Response to EGUSPHERE-2024-511 reviews for RC1

We thank Reviewer #1 for their effort and feedback on our manuscript EGUSPHERE-2024-511. In response to the suggestions and questions, please find our answers and corrections listed below: **Reviewer #1 comments are extracted in bold from original review supplement**; our responses are given directly below in normal font; *the original text in previous manuscript is repeated in red italic* and *revised text is typed in blue italic*.

General comments:

The manuscript is pleasant to read, also Figures and Tables are clear.

There is little I would recommend to change in this manuscript. My main concern are general statements about INPs in which their activation temperature is not mentioned. In this study, INPs include those measured by PINE (ca. -25 °C) and others measured by INSEKT (-5 °C to -25 °C). Throughout the text, it should always be clear which activation temperature applies in a statement. A first example is in the Abstract, line 25: "...approximately 1 in 10^6 aerosol particles serve as INPs." A much later example is on page 30, lines 753 and 754: "Therefore, the overall effect of precipitation/clouds on INPs observed at (HAC)2 shows a decrease when (HAC)2 lies within the PBL." It should be made clear that this finding relates to INPs active at around -25 °C. Testa et al. (2021; https://doi.org/10.1029/2021JD035186) made a similar observation for INPs active at around -25 °C, but at the same time INPs active at -12 °C were found to have increased (see Figure 5 in Testa et al., 2021). Hence, activation temperature matters not only in terms of the number concentration, but also in terms of atmospheric behaviour.

We thank Reviewer #1 for their positive comments, and thoughtful comments. We also apologize for not clarifying more the INPs temperature condition. The corresponding statements in the manuscript are now revised as below:

a. The original statement in lines 24–25 was as below:

   "*When the observation site is in the Free Troposphere (FT), approximately 1 in 10^6 aerosol particles serve as INPs.*"

   Now, it is revised as:

   "*When the observation site is in the free troposphere (FT), approximately 1 in 10^6 aerosol particles serve as INPs around −25°C.*"

b. The original statement in lines 754–755 was as below:

   "*Therefore, the overall effect of precipitation/clouds on INPs observed at $(HAC)^2$ shows a decrease when $(HAC)^2$ lies within the PBL.*"

   Now, it is revised:

   "*Therefore, the overall effect of precipitation/clouds on INPs observed at $(HAC)^2$ for temperatures around −24.2°C (Fig. 11f) shows a decrease when $(HAC)^2$ lies within the PBL.*"

Our results are also in agreement with Testa et al. (2021) and present that the INP abundance observed at $(HAC)^2$ not only depends on the temperature condition for INP observations but also is regulated by the atmospheric condition of the site, the relevant aerosol source properties and meteorological conditions. Those points were individually presented in the conclusion part of the manuscript. We now add a summary sentence in the conclusion part and refer to Testa et al. (2021):

"*Additionally, we note that the INP abundance is also regulated by the property of relevant aerosol source and meteorological conditions, e.g., precipitation (Testa et al., 2021), in addition to temperatures and FT/PBL scenarios.*"

Minor issues

1. **Page 5, section 2.2.1: Please add to the description of the offline INP observations the filter material, diameter, pore size, and the flow rate of the sampler.**

Good point. The revised statement is:

"*To prepare the freezing aliquots, aerosol particles were first sampled onto filters (0.2 µm Whatman Nuclepore track-etched polycarbonate membranes, 47 mm, with a flowrate of 9 liter per minute) from an omnidirectional total inlet …*"

2. Line 214: "40000 air parcels" probably should be "40000 particles"

The original text is correct. No change made.

3. Line 245: "take up a large fraction" or "make up a large fraction"?

Done. Change made ("*make up…*").

4. Lines 253 and 254: "to differentiate the difference" I do not understand the meaning of this expression.

Thank you for making this point. The statement now reads: "*For example, the synergy of in-situ and remote sensing results enables to differentiate the distinct characters of the sources in Fig. 2b and c.*"

5. Figure 5: Please add x-axes to the plots, even if they only state the running number of observations in each type of aerosol category.

