparisons. The authors state that the work by Kinsey et al., 2019 is an exception, but don't state how it impacted the mode diameter of particles. Aircraft engine emissions are known to vary with fuel composition and ambient conditions, but the authors do not state the relevance of these factors to their study.

Lns 362-364: The size distributions presented thus far have been shown to be bi-modal. Why was an assumption of log-normality made? Is the constraint only for the nucleation mode? Please be specific.

Lns 386-393: While this section discusses the possible mechanisms for the production of sub-10nm particles in jet engine exhaust, it does not explain the difference observed in sub-10nm soot particles reported in earlier studies. The authors should expand upon this. Are the sub-10nm particles non-volatile metals or soot or both?

Lns 405-407: See earlier comment about real-world vs. certification emissions measurements

Technical corrections:

Ln 33: “supply” is an awkward use of the word here. Suggest changing “can supply” to “emit”

Ln 49: change “significant evolution” to “significant formation and evolution”

Lns 151-152: change “might act as” to “might contribute to”

Ln 197: change “accord” to “accordance”

Ln 203: change “after” to “downstream of”

Ln 216: change “required by” to “in”

Ln 218: change “required specification” to “requirements”

Ln 233: change “individual aircraft” to “individual aircraft movements”

Ln 377: change “researches” to “research”

Ln 386: change “evidences” to “evidence”

Ln 395: change “organic matters” to “organic matter”

Figure 3: This figure does not add any value to what has already been described in the

text. It can be removed.

Figure 4 (a): In the legend, change “specification” to “manufacturer specification”

Figure 4 (b): In the legend, change “SAE ARP6320” to “SAE ARP6320 minimum specification”

Figure 5: delete “are shown” from figure caption

Figure 10 (a) and (b): change “Unheat” to “Unheated” in the legend and in figure

References:

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Lobo et al., Atmos. Environ. 2012, 61, 114–123

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