Interactive comment on "Seasonal variations in physical characteristics of aerosol particles at the King Sejong Station, Antarctic Peninsula" by Jaeseok Kim et al.

Anonymous Referee #2

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We thank the referee for valuable comments that we have used to improve our manuscript. We have considered the comments and have modified the manuscript accordingly. Our detailed responses to the referee's comments are below.

This manuscript summarizes measurements of aerosol physical properties (size distributions and number concentrations) as well as CCN concentrations performed at a research station in Antarctica. These data are needed to establish quantitative points of reference for a region that may face dramatic changes as a result of climate change. Because of this, this manuscript fulfills an important role and is suitable for publication in ACP.

I do feel that the authors have missed some opportunities in their presentation of the data to dig a little deeper into their data. I would like for the authors to comment on some of the more obvious issues to me:

(1) Very little is mentioned about the particle size distributions. For example, if new particle formation is expected (and there are several references to suggest this in the text), then what do the SMPS data tell us about the nature of the particle formations events. To address this question the data from the size distribution shown in Fig. 8 could show "box-whisker" data that better account for less frequent new particle formation events.

Authors' response: The main purpose is to understand general physical characteristics of aerosol particles at the King Sejong Station in Antarctic Peninsula. Because the study on new particle formation events is out of scope, in the manuscript, brief description about the particle size distributions was done and the particle size distribution data were used to support explanation for monthly trends of CCN concentrations as shown in Fig. 8. In accordance with referee's suggestion, we also showed "box-whisker" data of particle size distribution as shown in Fig. S1. Although there is much outlier in summer season, we don't know that it

indicates frequency of new particle formation events. We are preparing other manuscript related to new particle formation events and are analyzing deeply and carefully about results of the particle size distribution.

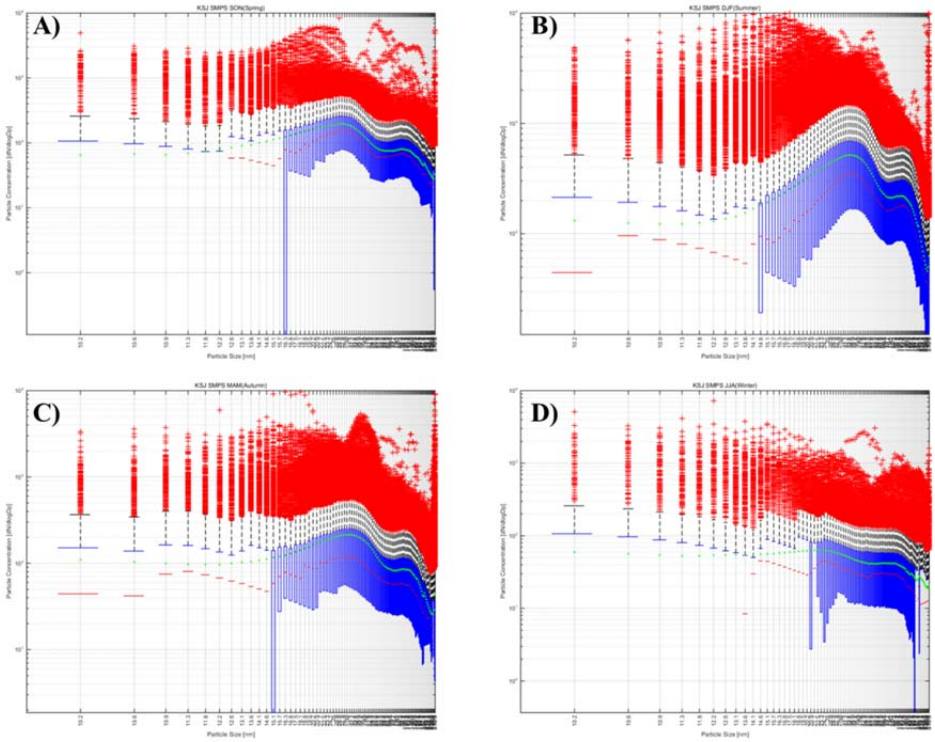

Figure S1. Box-Whisker plot of particle size distribution during (a) spring, (b) summer, (c) autumn, and (d) winter season. Red bars in the boxes indicate median values (mean values: green circle), whiskers indicate the 5th and 95th percentiles, and red cross out of whiskers represents outliers.

(2) Another missed opportunity is the lack of a thorough analysis of the CCNC data. Other than reporting concentrations at specific supersaturations, the "spectrum" of CCN activity is not really discussed in this paper. Some fitting parameters, namely "C" and "k", are presented but one of the most widely used parameters, kappa from k-Koehler theory, is not even mentioned. While I do not demand consideration of these issues as a condition for publication, I do urge the authors to consider how a somewhat minor investment in time might add great value to this publication.

