

Review comment on "New particle formation events observed at King Sejong Station, Antarctic Peninsula – Part 1: Physical characteristics and contribution to cloud condensation nuclei" by Jaeseok Kim et al.

The authors attempted valiantly to answer the points by the reviewers. Although the authors have succeeded in answering some points, our common and major criticism still remains. I (referee #2) did not call for more field measurements but for a better and clearer discussion. In the current revision, this is better and clearer, but some points of the revised manuscript are less clear.

Major comment

1. Impact of human activity in the Antarctic Peninsula in the summer

Generally, local contamination can affect strongly aerosol properties, particular in the Antarctic area as a pristine region. Therefore, we must remove locally contaminated data before analysis and discussion. Actually, authors attempted to do it in accordance with the procedure for data screening stated in the revised manuscript. However, this procedure can filter only the direct-contamination from the station (I mean King Sejong Station, here). Because local anthropogenic impact on BC concentrations depends on distance from the combustion source (Hagler et al., 2008), threshold value of 100 ng m⁻³ might be high for the contamination from other stations located in the Antarctic Peninsula.

Considering many ship-borne tourism and, any operating stations in the Antarctic Peninsula during summer, these impacts should be considered and discussed. Indeed, several stations are operating around King Sejong Station (King George Island). I understand that the authors removed hardly these impact from the measured data in this study. As shown by Shirsat et al (2009) and Graf et al (2010), however, human activity in the Antarctic Peninsula can have potential for atmospheric sulfur chemistry, particularly during summer. Additionally, BC concentrations at Ferraz Station (near King Sejong Station) were higher than those at other coastal stations (Pereira et al., 2006; Weller et al., 2013). These studies implies impact of human activities in the Antarctic Peninsula, although we must consider contribution of long-range transport from South America and latitudinal BC distribution. Thus, this is likely the current condition around the Antarctic Peninsula (in summer), although authors want to know aerosol properties in pristine conditions.

In the revised manuscript, higher aerosol concentrations, FR, and CS were observed at King Sejong Station. We can consider the following likelihoods for them; (1) distance from open sea surface, (2) oceanic bioactivity, (3) influence by human activity in the Antarctic Peninsula, and (4) long-range transport from South America. Therefore, some explanation and discussion about impact by human activity in the Antarctic Peninsula should be added into the text.

Hagler, G., Bergin, M., Smith, E., Town, M., and Dibb, J.: Local anthropogenic impact on particulate elemental carbon concentrations at Summit, Greenland, *Atmospheric Chemistry and Physics*, doi:10.5194/acp-8-2485-2008, 2008.

Pereira, E., Evangelista, H., Pereira, K., Cavalcanti, I., and Setzer, A.: Apportionment of black carbon in the South Shetland Islands, Antarctic Peninsula, *Journal of Geophysical Research: Atmospheres* (1984–2012), 111(D3), doi:10.1029/2005JD006086, 2006.

Weller, R., Minikin, A., Petzold, A., Wagenbach, D., and König-Langlo, G.: Characterization of long-term and seasonal variations of black carbon (BC) concentrations at Neumayer, Antarctica, *Atmospheric Chemistry and Physics*, doi:10.5194/acp-13-1579-2013, 2013.

Authors' response: We agree with referee's opinion. Although we applied strict rule to minimize effect of local contamination as mentioned in the manuscript, local pollution by human activities cannot be ruled out to be a potential factor to contribute the higher aerosol FR and concentrations. Because six stations are located within

a 10 km radius of sampling site, anthropogenic factors may influence concentrations and formation of atmospheric aerosols. We added text about effect of human activity in the revised manuscript on Page 10 Line 3.

“Besides, human activities should be one of the possible reasons of high aerosol FR and concentrations. Although strict data filtering procedure was applied to the raw data-set to minimize the effect of local contamination as mentioned in Section 2.2, previous study showed that BC concentrations at King Sejong Station were higher than those at other stations in Antarctica (Kim et al., 2017). In fact, other studies (Shirsat and Graf, 2009; Graf et al., 2010) also reported that there were local pollution sources from tourist ships and emissions associated with scientific activities in Antarctic Peninsula, especially during austral summer seasons. These periodic human activities around the Antarctic Peninsula cannot be ruled out to be a potential factor to contribute the higher aerosol FR and concentrations.”

