

### Reviewer #3:

Interesting paper, the authors present data about ultrafine particles from the Antarctic peninsula respectively the South Shetland Islands. There and at the tip of the peninsula at Grahamland, several of the Antarctic research stations are located, an on the first glance good location to investigate extremely clean air.

The authors present ultrafine particle measurements in the size range of about 8-10 nm, the threshold for nanoparticles typically for nucleation, to about 30 - 60 nm and claim that these particles contribute significantly to cloud condensation nuclei. This statement concerning CCN is well accepted and important for the local meteorology and climate.

We thank the reviewer for providing valuable suggestions that improved the readability of our revised manuscript.

However, the attribution of the observed particles to new particle formation (NPF), respectively gas to particle conversion from natural particle precursors is not supported by the data presented. Gas to particle conversion from biogenic emissions and DMS related sulphur compounds first leads to particles in the nucleation mode below 10 nm and growth to the measured sizes would need several hours (Kulmala et al, 2013). Such particles were not observed although the instrumentation used was specially included to investigate the particle nucleation size range down to 2.5 nm, an observation that is even stated by the authors. The particles were, accordingly, most likely produced elsewhere and advected to the site, as also stated in the text. Where and by which process are the particles produced?

Response: It should be stressed that particles at 2.5nm or cluster sizes are observed only at locations where the formation process takes place. If the particles were detected at larger sizes, they were advected from formation region elsewhere. Since the spatial scale of NPF (median value: 155 km) was estimated according to the local wind speed and time during which a distinct nucleation mode can be observed at the sampling site, we cannot pinpoint to an accurate location where particles in the nucleation mode below 10 nm were actually produced. Therefore, our estimates are only approximate. Based on the air mass analysis, chlorophyll and DMSP exposure, sea-ice coverage, we speculated that the particles were produced by photooxidation of biogenic DMS for marine NPF event or by halogen compounds released from ice-covered areas for sea-ice NPF event. In addition, terrestrial sources (e.g., animal colonies or vegetation) could have influenced the NPF for multiple NPF event. However, further measurements of the chemical properties of aerosol particles and precursor gases are required to clarify the NPF processes in the future.

The authors present a hypothesis about a potential production process and source location. Such a localized process only in a limited geographic location upwind and is, however, not supported by corresponding data on the regional distribution of nucleation precursors.

Response: To clarify the potential local source (e.g., emission from the animals), we included wind roses in Figure S8 as mentioned above. 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. Figure S8 showed the contour plots of the size distributions and wind roses during those days. However, given the proximity of penguin colony (~2-3 km away) we should have observed

newly formed particles in below 10 nm sizes. That was not case which strongly suggests that the nucleation event took place much further upwind and air mass overpass over the penguin colony most likely contributed to growth of existing particles without forming new.

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 106–140°). 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).”

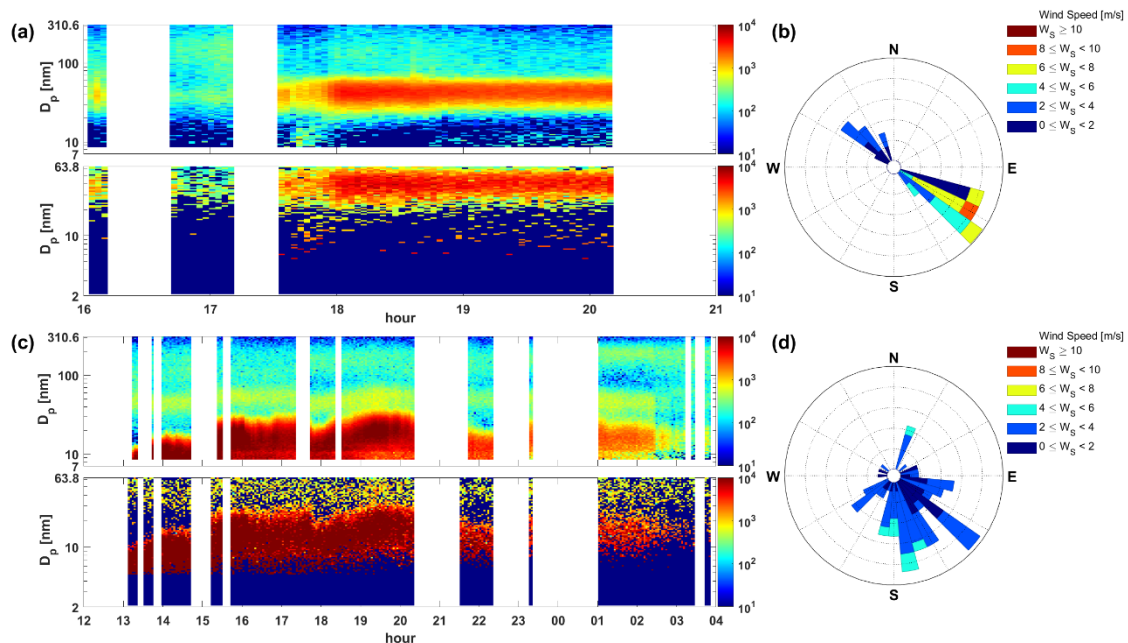


Figure S8. (a) Contour plots of the size distributions and (b) wind rose on 4 February 2018 and (c) contour plots of the size distributions and (d) wind rose on 18 February 2018. The southeast direction (106–140°) is designated as a sector where strong emission from the penguin colonies may originate.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

