Author response to RC1

August 26, 2025

We are grateful for the helpful comments and suggestions from the reviewer. Below the reviewers' comments are in blue with our responses in black directly below.

I have read the manuscript by Dr Böhmländer et al. and checked the associated dataset. In my opinion, this dataset is extremely valuable for the atmospheric scientific community, considered the scarcity and relevance of INP data. Additionally, INP concentration data are provided at high time resolution which is certainly an added value for investigating INP properties, sources and impact. Nevertheless, before publication some issues should be addressed in the manuscript.

My main concern regards the measurement uncertainty. This is a fundamental aspect characterising the dataset, yet it is not discussed at all in the manuscript, nor uncertainty ranges are presented in the data files. I would invite the authors to address this aspect of the data quality in the text and, if possible, to associate uncertainty "bars" to the provided data values.

One of the strong points of the dataset is the high temporal resolution, which provides valuable information on the short-term variability of INP concentration at the study site. I would invite the authors to provide some further quantitative information about this in describing the dataset. I understand that the main topic of a data journal is not the scientific exploitation of the data, but some further information can be provided. For instance, which is the extent of the short-term variability in INP concentration? How does it compare with the day to day and seasonal variability? Is the short-term variability constant trough the study periods or does it vary with season?

We thank the reviewer for their comments and we added a separate section in the manuscript to discuss the measurement uncertainty according to the "Evaluation of measurement data" (*Evaluation of measurement data - Guide to the expression of uncertainty in measurement* 2008) (lines 129-147).

old

new The uncertainty budget of PINE has a type B uncertainty (according to *Evaluation of measurement data - Guide to the expression of uncertainty in measurement* 2008) related to the individual uncertainties of the expansion duration t, the expansion flow F and the ice crystal number N_{INP} measured by the OPC

$$c_{\mathrm{INP}} = \frac{N_{\mathrm{INP}}}{F \times t} \ . \tag{1}$$

The uncertainty of the expansion flow is given as

$$\sigma_F = 0.5\,\%\mathrm{RD} + 0.1\,\%\mathrm{FS} \ , \tag{2}$$

where RD and FS denote the reading value and the full scale of the mass flow controller (MFC, EL-FLOW Select F-201CV, Bronkhorst High-Tech B.V.), respectively. The largest value, considering an expansion flow of $3\,\mathrm{l_{std}min^{-1}}$, is therefore $0.025\,\mathrm{l_{std}min^{-1}}$, which corresponds to a relative uncertainty for the flow of approximately 0.83 %, which is considered to be negligible. The uncertainty of the expansion duration just depends on the response time of the solenoid valve (Solenoid Valve XLS-16, SMC Corporation), which is below 0.2 s, and therefore is also considered to be negligible. The uncertainty of the ice crystal number depends on the OPC (fidas-pine, Palas GmbH). In the prototype version of PINE, a different OPC was used (welas, Palas GmbH, see Möhler et al. 2021). The previous OPC used a T-shaped optical detection volume to detect particles and had an uncertainty of 20 % (Benz et al. 2005). Since the new OPC measures all particles and not just a small percentage of the total particle number, it can be assumed that the uncertainty of the new OPC (fidas-pine) is smaller. We assume a conservative estimate of 10 % for the relative uncertainty of the ice crystal number. In addition, the type A uncertainty is related to a Poisson distribution for the ice crystal number. Combined, this leads to a total uncertainty for the INP concentration of

$$c_{\mathrm{INP}} = c_{\mathrm{INP}}^{\mathrm{measured}} \pm 0.1 \times c_{\mathrm{INP}}^{\mathrm{measured}} \pm \frac{c_{\mathrm{INP}}^{\mathrm{measured}}}{\sqrt{N_{\mathrm{INP}}}} , \quad (3)$$

where the first term is a type B uncertainty and the second term the type A uncertainty.

