Author response to EC1

April 17, 2025

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

1 General comments

The authors present an insightful and valuable study on a critically needed vertical measurement of INPs. While they have made substantial improvements in their revisions, I have a few minor suggestions for consideration before publication. Although I have marked this as a "major revision," the suggested changes are relatively minor.

Line 35: The authors should include one of the earliest vertically resolved INP measurements via balloon by Creamean et al. (2018). I recommend adding this reference and briefly describing it, as done for Porter et al. (2020).

We thank the editor for this comment and have accordingly added the reference to Creamean et al. 2018 in line 35:

old Some studies have been performed to measure INPs on a UAV (Bieber et al. 2020; Schrod et al. 2017) or with balloon-based sampling systems (Porter et al. 2020).

new Some studies have been performed to measure INPs on a UAV (Bieber et al. 2020; Schrod et al. 2017) or with balloon-based sampling systems (Creamean et al. 2018; Porter et al. 2020).

as well as a short description of the measurements done by Creamean et al. 2018 in line 39:

old

new Creamean et al. 2018 developed a lightweight system to measure the INP concentration of aerosol particles deposited on a filter via a launched balloon. The system was tested up to an altitude of 1.1 km agl and also measures the total particle concentration.

Line 142: Creamean et al. (2024) should also be cited, as this updated DOE ARM report on the Ice Spectrometer provides additional details and images beyond Hill et al. (2016).

We appreciate this comment and have added the additional reference.

old For a more detailed look into INSEKT and the used formulas, see Hill et al. 2016; Schneider et al. 2021; Vali 1971.

new For a more detailed look into INSEKT and the used formulas, see Creamean et al. 2024; Hill et al. 2016; Schneider et al. 2021; Vali 1971.

Line 174: The data from campaign 1 should either be shown, or, the absence of data should be explicitly addressed. Figure 2 from the first review response contains useful data that should be incorporated into the manuscript as a proof of concept. This figure provides valuable supporting evidence. However, if the authors feel strongly about

