Reply to referee #1: Interactive comment on "Unveiling atmospheric transport and mixing mechanisms of ice nucleating particles over the Alps" by Jörg Wieder et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-718-RC1, 2021

Reviewer comments are reproduced in **bold** and author responses in *italic*; extracts from the original manuscript are presented in *red italic*, and from the revised manuscript in *blue italic*.

The authors present the INP measurements from two sites. They find that INP concentrations at the mountaintop site are on average lower than high valley site. The authors discuss the importance of the orographic effect towards the INP concentrations. This is a unique study where the authors have analyzed the field INP data in the context of meteorology. I have the following minor comments, and after addressing these comments I recommend publication.

We want to thank the anonymous referee for reviewing our manuscript. We are pleased with the positive reception and grateful for the helpful comments which improved our manuscript and are answered individually hereafter.

Line 13: Sentence needs to be revised. Maybe add Our results "show that" the local ....

We thank the reviewer for catching this typo. We changed line 13 (revised manuscript) as follows:

Our results suggest a local INP concentration enhancement over the Alps during cloud events.

Section 2.1: It is not clear why a heated inlet was used. Would this affect the composition of ambient aerosol? Do volatile components of these aerosol will be evaporated? On Line 110, can a special feature of the inlet design (that prevents snow sampling can be explained here? What is the cut size of this inlet?

We thank the reviewer and agree that more information is needed. We changed lines 109-118 (revised manuscript) as follows:

Similar to Weingartner et al. (1999), both inlets were capped with a hat preventing snow and while sampling particles with diameter smaller than 40 µm from entering the inlet for wind speeds of up to 20 m s^{-1}. All outside parts (including the hat, at WOP approx. the first 0.7 meters, at WFJ all parts) were heated to 46 °C to avoid riming on the outside parts, to sublimate ice crystals, and to evaporate activated cloud droplets. The evaporation of volatile compounds of the aerosol cannot be excluded. However, the relevant ice active particles in the investigated temperature regime (T ≥ -20 °C) are mostly biological which should only degrade at temperature higher than 46 °C (Kanji et al. 2017; Huang et al., 2021). In addition, the flow rate through the inlet is high (300 L min^{-1}), as such the aerosol flow was likely at temperatures below 46 °C at which INPs typically do not become inactive. Contributions of resuspended particles from the snow-covered surface around the measurement sites cannot fully be excluded but are unlikely to have added significantly to the sampled aerosol due to the inlet's design (Mignani et al., 2021).

Section 3.4: Equation 4, how height, h, is calculated?

We thank the reviewer for pointing out the need for a definition. We changed lines 307-310 (revised manuscript) as follows:

[…] which was found to be representative for the mesoscale flow. The difference in altitude of the subsequently described weather stations was used as barrier height (h) per wind sector. The Brunt-Väisälä frequency was calculated using the meteorological data from WFJ and the respective upstream weather station in each sector (RAG for NW, ARO for SW, DAV for SE and NE, see Figure 1).

Section 3.5: Did the vertical profiles of potential temperature were measured? In Figure 6 (line 262), it is mentioned: "the potential vertical mixing" – please elaborate. It is not clear whether vertical mixing occurred or not. If yes, how this is justified. It is not clear what test was used to confirm the vertical mixing.

We thank the reviewer for pointing out the need for more clarity. We changed the caption of Figure 6 as follows:

In the NE wind case (b), the potential vertical mixing (i.e. rising of air masses originating from the valley and mixing with the air masses aloft) due to conditional instability of the narrow cross valley air masses is shown (dashed white arrows).

In addition, we phrased the calculation of the θ_e more explicitly. We changed lines 350-353 (revised manuscript) as follows:

An upstream weather station in each wind direction sector was used to calculate θ_e at the valley floor (SRS for NW, ARO for SW, DAV for SE and NE, see Figure 1). The θ_e gradient was calculated by dividing the difference in θ_e between WFJ and the respective upstream weather station by the height difference of both stations.

