Reviewer #2: The paper "new particle formation leads to CCN at the Antarctic Peninsula" aim to present one year of data (2018) of SMPS data and to connect it with CCN data.

I am not sure if there is a contribution at this stage. Similar and much in depth results were published from Jang et al 2019 and Kim et al 2019 on part A part B of ACP. This paper stresses the importance of the ocean, but the air mass classification and the SMPS data analysis is too weak to draw any further conclusion, I am not sure if this paper add anything new to the literature for a high impact journal like ACP.

We would like to thank the reviewer for valuable and constructive comments. Below is our point by point response to each of the comments.

In this study, we simultaneously presented one-year nano SMPS, standard SMPS, and CCN data during the pristine and clean periods (BC concentrations less than 50 ng m^{-3}), which enables to suggest more robust and topical hypothesis compared with the previous works by Jang et al. (2019) and Kim et al. (2019). It enables us to improve our understanding NPF and growth events, significantly enhancing CCN concentration. In fact, we newly suggested that spatial scale of NPF around Antarctic peninsula was found to be about 155 km away by using the nano SMPS data and 86% of NPF events were characterized by the simultaneous increase in the CCN concentration by 44% (by median) in the following 8 hours (by median) by comparing both SMPS and CCN data for each NPF event.

The paper also suffers from a poor literature review, totally unbalanced - it somehow reminds controversial marine organic aerosol topics discussed twenty years ago, with few respected scientists arguing over POC-DOC and the effect of organics on the sea spray production (still not solved!).

This comment seems to be not relevant to our topic. The POC-DOC and the effect of organics on the primary sea spray production are not discussed in this manuscript. Authors acknowledge the points raised by the referee and series of references were added in this revised version in the introduction and discussion parts.

(1) Introduction - poorly presented, it cites one paper (Kyro et al 2013) stressing the importance of Antarctic melt ponds waters, purely speculative and not shown in any data, only suggested as a possibility - remote, I would say; if you have an idea of the overall geography of the Antarctic continent and marine surrounding. The paper continue to report papers about animals and emissions, although from studies run very close to emission sources (indeed the island is called Bird island).

Response: In order to address the sources emitted from the animals, we newly included 2 NPF events (4 February 2018 and 18 February 2018) which were associated with local fauna. We presented the contour plots of the size distributions and wind roses when predominant wind possibly passing over a penguin colony (around 2 km away from our observation site) in supporting information. We discussed the influence of penguin colonies on NPF event and also added the references as given below.

Page 20, Line 513: “In fact, 2 NPF events (4 February 2018 for marine air mass origin and 18 February 2018 for multiple air mass origin) were observed when winds were seen to originate from the south sector where strong emission from the penguin colonies (southeast sector of 106–140º). Figure S8 showed the contour plots of the size distributions and wind roses during those days. Although we did not directly measure the precursor gases such as ammonia and amine that can trigger the NPF, we can speculate that the fauna on the land or at the shore such as penguin and seabird colonies could not be excluded as the potential source of NPF events locally although highly productive and ice melting Weddell sea is coinciding with southeast direction too. Previous studies reported that precursor gases for NPF (e.g., ammonia) can originate from the decomposition of excreta from seabirds and penguins (Lachlan-Cope et al., 2020; Legrand et al., 1998; Liu et al., 2018; Schmale et al., 2013). More recently, Quéléver et al. (2022) proposed that nitrogen-containing species could be land-sourced (e.g., from a high penguin population during the summertime) or marine-sourced (e.g., from the biological activity of plankton in the ocean and melting sea ice). The ammonia from seabird-colony guano is a key factor contributing to bursts of newly formed particles, which are observed in the summertime Arctic (Croft et al., 2016)."

