Review of "The effects of morphology, mobility size and SOA material coating on the ice nucleation activity of black carbon in the cirrus regime" by Zhang et al.

General Comment:

This study reports the ice nucleation abilities of three different types of black carbon (BC) particles at thermodynamic conditions relevant to cirrus clouds. The importance of different physicochemical properties such as morphology, size, and SOA coating on the ice nucleation of bare BC particles was evaluated. This is a very interesting topic that nicely fits with the ACP scope. The experiments were carefully performed and the manuscript is well written. The manuscript can be accepted for its publication after the following points are properly addressed.

Major comments:

1. From the data shown in Figure 5a, it is concluded that the highly oxidized toluene SOA-coated BC (T-10) reports similar onsets as the bare BC particles. However, it is shown that the slightly oxidized toluene SOA-coated BC (T-3) deactivate the BC particles reporting higher SS_i values. A clear explanation about this is missing and needs to be provided.

2. In Figure 5 important data is not reported. This information is needed to support the conclusions. a) missing bare BC data above -43°C; b) missing bare BC data at -40°C, missing D-10 data at -40°C, missing D-3 data below -43°C; and c) missing bare BC data at -40°C, and missing B-0 data below -44°C.

Minor comments:

Line 31: Add "coated BC" after "SOA".

Lines 32-33: "OH exposure levels of all SOA coating experiments, from an equivalent atmospheric 10 days to 90 days, did not render significant differences in IN potential". This is not true for Toluene SOA.

Line 62: I suggest to add some key studies in this topic instead of P&K.

Line 63: "ice nucleation".

Line 64: I suggest to add some key studies in this topic instead of the cited review paper.

Line 88: Add a reference after "weeks".

Line 89: Can the authors add an older study in addition to Kulkarni et al. (2016).

Line 102: It should be "-38°C".

Line 114: Add a reference after "combustion".

Lines 133-134: "β-caryophyllene has been found to be one of the most atmospherically abundant sesquiterpenes". Does it also apply to the upper troposphere (the focus of the present study)? What is its typical concentration at such high altitudes?

Line 145: experimental?

Lines 152-154: "All samples were then neutralized and size selected by a BMI differential mobility analyzer (BMI DMA, Model 2002; Brechtel Manufacturing Inc.) or TSI DMA (Model 3081, Classifier, Model 3082; TSI Inc.) for bare BC and BC-SOA mixing experiments, respectively". Are there any differences in the size selected particles when using the BMI or TSI DMA?

Line 160: Define "MOUDI".

Line 191: "monodisperse BC particles". Based on the data shown in Figures 2 and A3, the particles are not really monodisperse.

Lines 202-203: Please clarify the type of the AMS used.

Line 269: Add a reference after "pressure".

Lines 274-275: "signal (Garimella et al., 2016) was used to classify each particle as an inactivated aerosol or ice crystal over the course of an experiment". Could have liquid droplets been present? How was this evaluated?

Lines 279-281: "SPIN. For the size-selected bare BC experiments, the total particle number concentration was measured by a CPC operating simultaneously with SPIN, while for the SOA coating experiments, the total particle number concentration was integrated from the SMPS measurement." Are there any particle losses during the SMPS analysis?

Lines 285-286: As mentioned above the particles were not truly monodisperse.

Line 291: Add "(Table 1)" after R2500U.

Line 308: "The results in Fig. 3A demonstrate that the particle size is relevant to particle IN ability". What has been reported in the literature?

Lines 346-347: The 350 nm bare BC particles data at temperatures above -43°C on *panel a* is not shown.

Lines 347-348: The discussed data from the present study was not pure Toluene SOA. It was a mixture of BC/SOA, and the ice nucleation should be attributed to the BC and not the SOA as shown by the pure toluene SOA data. Also, do the authors claim here that all aromatic SOA should behave in the same way?

Line 348: "aromatic SOA". Indicate the SOA precursor.

Lines 350-351: I don’t get the point of this sentence.

Lines 348-361: I do not fully understand the reasoning here. This discussion is useless to understand this (Major comment) as it compares the toluene-SOA with the other two SOA but does not discuss the differences between the slightly and highly oxidized toluene SOA.

Line 370: "between -46 and -42 °C". How about at -40°C?

Line 371: "between -43 and -40 °C". How about below -43°C?

Line 403: "while β-caryophyllene SOA oxidized by O3 did not alter the SS_i of the soot particles". Why not? What do the authors think happened here?

Lines 403-405: this deserved to be deeper discussed.

Line 410: "aerosols". How about gasses?

Line 441: are they really monodisperse?

Figure 2. Why the 350 nm bare BC selected particles did not show a narrow peak at 350 nm?

Figures 3 and 5. I am wondering why the authors did not include literature data in both figures. This will help the readers to directly compare the present results with previous studies.

Figure 7: I think this figure add very little to the main text, and therefore, it can go to the supplementary material.

Figure A3. Why are the size distribution so polydisperse after size selection?

Figure B1. This figure is not easy to follow. Is it time in the x-axis?

Figure B2. It is not mentioned/discussed in the text.