Authors' response: If chemical constituents of aerosol particles are size-dependent, it is complicated to estimate CCN concentrations by using particle size distribution. Because size-dependent chemical information of aerosol particles is not available in this study, an

empirical parameterization using in-situ CCN measurements was used in this study. The CCN concentrations as a function of SS were fitted with an equation of the form $Nccn=C(SS)^k$, where Nccn is CCN concentration at a certain SS value, and *C* and *k* are the fitting parameters. The fitting was done separately for each SS cycle of CCNC data. Besides that we have focused and found the fitting values c and k values, we tested single hygroscopicity parameter, kappa in κ-Köhler theory, as suggested by referee. We roughly estimated kappa by using monthly mean CCN concentration at SS of 0.4% and monthly mean total particle concentrations obtained from SMPS data. The kappa is approximately 1.18 in December. The possible reason for the high kappa value would be explained by limitations of measurements available. For example, we decided the critical diameter (d_{crit}) by comparing CCN concentration with the integrated SMPS data. In addition, CCN concentrations were measured without size-selection. We decided not to mention the kappa value in the revised manuscript.

The following are a list of edits and concerns, with the page and line numbers listed:
P2, line 5: lager -> larger
Authors' response: text was corrected accordingly.

Line 10: This abstract should not assume that the reader understands what C and k refer to. If you want to include these in the abstract you need to explain what they are.
Authors' response: We agree with referee's opinion. To help reader's understanding, text was added to explain what the *C* and *k* are.

We added following sentence on Page 2 Line 9:
"Based on measured CCN data at each supersaturation ratio (SS), empirical parameterization were also fitted using formula expressed by power-law function ($N_{ccn}=C\times(SS)^k$), where N_{ccn} is the CCN concentrations at a given SS, and *C* and *k* are the fitting parameters."

Line 17: improper use of semicolon. Replace with colon
Authors' response: text was corrected accordingly.

P3, line 9: "unascertained" may be a word (I'm not sure) but many simpler words like "undetermined" or "unknown" are better suited.

Authors' response: text was corrected accordingly.

Line 10: remove "their"

Authors' response: text was corrected accordingly.

Line 21: e.g. not i.e. (this is not an exhaustive list of physical properties).

Authors' response: text was corrected accordingly.

P6, line 1: "decided" should be replaced with "determined"

Authors' response: text was corrected accordingly.

Line 2: delete the second "only"

Authors' response: text was corrected accordingly.

Line 7: what model of DMA was used?

Authors' response: We used a cylindrical DMA similar to the TSI 3081 model. The length, inner diameter, and outer diameter of the DMA were 44.42 cm, 0.953 cm and 1.905 cm, respectively.

We added following sentence in Page 6 Line 17:

"The length, inner diameter, and outer diameter of the DMA were 44.42 cm, 0.953 cm, and 1.905 cm, respectively."

Line 12: "Besides" might be better replaced with "in addition" (this is clearly a style suggestion)

Authors' response: text was corrected accordingly.

18: "were" should be "was"

Authors' response: text was corrected accordingly.

P7, line 8: Please review this sentence and correct grammar

Authors' response: text was corrected accordingly.

"The solar radiation varied from 2.3 W m^{-2} to 375.4 W m^{-2}, with a mean value of 81.2 ± 38.9 W m^{-2}."

P9, Line 1: Please explain why, for this analysis, a supersaturation of 0.4% was chosen

Authors' response: Anttila et al. (2012) measured cloud droplet number concentration (CDNC) and CCN concentration at five different SS values (0.2, 0.4, 0.6, 0.8, and 1.0%) during the third Palls Cloud Experiment (PaCE-3). The campaign was performed from 11 September to 11 October, 2009. According to their results, they found high correlation between CDNC and CCN concentrations at a supersaturation of 0.4%. The CCN concentrations at less 0.4% supersaturation were lower than CDNC, while the CCN concentrations at higher than 0.4% supersaturation were higher than CDNC. Based on this result, variation of CCN concentrations at the supersaturation of 0.4% was analyzed in this study.

We added following sentence on Page 10 Line 7:

"Anttila et al. (2012) measured cloud droplet number concentration (CDNC) and CCN concentrations at five SS values (0.2, 0.4, 0.6, 0.8, and 1.0%) during the third Palls Cloud Experiment (PaCE-3). They showed correlation between CDNC and CCN concentrations at each supersaturation. The relationship between CDNC and CCN concentrations at the SS value of 0.4% was approximately linear, while CCN concentrations were lower than CDNC when the SS value was lower than 0.4% and CCN concentrations at upper 0.4% higher than CDNC. Based on this result, in this study, the supersaturation of 0.4% was chosen to investigate seasonal variations of CCN."

Line 10: is this redundant with the previous sentence in line 5?

Authors' response: We agree with referee's opinion. Because meaning of two sentences was similar, in same paragraph, we removed the sentence in line 5.