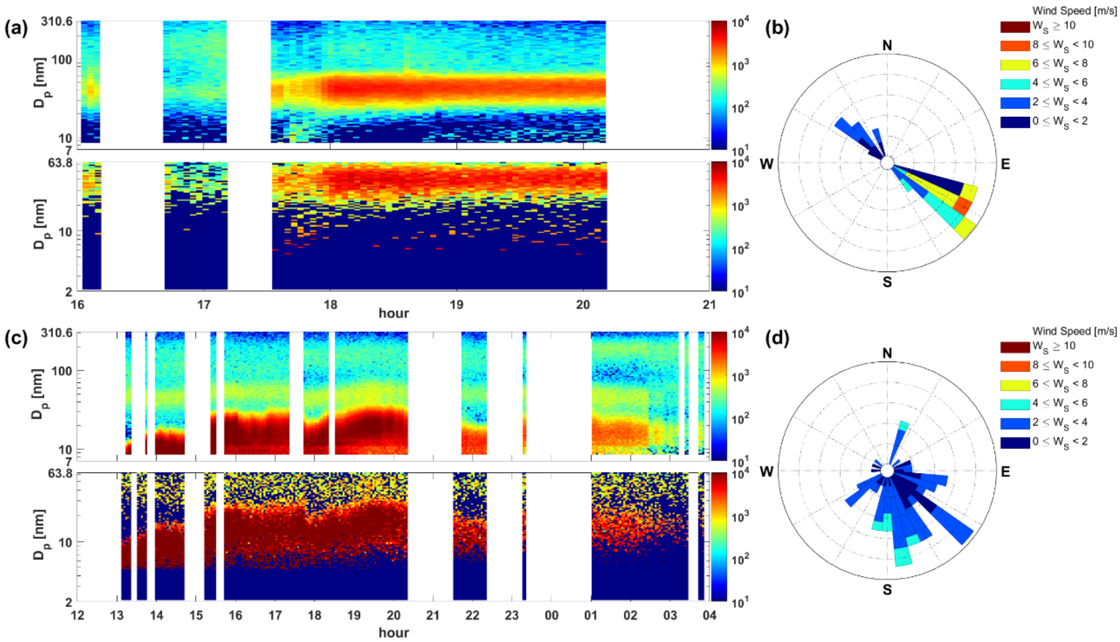

Figure S8. (a) Contour plots of the size distributions and (b) wind rose on 4 February 2018 and (c) contour plots of the size distributions and (d) wind rose on 18 February 2018. The southeast direction (106–140º) is designated as a sector where strong emission from the penguin colonies may originate. The x-axis represents local time.

What is even funnier is that the authors do not mention any of recent open ocean and coastal Antarctic expeditions (i.e. PEGASO, ACE Schmale Baccarini et al, PI-ICE) - that is funny, cause some of the authors were even on board of such cruises (and continue publishing data - without the PIs involved - from such cruises). Overall it is a pity in 2023 these things are still happening - I suggest to write a better and more fair introduction. Also, recent papers published by Australian groups talking about Antarctica and CCN may be worth mentioning and consider in the discussion. At this stage the paper is about a report of measurements.

Response: In this study, we measured the NPF event and CCN activity at land-base station, so we focused primarily on mentions of the previous studies conducted at Antarctic land-base stations for comparison. Based on the review's comment, we newly added and discussed several references for recent open ocean and coastal Antarctic expeditions (Brean et al., 2021; Dall'Osto et al., 2017; Dall'Osto et al., 2022; Decesari et al., 2020; Humphries et al., 2021; Humphries et al., 2023; Schmale et al., 2019; Simmons et al., 2021; Walton and Thomas, 2018) in introduction and discussion sections as follows.

Page 2, Line 51: "Furthermore, open ocean and coastal Antarctic expeditions such as SIPEXII (Sea Ice Physics and Ecosystems eXperiment, 2012; Humphries et al., 2015; Humphries et al., 2016), PEGASO (Plankton-derived Emissions of trace Gases and Aerosols in the Southern Ocean, 2015; Dall'Osto et al., 2017; Decesari et al., 2020; Fossum et al., 2018), ACE-SPACE (Antarctic Circumnavigation Expedition – Study of Preindustrial-like Aerosol Climate Effects, 2017; Schmale et al., 2019; Walton and Thomas, 2018), PCAN (Polar Cell Aerosol Nucleation, 2017; Simmons et al., 2021); PI-ICE (Polar atmosphere-ice-ocean Interactions: Impact on Climate and Ecology, 2019; Brean et al., 2021; Dall'Osto et al., 2022) studies on the influences of marine aerosols on climate and ecology."