Conclusions: To enhance the impact, how INP concentrations observed in this study compare with other field studies? Line 416, is this "absence of a relation" view supported by other studies? Can APS (Figure 2e) data be shown here? On line 418, it is said that this relation does not hold for a temperature warmer than -20 degC. Is this temperature threshold based on the present study? Are experiments are performed at colder temperatures to conclude this statement?

We thank the reviewer for the suggestion and agree with the necessity of a comprehensive comparison. To our best knowledge, Conen et al. 2017 is the only comparable study available. The same method (drop freezing assay) is used and the vertical distribution of INP in the Alpine region is investigated. Many studies measured INP at Jungfraujoch in the Bernese Alps. However, Jungfraujoch at 3580 m a.s.l. is located higher than WFJ and available studies at Jungfraujoch investigated INPs at lower temperatures and with different methods (e.g., Lacher et al. 2017; Brunner et al. 2021) or collected particles of larger size (Creamean et al. 2019). Hence, we compare to Conen et al. 2017 which is discussed in Section 3.1.

To support our argument for the absence of a relation between INP concentration and aerosol number concentration, we added Appendix A3 (see below) presenting correlation coefficients between the two observables. We added lines 264-268 (revised manuscript) to link the new appendix to the main text:

Whether these air masses originated from the valley and were transported to WFJ or if WFJ and WOP are affected by the same air masses is not clear yet. The disproportional changes in median INP concentration and $AF_{0.5}$ at both sites likely caused by the aforementioned effects also imply the absence of a relation between the INP concentration and aerosol number concentration. A more detailed analysis confirmed that a stable relation between the two variables is not present in the dataset (see Appendix A3).

In addition, we changed lines 441-444 (revised manuscript) as follows:

Additionally, we note the variability of the observed activated fraction, i.e. the absence of a relation between INP concentration and the aerosol (number) concentration (see Appendix A3). It implies that predicting continental INP concentrations at warmer temperatures (T≥-20 °C, observed temperature range in this study) based on aerosol number concentration alone can be uncertain and that dynamics play the dominant role, especially over orographic terrain.

A3 Correlation coefficients of INP concentration at different temperature versus aerosol number concentration

Figure 5 suggests the absence of a relation between INP concentration and aerosol number concentration. Table A1 summarizes correlation coefficients between INP concentration across the observed temperature range to aerosol number concentration. In some cases (e.g. at WFJ in the night for temperatures -14 °C to -16 °C) a stronger and significant relation was found. However, based on the entire dataset aerosol number concentration does not seem to be a good predictor for the INP concentration as a stable relation was not found. In turn, a stable and significant relation for INP concentration observed at WFJ was found with the Froude number for certain wind directions (see Section A4).

Table A1. *Spearman's rank coefficients (ρ) between aerosol number concentration for particles with physical diameter larger than 0.5 µm ($n_{0.5µm}$) and INP concentration at different temperatures (-7 °C to -18 °C) at WOP and WFJ for the three periods morning (03:00 - 11:59 UTC), afternoon (12:00 - 17:59 UTC), and night (18:00 - 02:59 UTC). Numbers in bold represent a significant result (two-sided $p < 0.05$).*

ρ	-7 °C	-8 °C	-9 °C	-10 °C	-11 °C	-12 °C	-13 °C	-14 °C	-15 °C	-16 °C	-17 °C	-18 °C
WOP												
morning	0.05	0.13	0.14	0.15	0.15	0.12	0.15	0.20	0.25	0.24	0.21	0.27
afternoon	0.20	0.20	0.21	0.19	0.19	0.24	0.27	0.23	0.25	0.28	**0.34**	0.36
night	-0.21	-0.15	-0.12	-0.07	-0.05	-0.02	0.01	0.06	0.13	0.20	0.48	0.37
WFJ												
morning	-0.11	-0.12	-0.26	-0.27	-0.17	-0.00	0.06	0.16	0.13	0.12	0.30	**0.44**
afternoon	0.25	0.32	0.25	0.27	0.31	0.25	0.27	0.26	0.25	0.23	0.18	0.10
night	0.43	0.34	0.24	0.26	0.32	0.42	0.47	**0.63**	**0.69**	**0.58**	0.47	0.57

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