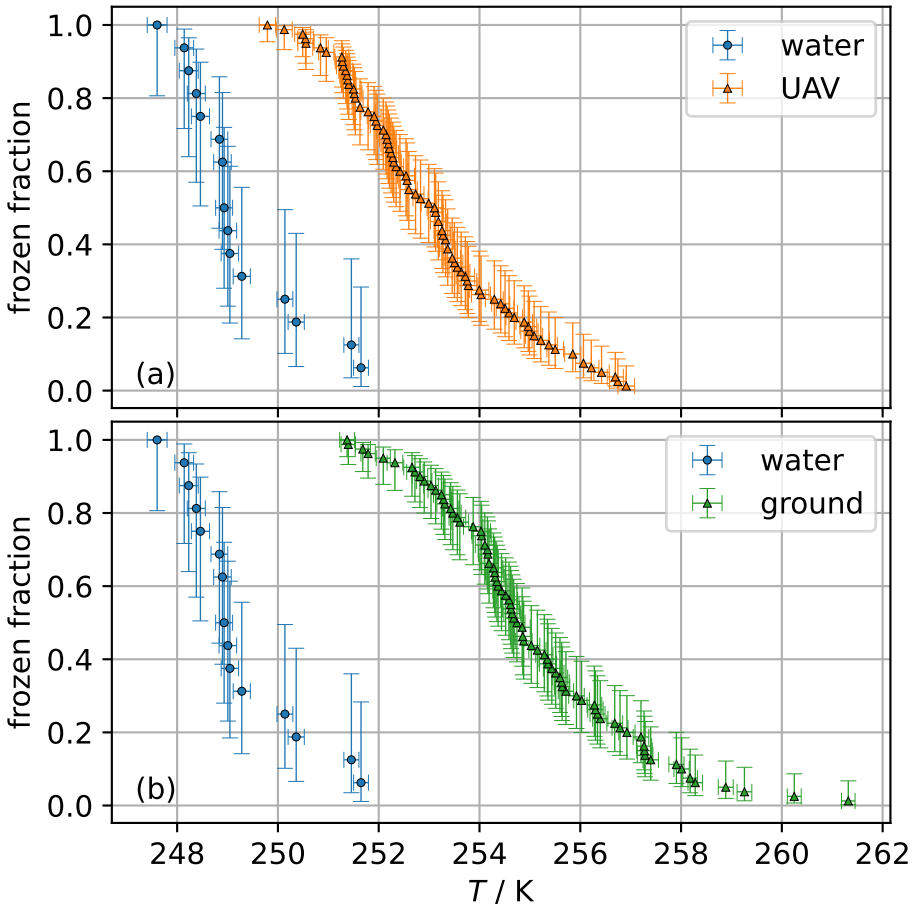

Figure 1: The frozen fraction as a function of the freezing temperature T is shown for a UAV filter suspension from campaign 1 in comparison to its Nanopure water background (panel (a)). Panel (b) shows the equivalent for the ground filters. The errorbars represent the 95 % confidence interval.

not including that plot, they should clarify why the data from Campaign 1 are not included, as their omission currently raises questions about its necessity to the study.

We have incorporated the figure into the main text of the manuscript. We updated the plot to fit to the style of the other figures and changed the following part to refer to it and describe it briefly.

old No data obtained during campaign 1 is shown here.

new The frozen fraction of a UAV and a corresponding ground filter from campaign 1 is shown in Fig. 1. The frozen fraction of the undiluted sample shows a clear separation from the water background.

Figures 6 and 7: The panels would be more visually accessible if they were wider rather than taller. I suggest adjusting their scale accordingly. Additionally, the label should read "frozen fraction" without the "/-" notation.

We have removed the notation on the y-axis label. We agree that a different layout will improve the visualization and have therefore switched the layout of the two graphs to allow for more spacing on the temperature axis. The old and new figure 6 are shown in figure 6 (old) and figure 6 (new), respectively, whereas the same is shown in figure 7 (old) and figure 7 (new) for figure 7. Please also note that the figure number has changed due to the addition of a new figure (see previous comment and figure 1).

Section 3.2: I recommend including a figure for campaign 3 similar to Figure 7 to further emphasize the importance and utility of vertical INP measurements. It is not clear why these data are not shown.

Campaign 3 was a test of the newest setup, but unfortunately due to bad weather and a short duration of the campaign, we were only able to collect three filters. Due to the low amount of samples, we would like to refer