Page 4, Line 90: "To date, number size distribution of particles > 3 nm has been reported by Asmi et al. (2010) at Aboa during from December 29, 2006 to January 29, 2007; by Pant at al. (2011) at Maitri from January 1 to February 28, 2015; by Weller et al. (2015) at Neumayer from January 20 to March 26, 2012; by Jokinen et al. (2018) at Aboa from November 2014 to February 2015; by Weller et al. (2018) at Kohnen during January 2015 and 2016; by Quéléver et al. (2022) at Marambio during the austral summer between January 15 and February 25, 2018; and by Brean et al. (2021) during the PI-ICE cruise from January 25 to February 4, 2019."

Page 4, Line 105: "Ship-based observations during the ACE-SPACE found that the fraction of particle serving as CCN was higher near the coast of Antarctica compared to open ocean, resulting from multiple processing cycles of dissipating and condensing clouds and/or the higher availability condensable gases originating from marine microbial activity (Schmale et al., 2019)."

Page 18, Line 458: "In comparison, Jokinen et al. (2018) reported that GR values ranged from 0.3 to 1.3 nm h^{-1} at Aboa, and Brean et al. (2021) showed GR of 0.4 to 0.6 nm h^{-1} measured during the PI-ICE cruise."

Page 21, Line 537: "The values are in line with previous studies published from the Antarctic regions. Humphries et al. (2023) reported CCN concentrations nearby East Antarctic observations from Macquarie Island and Kennaook / Cape Grim as well as recent ship voyages of the RSV Aurora *Australis* and the RV *Investigator* in the region. The median CCN value at a SS of 0.5% was in the ranges of 88–145 cm^{-3} at Macquarie Island, 57–158 cm^{-3} at Kennaook / Cape Grim, and 40–230 cm^{-3} during the voyages (No voyage data exist for the winter months), respectively. The PCAN project exhibited that a median particle number concentration larger than 3 nm of 354 cm^{-3} was observed from the voyage and median CCN at 0.55 % supersaturation were 167 cm^{-3}, implying approximately half the particles measured as CN_3 could be activated as CCN (Simmons et al., 2021). Recently, several ship-based measurements over the Southern Ocean found significantly increased MSA concentrations in air masses originating close to the Antarctic coastline, alongside enhancements in CCN concentration (Humphries et al., 2021)."

(2) BC data. Not sure if this is all necessary - if you want to compare other data, consider to compare Antarctic station or Arctic station, mentioning Mace Head is a "little" bit out of scope here. It is evident that marine Atlantic aerosols has nothing to do with Antarctic - consider remove all this section for eventually a future publication elsewhere.

Response: We agree with the reviewer's comment. Since environmental conditions could be significantly different, the statement on the BC comparison between North Atlantic Ocean and Southern Ocean was removed. We newly added the information about BC concentration measured in Antarctic regions as given below.

Page 8, Line 187: "Hara et al. (2019) measured BC concentration at Syowa station Antarctica from February 2005 until December 2016. They found that the daily median BC concentrations were below the detection limit (0.2 ng m^{-3}) to 63.8 ng m^{-3} at Syowa Station (median, 1.8 ng m^{-3}; mean, 2.7 ng m^{-3} during the measurement period). During the ACE-SPACE expedition, BC concentration reach its background levels of 19.2 ng m^{-3} (Schmale et al., 2019). Arctic shipborne-observations measured BC concentration throughout the Arctic Ocean and Pacific Ocean during the summer of 2017, all pointing to pristine clean marine air masses with BC values of approximately 20 ± 10 ng m^{-3} (Park et al., 2020)."