The size distributions shown are well in agreement with known anthropogenic emissions. Fossil fuel generators are used at all the Antarctic stations, see also the section in the manuscript about the sector which might be polluted by the own power generation. There are several stations about 20 km and several others within ~ 150 km upwind. The plumes of these research

station generators may not be strong enough to produce a measureable signal at neighboring stations, however, they contribute to background levels depending on wind direction and also point towards another and likely stronger anthropogenic source, which appears from time to time at the same locations, in direct vicinity of the research stations in austral summer, always for a couple of days.

Such a source for ultrafine particles are the supply vessels providing support for the stations (Hobbs et al, 2000, Kivekäs et al, 2014, Junkermann and Hacker, 2022). Their plumes are under selected cloud patterns visible from satellite for distances of more than 100 km especially in an otherwise extreme clean environment (Twomey, 1977, Rosenfeld, 2000). Definitely, ships, which produce a much stronger emission than a mid-size research station generator have no fixed location. However, their position, type and size is readily available from AIS marine traffic repository. The vessels normally stay even for a couple of days close to the research stations. Alternatively, also larger commercial cruise vessels appear increasingly in the area. They move slowly or stay locally for several hours to enable tourist excursions. Pictures in Google Earth document all these anthropogenic activities in the area. Also, these vessels are traceable via AIS.

The paper thus indicates a different problem, the pollution of the Antarctic environment by increasing anthropogenic shipping activities on top of unavoidable research station supply. However, the obvious anthropogenic pollution in this pristine location is not discussed in the manuscript.

Response: We agree with the reviewer's comment. Anthropogenic activity and local contamination (from fossil fuel generators) can influence the size distribution of Antarctic aerosol particles, including the NPF events. To minimize the impact of local contamination, we used black carbon (BC) concentration, wind speed and wind direction data as described in section of 2.2. The observatory is located ~400 m southwest of the main station buildings (e.g., a power generator and crematory). Thus, the northeastern direction (355–55°) is designated as a local pollution sector due to emissions from the power generator and crematory. Data collected from this sector were discarded without considerations. In addition, when BC concentration was higher than 50 ng m<sup>-3</sup>, data were also excluded from analysis regardless of wind direction. Median value of BC concentrations during NPF events was 21.0 ng m<sup>-3</sup>. We compared BC concentration for each air mass as shown in Figure S5. We addressed this issue in the manuscript as given below.

Page 7, Line 164: “As the observatory is located ~400 m southwest of the main station buildings and several kilometers away from other research stations, measurement data were impacted by local emissions from station activities (e.g., power generators and incineration) or anthropogenic pollutions near the observatory (e.g., plumes from other research station about several kilometers, vessels providing research station supply, and commercial cruise vessels)”

Page 14, Line 353: “Median BC concentration for marine, sea-ice, and multiple air masses found to be 23.8 ng m<sup>-3</sup>, 12.7 ng m<sup>-3</sup>, 9.8 ng m<sup>-3</sup>, respectively, (Figure S5), indicating pristine clean air masses with minimum influence from anthropogenic pollutions during each NPF event case.”

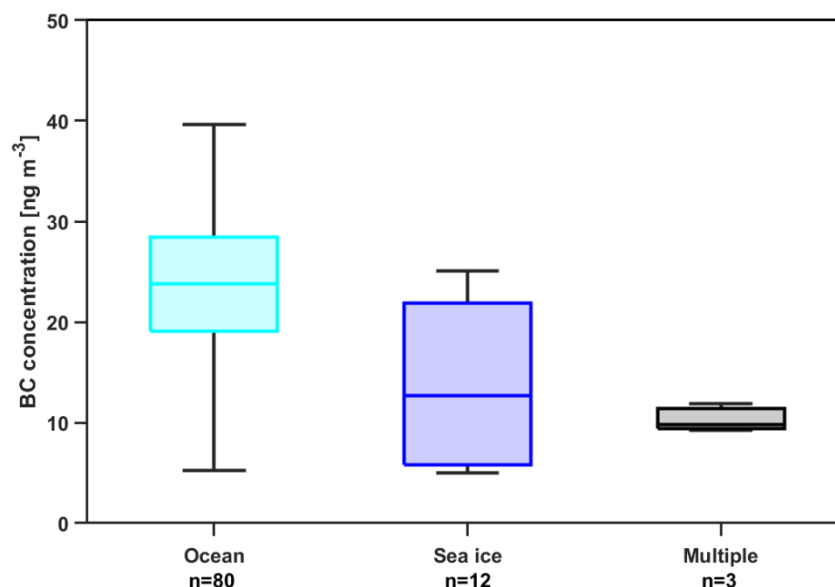


Figure S5. Median, 25 and 75 percentile BC concentration for marine, sea-ice, and multiple air masses analyzed in this study.

#### Literature:

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#### Newly added references

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