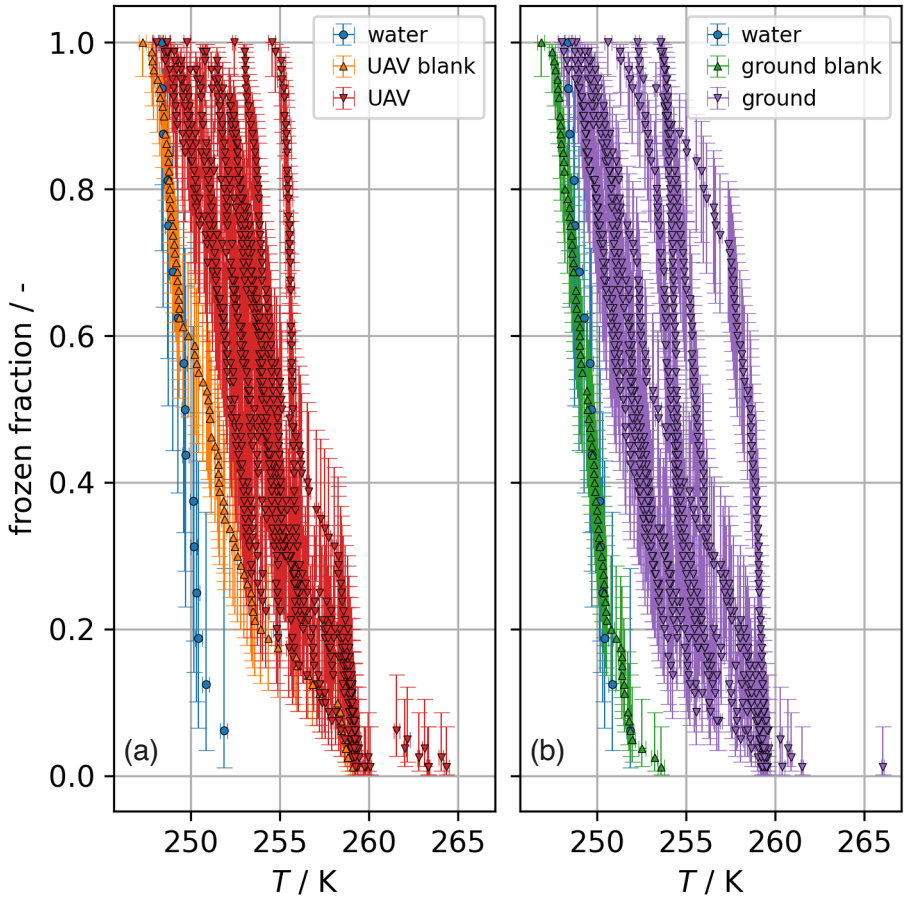

Figure 6 (old): Old figure 6.

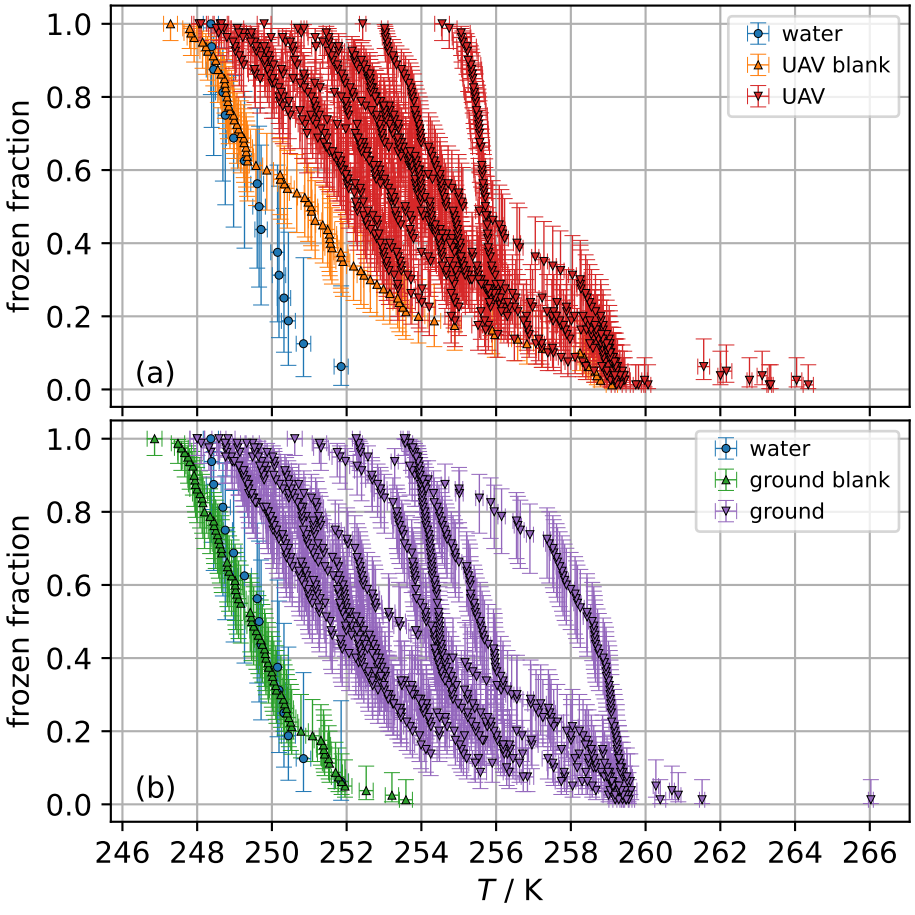

Figure 6 (new): New figure 6.