(3) Definition of different events - beside the dozens of papers discussing different types of nucleation with K-means clustering, do not you have better examples than the ones presented? Out of the 97 NPF events, you may want to have a look at what you presented:

Response: We did not analyze K-means clustering. Most of papers discussing different types of NPF based on the K-means clustering focused on the characteristics of NPF event. In this work, our main aim is to investigate the connection between NPF and CCN for one-year dataset. Instead, we added more examples for NPF event in Figure S3 and Figure S8. Figure S3 included examples of two types of the NPF event based on the SMPS data such as burst event and nucleation with growth. Figure S8 showed examples of the NPF event when winds were seen to originate from the south sector with potentially strong emissions from the penguin colonies.

Figure 6 - is this a NPF event or did you by mistake add a wrong figure? Given you comment it in the text, I assume this is the right figure. I am not sure this is a NPF event, it looks to me it is a background mode of about 20nm that is existing in a large area, it reminds what was discussed in O´Dowd et al (GRL, 2010) and in other papers of open ocean slow growing ultrafine particles. What I am not sure is that if there particles are growing in Figure 6, it looks to me they stay there, and they were detected as a background small Aikten (20-30nm) mode - could be primary or secondary or something interesting, surely not a "tyipcal" NPF for a marine case I would say.

Response: O'Dowd et al. (2010) presented open ocean new particle production and growth events occurred during periods of high oceanic productivity over the Northeast Atlantic. As mentioned by reviewer for BC issue, since environmental conditions between Northeast Atlantic Ocean and Southern Ocean are significantly different, we cannot compare the NPF event observed between both areas. In the current study, we cannot find particle formation starting directly from the lower end of the particle size spectrum (2.5 nm). The initial diameter of particles that arrived to the measurement site during the NPF ranged from 4 nm to 16 nm, indicating the spatial extension of regional NPF event. Our results are broadly in line with previous results published from the Arctic and Antarctic regions. We discussed this issue as given below.

Page 13, Line 341: "A ship-borne field campaign over Arctic Ocean found a trimodal distribution at 18 ± 3 nm, 53 ± 6 nm and 150 ± 6 nm for open-ocean marine Arctic NPF event and a bimodal distribution at 24 ± 3 nm and 151 ± 3 nm for Open-ocean terrestrial Arctic NPF event (Park et al., 2020). Lachlan-Cop et al. (2020) presented k-mean cluster analysis of particle size distribution measured at Halley, Antarctica, showing a nucleation peak at 15 nm for "nucleation" ultrafine category and a nucleation peak at 27 nm for "bursting" ultrafine category."

Figure 7 The second may be a NPF event, the first one is a little bit a burst, of 30 min, followed by a 20-30nm mode lasting for several hours - I suggest to look for better examples or to use a more detailed classication.

Response: Based on the reviewer's comments, we changed the example of sea-ice NPF event as shown in Figure 7. The sentence was modified as given below.

Page 16, Line 406: "The NPF event with subsequent particle growth were detected from around 19:00 on January 13, 2018, to around 08:00 on January 14, 2018 (Figure 7). Air temperature and RH during the event were 0.1 °C and 85%, respectively, while solar radiation decreased from 131.7 to 0.2 W m^{-2}. Winds were mild and stable (1.9–5.7 m sec^{-1}), with a prevailing northwesterly (262–350°) direction and air masses predominantly coming from sea-ice. The average retention times of the 2 d back trajectories traveling over ocean, sea-ice, and land were 20.0, 20.9, and 7.1 h, respectively, indicating sea-ice-influenced air masses (Figure 5b). During the NPF event, both total DMSP and chlorophyll exposure values are stable, with median exposures of 13.3 nmol L^{-1} and 0.2 mg m^{-3}, respectively.
During the event, $CN_{2.5}$ and CN_{10} increased to 5669 and 5097 cm^{-3}, respectively. Furthermore, the median N_{NUC}, N_{AIT}, and N_{ACC} values were 508, 376, and 66 cm^{-3}, respectively. Elevated CCN concentrations at 0.2 and 0.4 % supersaturations were not observed, whereas CCN concentrations at 0.6, 0.8, and 1.0 % supersaturations slightly increased during the event. For instance, CCN concentration at 0.8 % supersaturation was 517 cm^{-3} at 20:00 on January 13, then increased to 688 cm^{-3}, until 23:00 on January 13. The CCN concentration at 0.6, 0.8, and 1.0% supersaturations increased by 11%, 33%, and 58%, respectively."