Regarding the second remark, we have added an additional statement looking at the interquartile range of the hourly INP concentration (lines 120-123):

old

new Looking at hourly INP concentration data measured in the half-open temperature bin $T = (247, 249]\,\mathrm{K}$, the mean of the interquartile range is $c_{\mathrm{INP}} = 0.9\,\mathrm{L}_{\mathrm{std}}^{-1}$ with a maximum of the interquartile range of $c_{\mathrm{INP}} = 21.6\,\mathrm{L}_{\mathrm{std}}^{-1}$. The interquartile range can be used to assess the spread of data.

We do not see any clear seasonal variability, but we will investigate this in more depth in a future publication, also taking into account additional data collected during PaCE-2022.

1 Specific comments

L12. It is not clear what the authors mean with "arriving aerosol particles"; are they referring to long range transport, maybe? Please reformulate this sentence for major clarity.

We mean aerosol particles, that enter the inlet of the measurements station, to make this more clear we have adjusted this sentence (lines 12-13).

old In addition, the data provides the ice nucleating ability of arriving aerosol particles, which can be combined with models to study the nature, the source and the age of the INPs.

new In addition, the data provides the ice nucleating ability of ambient aerosol particles, which can be combined with models to study the nature, the source and the age of the INPs.

L104. cINP = 108.495 L−1: I am wondering if all the figures are significant in this concentration.

We agree and therefore have adjusted this to the smallest resolution of PINE, which is around $0.5\,\mathrm{L}_{\mathrm{std}}^{-1}$ (line 118).

old The highest concentration of $c_{\mathrm{INP}} = 108.495\,\mathrm{L}_{\mathrm{std}}^{-1}$ was measured on 2022-11-10 07:59:39+0000 at a temperature of $T = 241.67\,\mathrm{K}$.

new The highest concentration of $c_{\mathrm{INP}} = 108.5\,\mathrm{L}_{\mathrm{std}}^{-1}$ was measured on 2022-11-10 07:59:39+0000 at a temperature of $T = 241.67\,\mathrm{K}$.

I have noticed some discrepancies between the data files and the manuscript. (1) the "flag" data column is labelled "INP_qc" in the data file, while it is "INP_cn_qc" in the text and in the data info file. (2) The column "INP_cn_flush" is "INP_flush" in the data info file. (3) There is not information on the meaning of the "INP_flush" data column in the data info file.

We appreciate the careful checking of the data variables and have added a paragraph to describe the variable of "INP_cn_flush" (lines 103-106):

old

new The ”INP” concentration measured during the flush mode is given in the variable `INP_cn_flush`. This assumes that all larger aerosols or ice crystals from the walls that are detected during the flush mode above the ice threshold, might appear as an INP during the expansion. This value is typically much lower than the measured INP concentration (`INP_cn`) and is flagged as a ”warning” if the condition `INP_cn_flush` $> 0.5 \times$ `INP_cn` is true.

We are unsure what the reviewer means regarding the naming of the `INP_qc` data variable, since the data variables are named as `INP_cn_qc` in the NetCDF files and also in the `INP_cn` under the ancillary variable attribute.

References

Benz, S. et al. (2005). “T-dependent rate measurements of homogeneous ice nucleation in cloud droplets using a large atmospheric simulation chamber”. In: *Journal of Photochemistry and Photobiology A: Chemistry* 176.1–3, pp. 208–217. ISSN: 1010-6030. DOI: 10.1016/j.jphotochem.2005.08.026.

Evaluation of measurement data - Guide to the expression of uncertainty in measurement (2008). Working Group 1 of the Joint Committee for Guides in Metrology.

Möhler, O. et al. (2021). “The Portable Ice Nucleation Experiment (PINE): a new online instrument for laboratory studies and automated long-term field observations of ice-nucleating particles”. In: *Atmospheric Measurement Techniques* 14.2, pp. 1143–1166. DOI: 10.5194/amt-14-1143-2021.