

Reviewer Comments on manuscript titled “Investigation of New Particle Formation mechanisms and aerosol processes at the Marambio Station, Antarctic Peninsula” by Quéléver et al. submitted to ACP Discussions

The authors present a very significant work observing the prevalence of New Particle Formation (NPF) events ($\sim 40\%$) for the later 35 days of austral summer in 2018 (15 January-25 February) at the Marambio research station ($64^{\circ}15'S$ – $56^{\circ}38'W$), located North of the Polar region of Antarctic Peninsula, which has minimal anthropogenic influences. This manuscript characterizes NPF events, formation pathways leading to NPF, and growth parameters from reported observations of both neutral (iodic acid (IA), sulfuric acid (SA) and methane sulfonic acid (MSA)) and charged (anion clusters of dimethylamine (DMA)-bisulfate (2SA) as well as numerous ammonium-(bi)sulfate clusters) aerosol precursor molecules with their, number concentrations and size distributions. The role of abundant biogenic precursors (MSA) to aerosol formation via ocean-ice-land interactions in NPF events enhanced by optimal meteorology in austral summer for the northern Antarctic Marambio site is highlighted as well.

Various insights were confirmed with past observations and some novel insights (qualitative, if not quantitative yet) were made regarding NPF pathways in Antarctic region: SA-MSA found to be more significant contributor in NPF event days compared to IA (low concentrations in this location and austral summer study period), and SA-DMA clusters being 1000x more efficient than SA-NH₃ clusters in creating peak nucleation events. However, DMA or amine concentrations are not quantified in this study to assess the exact contribution of DMA or NH₃ or amine concentrations on nucleation. Ion-induced nucleation driven by the ternary system SA-ammonia(-water) is consistent with previous observations reported in literature, but not as significant as that driven by neutral clusters. Caveats like, instrumental artifacts (not sufficiently explaining compositional factors contributing to ion-induced nucleation) and possibility that IA may contribute to NPF in other season(s). These new insights on formation of atmospheric aerosol particles are a crucial step to improve modeling capabilities in predicting the future climate in Earth system/Global-scale climate models. However, as authors suggest mechanisms need to be characterized in more detail as observed in this Antarctic polar region study. Overall, the discussions and conclusions are logically summarized, with effective visualization to present and

explain the observational data in this manuscript. I would suggest the following minor and technical comments to be addressed before accepting this manuscript:

Minor and technical comments:

Lines 15-18, Page 1: *“Antarctic primary particles, mainly originating from sea spray or blowing snow, only weakly contribute to total particle number concentration (Lachlan-Cope et al., 2020). Secondary formation of aerosol particles, on the other hand, is believed to be the principal contributor to cloud condensation nuclei (CCN) (Jokinen et al., 2018; Kerminen et al., 2018).”*

Can the authors also quantify the above stated contributions ?

Line 35, Page 1: *“At Marambio, ABOA...”*: Please expand the abbreviation of ABOA on first use and also highlight the location of the Marambio site more clearly in Figure 8 (using a separate legend) or through a separate figure showing the geographical location of the study site.

Lines 39-42, Page 1: Specify that this period corresponds to ‘austral summer’ (i.e., summer in the southern hemisphere) here or wherever relevant in the Introduction section:

“At the Antarctic coast, oceanic DMS concentrations are the highest during December to January (i.e., austral summer) with concentration that could exceed 15 nM within the upper 10 m layer of the ocean around the Peninsula compared to a yearly average of ~5 nM (Lana et al., 2011).”

Lines 42-44, Page 1: Please add suitable citations here: *“DMS has two well-known oxidation products formed from gas-phase reaction with OH radicals: sulfuric acid (H_2SO_4 , SA, formed via sulfur dioxide, SO_2) and methane sulfonic acid (CH_3SO_3H , MSA), which can then initiate particle formation and subsequent particle growth.”*

Lines 51-53, Page 1: *“At the Antarctic Peninsula, the Weddell Seaside – that undergoes consistent and recurrent phytoplankton bloom episodes every early spring - is a potential reservoir for iodic acid emissions, especially due to slower ice retreat during the summer and colder sea surface temperature than the Southern Ocean on the north and west-side of the peninsula.”*

- a) Suggestion to authors to highlight the geographic location of, Weddell Sea and Marambio site (used frequently in this manuscript text) in Figure 8 or in a separate introductory figure,

to familiarize the wider atmospheric community readers with the context of this study at the start of the manuscript. (Same comment as on **Line 35, Page 1**)

- b) Please add suitable citation(s) that establishes this early spring phytoplankton bloom as a significant source of iodic acid (IA) neutral clusters critical to NPF?

Line 17, Page 5: Is it supposed to be N_{Dp} instead of N_{Dp} here?

“ N_{Dp} is the number concentration of the pre-existing particles.”

Line 49, Page 5: edit to “area”: “(especially in the Weddell Sea aera)”

Lines 1-17, Page 8: Can the authors elucidate more on different possible reasons/hypothesis on why, formation rates for 1.5 nm and 3 nm particles ($J_{1.5}$ and J_3) observed in this study are much higher than those observed in past literature? Also from **Lines 295-301, Page 18 [(7) in Discussion]** is convection (upward/downward draft) a possible explanation? And what further steps say via modeling or analysis can validate that?

Section 3.3.1, Page 10-11: Briefly mention how ‘zenith time’ differs from noon (midday) , at the first use of the term.

Lines 79-80, Page 12: Please use consistent time format (12:00 or 24:00 hours, also ensure it throughout the manuscript) : “...respectively around 05:30 – 06:30 and shortly after 13:00.”

Line 185, Page 15 & Line 275, Page 17: edit typo: *penguin* to “penguin”

Figure 7: See if it can be revised with better resolution and labels (axis labels).