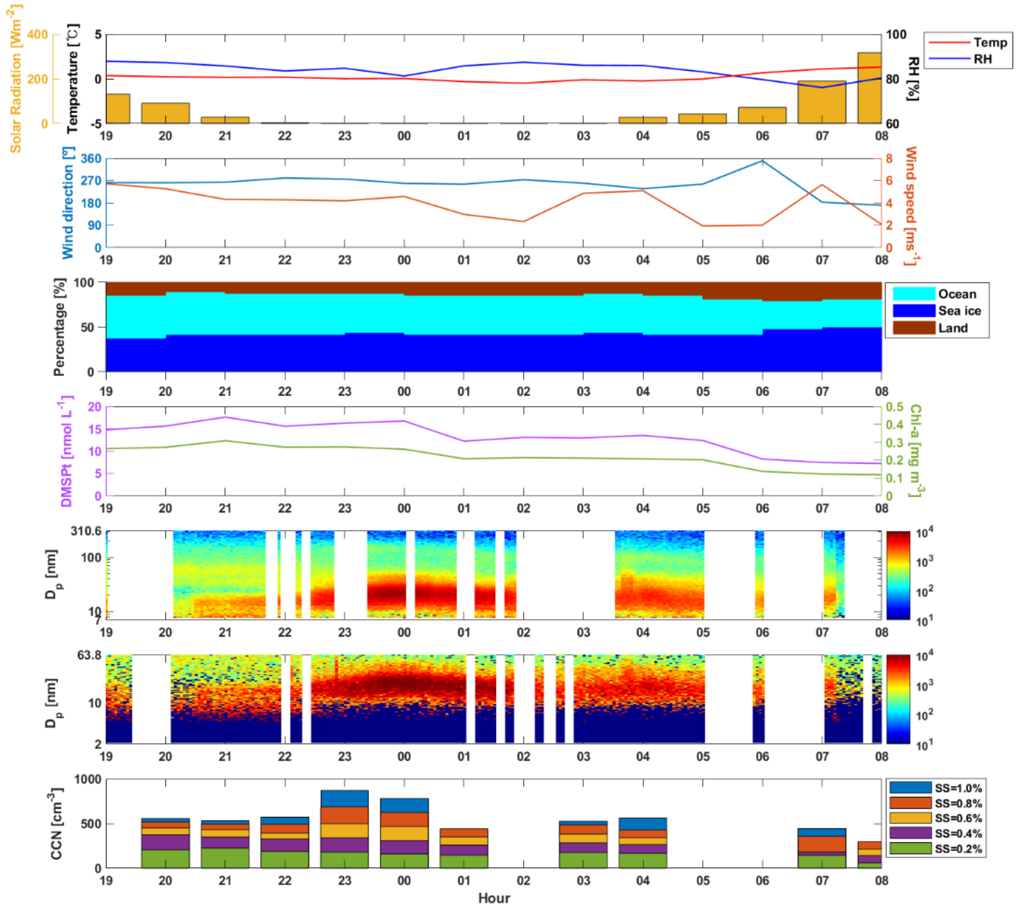

Figure 7. Sea ice NPF event observed from January 13–14, 2018. From top to bottom, the parameters are as follows: meteorological variables, the residence time of air masses that passed over the ocean, sea ice and land areas, number size distribution with the standard-SMPS and nano-SMPS, and CCN number concentration. The x-axis represents local time.