2. Comparison between size distribution and CCN

NPF is important aerosol source even in the Antarctic atmosphere. After growth to size of critical diameter, aerosol particles can act as CCN. If CCN concentrations depended on time after NPF as shown in Figure 5, this might relate to growth of nucleated particles. In other words, the normalized CCN variation can be varied in NPF types (Type A - C). In particular, authors can compare among aerosol number concentrations larger than critical diameter (ca. 50 nm), particles growth (change of size distribution after NPF), and CCN concentrations. Because authors had excellent data set of aerosol size distributions and CCN concentrations, comparison between size distribution and CCN can provide useful and valuable knowledge to us.

Authors' response: The aim of the section 3.3 'CCN concentration during NPF events' is to show the increasing pattern of measured CCN concentration (at 0.4% supersaturation) when NPF is observed. The authors are analyzing direct comparison between aerosol size distribution (SMPS data) and CCN concentration (CCNC data) for various meteorological conditions and air mass origins, not only the NPF cases. This further analysis using the long-term SMPS and CCNC data set will make a follow-up work. To comply with the referee's comment and respect the scope of the section 3.3, authors calculated particle concentrations larger than diameter 50, 80, 100 nm only for NPF cases as a function of time (hour) elapsed after the event. For this further analysis, authors had to limit the number of cases when all the three data-set (CPC, SMPS, CCNC) are available, which resulted the number of cases is 27. This result (with error bar) is shown as Figure 5, and text in Section 3.3 has been modified accordingly.

“In this section, the contribution of particle formation to the variation in CCN concentration is investigated. Although recent studies reported that number concentrations of climate-relevant particles increased during NPF events (Pierce et al., 2014; Shen et al., 2016; Rose et al., 2017), the contribution of NPF to CCN concentration was estimated by using an indirect method. The number concentrations of particles larger than 50, 80 and 100 nm were estimated by using size distribution data. That value was considered as potential CCN concentration at different supersaturation value. In the present study, CCN concentrations at a supersaturation value of 0.4% were directly measured using CCN counter. Hourly mean CCN concentrations were compared with CN concentrations measured by CPC and size distribution results measured by SMPS (Fig S3 in the Supplement). Data for only 27 days, when all the three data-set (CPC, CCN counter, and SMPS) were available, were analyzed. Fig. 5 shows variation in $CN_{2.5-10}$ concentrations, CCN concentrations, and number concentrations as a function of time elapsed after the NPF event. The zero in the x-axis means the start time of the NPF event. As shown in Fig. 5a and b, the $CN_{2.5-10}$ concentrations sharply increased at NPF start time and the peak concentration occurred 2 h afterward, whereas the CCN concentrations gradually increased for 8 h.

Indeed, the maximum CCN concentrations rose from $191.4 \pm 16.3 \text{ cm}^{-3}$ to $213.2 \pm 17.7 \text{ cm}^{-3}$ before and after the NPF events, respectively, showing an increase of 11%. Fig 5b also shows variation of number concentrations (N_{50} , N_{80} , and N_{100}) of particles larger than 50 nm, 80 nm, and 100 nm, respectively. Number concentrations were calculated from aerosol size distribution data. Variation trends of the number concentrations were similar to those of CCN concentrations, increasing approximately 15% before and after the NPF events.”