Good point! Fig.5 is now modified, and the caption is now revised to describe the axes.

6. Figure 8: I wonder why the number of INPs measured with PINE does not increase with decreasing temperature. Please add a note on this issue to the Figure legend.

Good point. An extra statement is now added to the legend of Figure 8 as: "*Higher PINE INP concentrations at −24°C compared to lower temperatures are because PINE was run during the Saharan dust event (i.e., the source of South dust in PBL as defined in Fig. 3) whereas INPs at lower temperatures originate from other aerosol sources with lower IN abilities.*"

7. Figure 9a: The temperature indicated for measurements of "South dust in PBL after marine aerosols" is -2.39. I guess it should be -23.9.

Done.

8. Figure 9c and 9d: The effect of precipitation/clouds on INPs in FT is very similar in direction and magnitude as observed in winter in the Swiss Alps by Mignani et al. (2021; https://doi.org/10.5194/acp-21-657-2021).

Good point! The following statement is now added to the text to reflect this point: "*Also, the results in Fig. 9a, c and d are consistent with Mignani et al. (2021) who reported decreased* $Total_{APS}$ *and* $Coarse_{APS}$ *particles but slightly increased INPs after precipitations.*"

9. Table 2: Readability of p-values would be improved by replacing the scientific notation of very small values (e.g. 9.3e-122) by "< 0.001".

Thank you for this suggestion! Change made.

10. Line 548 to 550: A further explanation of why values reported by Lacher et al. (2021) for Jungfraujoch (3580 m) were smaller than what was found at Mt. Helmos (2314 m) could be the higher elevation of Jungfraujoch.

Good point. A sentence is now added to the text as follows: "*Note that the lower INP concentrations observed at Jungfraujoch compared to (HAC)^2 can be attributed to the much higher altitude of the former.*"

11. Lines 588 and 589: Also in the Arctic, fluorescent particles constitute the vast majority of INPs (active at -15 °C), as Freitas et al. have recently reported (2023; https://doi.org/10.1038/s41467-023-41696-7).

Good point. A sentence is now added to the text as follows: "*…, and it is consistent with Pereira Freitas et al. (2023) who found fluorescent biological aerosol particles as dominant sources for INPs activating at T around −15°C.*"

12. Line 725: "...ABCWIBS particles are relevant for biological particles..." I am not sure what is meant by this expression. Do you mean something like "...ABCWIBS particles are related to biological particles..."

Indeed so! The expression now reads: "*With increased influences from the PBL, the increases in both ABC_{WIBS} and eBC particles (Fig. S12e and f) suggest that ABC_{WIBS} particles are related to biological particles and eBC emissions are mainly from the PBL.*"

References:

Mignani, C., Wieder, J., Sprenger, M. A., Kanji, Z. A., Henneberger, J., Alewell, C., and Conen, F.: Towards parameterising atmospheric concentrations of ice-nucleating particles active at moderate supercooling, Atmos. Chem. Phys., 21, 657-664, https://doi.org/10.5194/acp-21-657-2021, 2021.
Pereira Freitas, G., Adachi, K., Conen, F., Heslin-Rees, D., Krejci, R., Tobo, Y., Yttri, K. E., and Zieger, P.: Regionally sourced bioaerosols drive high-temperature ice nucleating particles in the Arctic, Nat. Commun., 14, 5997, https://doi.org/10.1038/s41467-023-41696-7, 2023.
Testa, B., Hill, T. C. J., Marsden, N. A., Barry, K. R., Hume, C. C., Bian, Q., Uetake, J., Hare, H., Perkins, R. J., Möhler, O., Kreidenweis, S. M., and DeMott, P. J.: Ice Nucleating Particle Connections to Regional Argentinian Land Surface Emissions and Weather During the Cloud, Aerosol, and Complex Terrain Interactions Experiment, J. Geophys. Res. Atmos., 126, https://doi.org/10.1029/2021jd035186, 2021.