Figure 8 are these data in local time? Please define the time, it looks this is a night time nucleation event?

Response: We used the local time (LST). As suggested by the reviewer, we define the time in the figure captions. As illustrated in Figure 8, initial stages of nucleation are observed from 17:00 when sunlight exists. Thus, the plausible explanation for the NPF event is that the actual formation and growth occurred during daylight hours upwind from measurement location, but very slow growth continued over the Antarctic Peninsula allowing the detection of ～7 nm particles after the sunset.

(4) classification of air masses. Please consider to discuss different types of environment and to discuss it well, especially cause there are marine simpagic and pelagic zones, including the consolidated pack sea ice and the sea ice marginal zone. All these environments are more complex than a simple ocean - sea ice area. I suggest a better analysis, perhaps using a clustering method such us the one presented in Jang 2022 (Science of the Total Environment 803 (2022) 150002). The study of Jang et al 2022 also stress that EAP and WAP are main sources of ultrafine particles (10-25nm) so in contrast to what this current study suggests.

Response: In the present study, we classified air mass origins into ocean, sea-ice (including marginal ice zone and pack-ice area), and land. Since we only refer to the air mass origins when

NPF event occurred, we did not need to perform the clustering analysis. In addition, we did not divide sea-ice zone into marginal ice zone and pack-ice area, because most of NPF events (82%) were observed in ocean-influenced air masses and remaining 18% of NPF event were influenced by sea-ice or land. Jang et al. (2022) considered the domains of pelagic (open ocean area), first-year ice, and multi-year ice zones during entire study periods (from December 2018 to April 2019 and from November 2019 to February 2020). Moreover, Jang et al. (2022) defined the ice zone as maximum sea ice extent observed in August 2018 and 2019. The clusters of air masses were reclassified into three groups representing the Antarctic open ocean (AOO) (*n* = 1983), western Antarctic Peninsula (WAP) (*n* = 1675), and eastern Antarctic Peninsula (EAP) (*n* = 1356). Then, they showed the hourly mean number concentration of newly formed particles (CN_{10-25}) assigned for the AOO, WAP, and EAP. Therefore, a role of first-year sea ice on the particle concentrations was addressed in the previous work (Jang et al., 2022) and was out of scope of this study.

The current paper aims to give a clear message: it is all marine open ocean and little sea ice. This is in contrast with the literature, and recent studies (Jang 2022). Unfortunately the previous studies, Jang 2019 part 1 and part 2 did not consider sea ice air masses, and only partially presented data showing only data from open ocean seas from the north. I suggest a more in depth analysis, at the moment this is a qualitative analysis showing some very broad classifications of both air masses and NPF events with a broad terminology - broadly concluding the identical results published before from a much bigger dataset (2009 till 2016) with both SMPS and CCN data.

Response: This is a similar question to the above. Again, the definition of air mass origins is different. Jang et al. (2022) compared the mean value of newly formed particles (CN_{10-25}) for each air mass during entire sampling periods, whereas we compared the NPF properties according to air mass origin when NPF event occurred. In the present study, we focused on the NPF characteristics and its linkage with CCN properties. To clarify the connection between growing particles and CCN, we determined the increase in the median CCN concentration at different SS during growth larger than 40 nm and growth smaller than 40 nm times compared with background times based on the method by Chang et al. (2022). Detailed information is provided in the manuscript as given below.