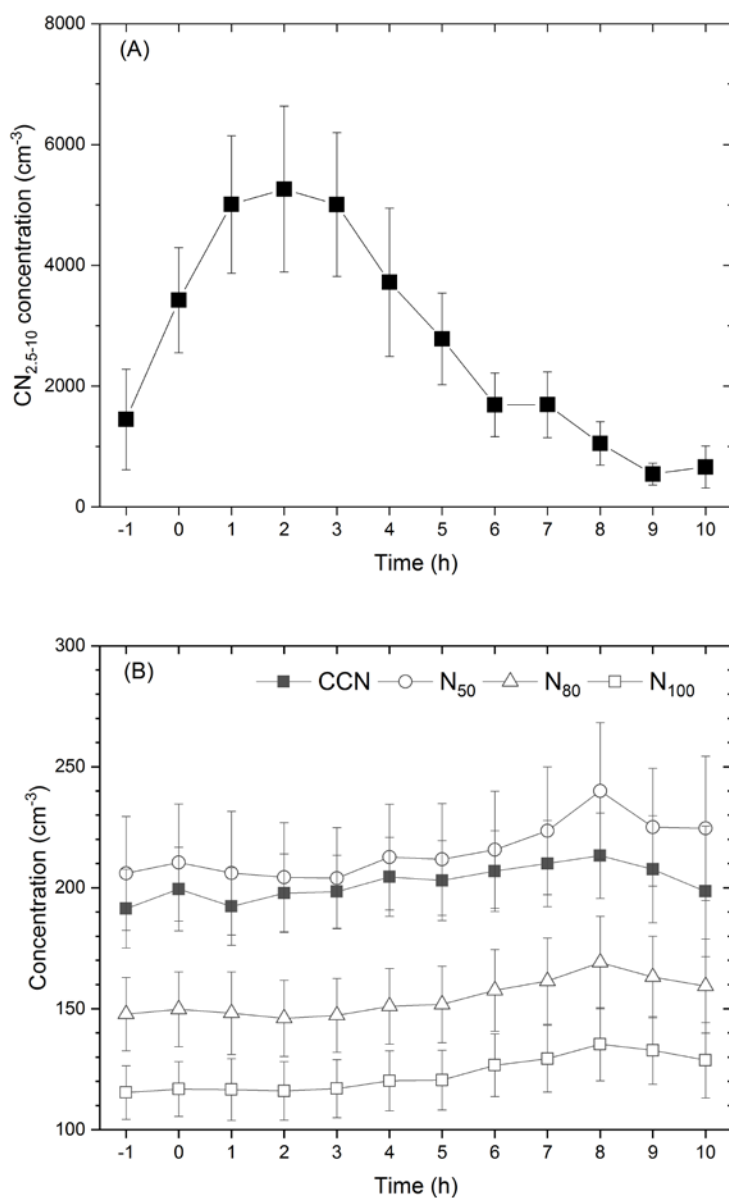


Figure 5. Variation in (a) $CN_{2.5-10}$ concentrations measured using CPC and (b) CCN concentrations measured with CCN counter and number concentrations calculated using SMPS data with time. N_{50} , N_{80} , and N_{100} represent number concentrations of particles larger than 50 nm, 80 nm, and 100 nm in diameter, respectively. The zero in the x-axis indicates the start time of the NPF events.

Minor comments

1. Page 10 line 20: the ultrafine particles of <100 nm in diameter can...

Authors' response: Authors changed text.

2. Procedures of log-normal fitting (I mean that equation) should be mentioned and/or earlier works should be referred.

Authors' response: Authors added reference for procedures of log-normal fitting in the revised manuscript on Page 6 Line 19.

"Here, the GMD was calculated from log-normal fitting analysis (Hinds, 1999)."

3. Specific values of diffusion coefficient (H₂SO₄) and transitional regime correction factor should be added in the text. These descriptions are helpful for readers.

Authors' response: Authors added specific values of diffusion coefficient (0.1 cm² s⁻¹) in the revised manuscript on Page 7 Line 8, whereas transitional regime correction factor is not added because it is related to particle size.

"where D is the diffusion coefficient of the condensable vapor (0.1 cm² s⁻¹), β is the transitional regime correction factor from Fuchs and Sutugin (1970),"

4. Fig. 4: No data of GR, CS, and Q were mentioned in the text. I recommend that no data are marked by symbols such as asterisks and short explanations are added in the figure caption.

Authors' response: Authors added short explanations in the Figure 4 caption.

"No NPF events were observed in June, July, and August. The GRs, CSs, and Q values in September and October were not shown due to mechanical troubles of the instruments."

5. Figure 5: Error bars should be shown in both plots.

Authors' response: Authors added error bars in Figure 5.

6. Table 3: I recommend that the parameters, FR, GR, CS, and Q, in Case I are shown in Tab. 3. Because of low data number, min-max of the parameters are useful for us (readers).

Authors' response: In revised manuscript, for Case I, authors added parameters such as the FR, the GR, the CS and the Q in Table 3.