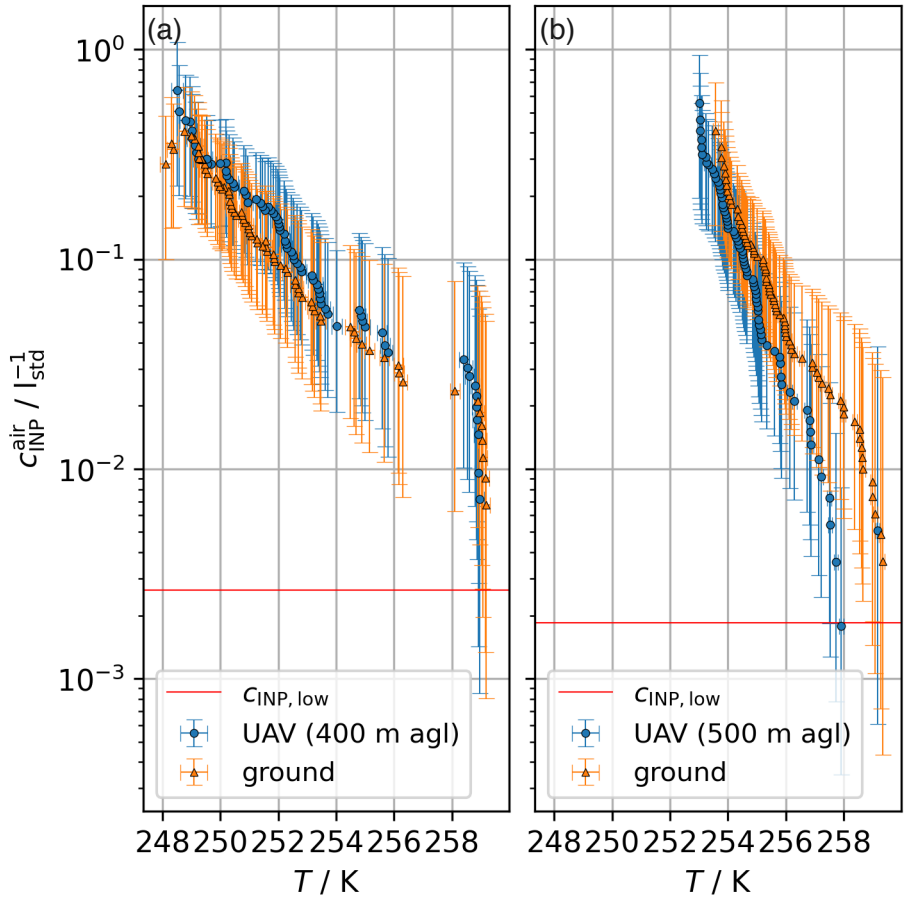

Figure 7 (old): Old figure 7.

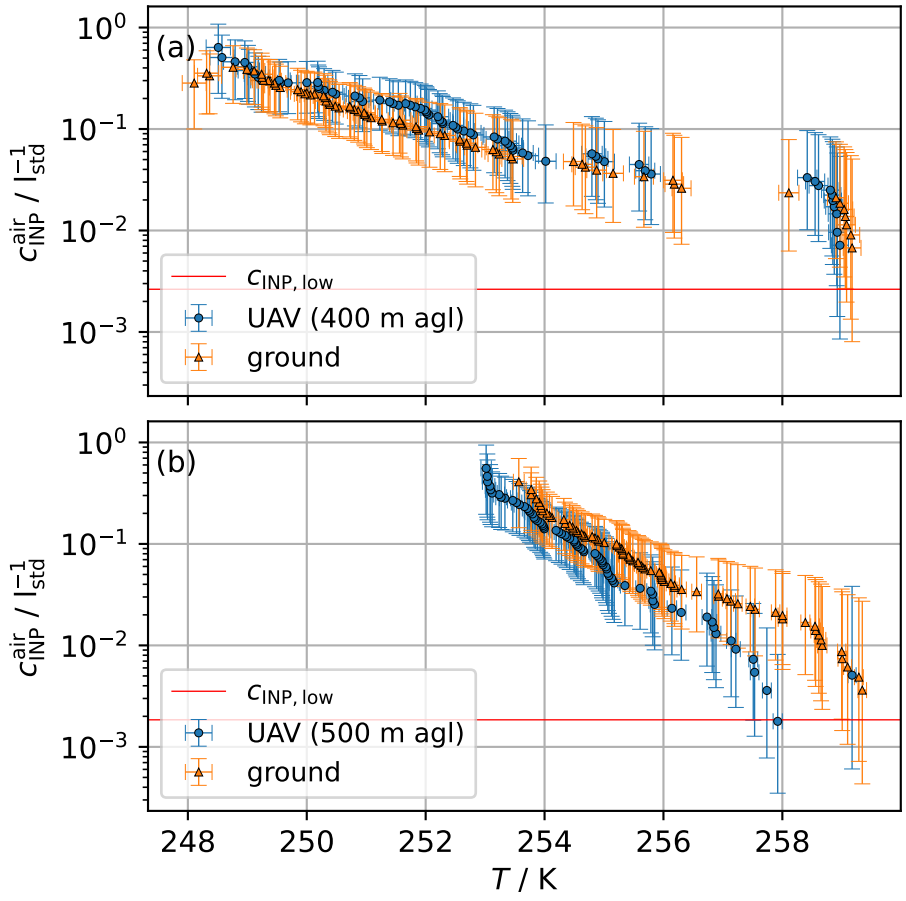

Figure 7 (new): New figure 7.