In the manuscript, we remove following sentence in Page 9 Line 5:

"It was similar to the seasonal cycle of the CN concentrations."

Line 19: any evidence of growth from Aitken to nucleation mode?

Authors' response: If the referee raises an issue if there is any evidence of growth from Aitken mode particle to CCN size, we cannot provide any direct evidence of this. Nevertheless, we compared monthly mean particle concentration measured from SMPS with CCN concentrations. The calculations showed that the number of accumulation mode particles cannot explain the measured CCN concentrations. It means that the rest of CCN are from the growth of smaller than accumulation mode particles, say from the Aitken mode, or residuals of cloud process. We could not provide direct evidence to distinguish these processes, we modified the sentence as:

Page 11, line1 has been changed to
"Accumulation mode particles can easily act as CCN (Dusek et al., 2006), hence CCN concentrations increase during the summer and decrease during the winter."

P10, Line 15: correct spelling of Arctic
Authors' response: Thanks. We checked spelling and changed.

P11, Line 5: how well did this model fit the data? There is no mention of this.
Authors' response: We estimated *C* and *k* values by using daily mean CCN concentrations at each SS value. The average correlation coefficient, r, was 0.978. We think it was a good fit.

In the revised manuscript, we added following sentence in Page 12 Line 18:
"The average correlation coefficient, r, was 0.978."

Line 17: period (not periods)
Authors' response: text was corrected accordingly.

P13, Line 6: no comma after "for"
Authors' response: text was corrected accordingly.

P14, Line 5: all mention of CCN concentrations need to state the SS
Authors' response: In summary section, we missed SS values for explaining CCN concentrations. It can give readers confusion. Thus, we modified sentence in the manuscript.

To clarify we modified sentence to following text on Page 15 Line 22:

"In addition, we presented the clear seasonal trends of CCN concentrations at the supersaturation of 0.4%."

Line 10: again, I don't think the reader knows immediately what C and k refer to. If the authors want this section to summarize results I would suggest explaining this to the reader.

Authors' response: We agree with referee's opinion.

To clarify meaning of *C* and *k*, we added following sentence on Page 16 Line 3:

"The C and k are constants were estimated using approximate formula expressed by a power-law function ($N_{CCN}=C\times(SS)^{k}$) (Twomey 1959)."

Figure notes: Figs 4, 8, 10-13: what do the error bars represent? This needs to be in the caption.

Authors' response: The error bars represent a standard deviation.

We add caption in Figures 4, 8, 10-13.

"Here the error bars represent the standard deviation of the measurements from the mean value."

Figure 9. Why not normalize to total N?

Authors' response: To investigate seasonal variations of fractions of CCN concentration at each SS value in aerosol particles activated CCN at a SS of 1.0%, we normalized it to CCN concentrations at a SS of 1.0% without total N.

Fig 13: seems statistically the same to me.

Authors' response: In this Figure, we found that seasonality of $CN_{2.5}$ concentrations were different in accordance with the air mass history. For instance, the $CN_{2.5}$ concentrations originating from the South Atlantic (Case II) were the highest in November, whereas the $CN_{2.5}$ concentrations originating from the South Pacific (Case IV) were the highest in February as can be seen in Figure 13. This is probably due to difference in chemical compounds that contributed to aerosol formation processes and/or in variations of biogenic activity according to the origin and transport pathway of air masses. This analysis has been

explained in the section 3.3. Unfortunately, we don't have chemical data of aerosol particles depending on air mass. To verify our hypothesis, further studies on chemical compositions of aerosol particles need to be carried out in the future.

Fig 14: needs to show something about the variability of the size distributions.
Authors' response: we showed the variation of modal diameter and number concentrations of the size distribution as can be seen in Table 2. In the revised manuscript, the following sentence on Page 14 Line 20 was mentioned.

"The modal diameters with standard deviation and number concentrations are summarized in Table 2. It is obvious that the modal diameters during the summer are larger than those during the winter for both Aitken and accumulation modes: 0.023 μm in the winter and 0.034 μm in the summer for the Aitken mode and 0.086 μm in the winter and 0.109 μm in the summer for the accumulation mode. The number concentrations for the summer are also higher than the value for the winter for the Aitken and accumulation modes, 49.16 ± 3.88 cm^{-3} during the winter and 304.36 ± 20.10 cm^{-3} during the summer for the Aitken mode and 44.78 ± 14.24 cm^{-3} in the winter and 140.25 ± 10.64 cm^{-3} in the summer for the accumulation mode."

Reference

Anttila, T., Brus, D., Jaatinen, A., Hyvärinen, A. P., Kivekäs, N., Romakkaniemi, S., Komppula, M., and Lihavainen, H.: Relationships between particles, cloud condensation nuclei and cloud droplet activation during the third Pallas Cloud Experiment, Atmos. Chem. Phys., 12, 11435-11450, 10.5194/acp-12-11435-2012, 2012.