Page 22, Line 574: "To understand the contribution of growing particles on the CCN concentrations during NPF event, we determined the increase in CCN concentration during growth periods (i.e., growth to smaller than 40 nm particles and growth to larger than 40 nm particles) compared to baseline values (black) under different supersaturation conditions (Figure 10), according to the method suggested by Chang et al. (2022). When particle growth was smaller than to 40 nm (growth ≤ 40 nm), the mean CCN concentrations increased by 59–178 cm^{-3} for a SS of 0.2 %–1.0 %, representing a 172.3–216.7 % increase compared to the values during baseline conditions. When particle growth was larger than to 40 nm (growth > 40 nm), the mean CCN concentrations increased by 57–227 cm^{-3} for a SS of 0.2 %–1.0 %, representing a 169.9–249.1 % increase compared to baseline values. Our results indicate that particles formed from NPF events can lead to the significantly enhanced CCN concentration in Antarctic Peninsula, and this effect is more pronounced if we consider particle growth larger than 40 nm, consistent with ship-based observations (Chang et al., 2022) and aircraft-based observation (Willis et al., 2016) in the Canadian Arctic during summer."

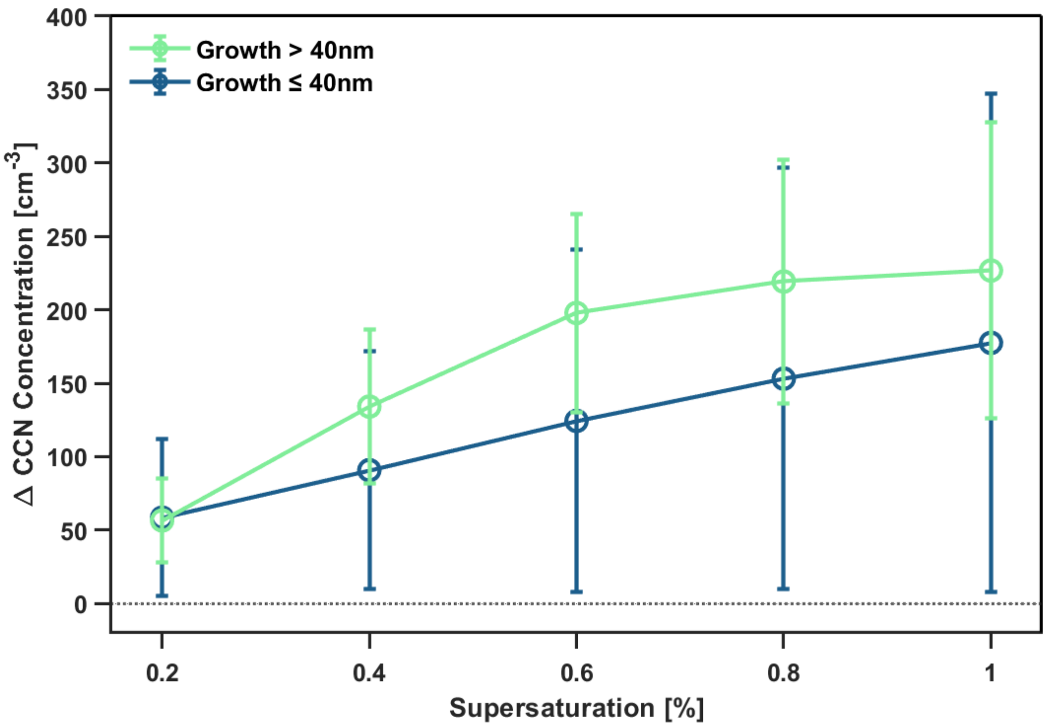

Figure 10. The increase in CCN concentration during growth to larger than 40 nm particles (green) and smaller than 40 nm (blue) times compared with background times at five different supersaturations.

(5) Wind roses or potential source function analysis to prove and or exclude local sources as suggested by reviewer 1.

Response: We agree with the reviewer's comment. To minimize the influence of local pollution sources from a power generator and crematory during the data analysis, we used black carbon concentration, wind speed and wind direction data as described in section of 2.2. Thus, the northeastern direction of 355–55° is designated as a local pollution sector due to emissions from the power generator and crematory. Data collected from this sector were absolutely discarded. Again, to address the potential local source from wild-life emissions, we included wind roses in Figure S8 as mentioned above.

I suggest to publish this paper in a lower impact journal or in measurement report.

Response: Authors do believe the revised version brings significant scientific advancement to the topical area.

Newly added references

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