to the extensive Pallas Cloud Experiment 2022 (PaCE-2022), where we collected aerosol filter samples using the setup described in this paper. A preprint describing the dataset obtained is available as a preprint in a special issue of Earth System Science Data (Böhmländer et al. 2025).

The authors note in their first review response that no significant difference was observed in INPs, suggesting that the sampling setup did not yield an improvement. Can they provide an explanation for this? A discussion of potential reasons would be a valuable addition to the manuscript.

We assume that his comment is in relation to our first response to reviewer 2, where we write: "Unfortunately, we are unable to directly report an improvement in the quality of the INP conentration measurements from the setup improvements." The setup definitely improved on the ease of handling as well as on the collection efficiency of smaller and larger aerosol particles. Since we do not know the size range of the ambient INPs, we are unable to quantify the improvement of the obtained INP concentration. It is true however, that the obtained INP concentration is more representative of the total aerosol population.

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2 Additional changes

We identified two spelling mistakes, that we have fixed now:
in line 49:

old duations

new durations

and in line 166:

old occurence

new occurrence

References

Bieber, P. et al. (2020). "A Drone-Based Bioaerosol Sampling System to Monitor Ice Nucleation Particles in the Lower Atmosphere". In: *Remote Sensing* 12.3, p. 552. DOI: 10.3390/rs12030552.

Böhmländer, A. et al. (2025). "Measurement of the ice-nucleating particle concentration using a mobile filter-based sampler on-board of a fixed-wing uncrewed aerial vehicle during the Pallas Cloud Experiment 2022 [dataset]". In: *Earth System Science Data*. in preparation. DOI: 10.5194/essd-2025-87.

Creamean, J., T. Hill, C. Hume, and T. Devadoss (2024). *Ice Nucleation Spectrometer (INS) Instrument Handbook*. Tech. rep. DOE/SC-ARM-TR-278. Richland, Washington: U.S. Department of Energy, Atmospheric Radiation Measurement user facility.

Creamean, J. M. et al. (2018). "HOVERCAT: a novel aerial system for evaluation of aerosol–cloud interactions". In: *Atmospheric Measurement Techniques* 11.7, pp. 3969–3985. ISSN: 1867-8548. DOI: 10.5194/amt-11-3969-2018.

Hill, T. C. J. et al. (2016). "Sources of organic ice nucleating particles in soils". In: *Atmospheric Chemistry and Physics* 16.11, pp. 7195–7211. DOI: 10.5194/acp-16-7195-2016.

Porter, G. C. E. et al. (2020). "Resolving the size of ice-nucleating particles with a balloon deployable aerosol sampler: the SHARK". In: *Atmospheric Measurement Techniques* 13.6, pp. 2905–2921. DOI: 10.5194/amt-13-2905-2020.

Schneider, J. et al. (2021). "The seasonal cycle of ice-nucleating particles linked to the abundance of biogenic aerosol in boreal forests". In: *Atmospheric Chemistry and Physics* 21.5, pp. 3899–3918. ISSN: 1680-7324. DOI: 10.5194/acp-21-3899-2021.

Schrod, J. et al. (2017). "Ice nucleating particles over the Eastern Mediterranean measured by unmanned aircraft systems". In: *Atmos. Chem. Phys.* 17.7, pp. 4817–4835. DOI: 10.5194/acp-17-4817-2017.

Vali, G. (1971). "Quantitative Evaluation of Experimental Results an the Heterogeneous Freezing Nucleation of Supercooled Liquids". In: *J. Atmos. Sci.* 28.3, pp. 402–409. DOI: 10.1175/1520-0469(1971)028<0402:qeoera>2.0.co;2.