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Reply on RC2

Nikou Hamzehpour et al.

Author comment on "The Urmia playa as a source of airborne dust and ice-nucleating particles – Part 2: Unraveling the relationship between soil dust composition and ice nucleation activity" by Nikou Hamzehpour et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-449-AC2, 2022

We thank Reviewer 2 for his/her thoughtful comments. We reproduce the reviewer's comments in black and our responses starting with "reply" at the begining of the paragraph. Line numbers refer to the revised manuscript.

Summary

The manuscript submitted by Nikou Hamzehpour and co-authors provides a detailed insight into the potential driving factors of the ice-nucleation (IN) ability of dust particles from a dried lakebed. Due to an increase in desertification, it is expected that such sources for airborne dust particles are becoming more abundant, and might therefore impact cloud microphysical processes such as the initiation of ice crystal formation.

Soil dust particles can have distinct IN abilities related to their mineralogical composition, and they can contain organic matter and soluble salts. Here, the authors investigate the impact of each component on the ice nucleation ability of the dust sample. The bio-organic matter is found to determine the onset temperature for ice nucleation, and the removal of soluble salts and carbonates leads to an increase in the IN activity. After the removal of the constituents, the IN activity is determined by the clay mineral fraction, and to a lesser extent to quartz and microcline.

The paper is well written and I only have minor comments and suggestions. More of such systematic investigations of driving factors for the ice nucleation ability of natural soil samples are needed to improve our understanding in this field.

General comments

- Please consider shortening the abstract

Reply: we shortened the abstract

- I recommend moving some figures in the appendix and only showing key figures in the manuscript (e.g. figures 3, 4, 10).

Reply: Figures are moved to the appendix and figure numbering in the text is revised throughout the manuscript.

- In some cases, the mentioned publications are examples and do not represent all existing literature. Please check and make use of “ e.g.” in such cases or complete the cited literature.

Reply: We added “e.g.” where applicable.

- What is the atmospheric relevance regarding the size of the samples collected with high-volume samplers and the ground-collected samples? Super micron particles are typically not transported over longer distances, such that they could be lofted into levels in the atmosphere where they could impact microphysics by their ice nucleation ability. Please elaborate on this.

Reply: Recent studies have shown that dust with diameters >5 mm and even >20 mm is longer lived in the atmosphere and present in larger amounts than previously assumed (e.g. Adebiyi and Kok, 2020; Heisel et al., 2021; Froyd et al., 2022).

Moreover, droplets within emulsions contain only few particles. Since the number size distribution of the dust and soil samples peaks in the submicron region, the freezing signal in emulsion freezing experiments is characteristic for this particle class.

- Is it possible to give temperature-dependent F het? This might allow comparing nucleation efficiency of the organic INPs and dust INPs in the sample.

Reply: The differential scanning calorimeter registers heat transfer and not freezing events. This hampers an unambiguous division between organic and mineral signal. We think that T_{het} and F_{het} are the most robust parameters to characterize the DSC thermograms. To give a visual impression of the freezing signal, we also depict the whole thermograms in the manuscript.

- What is the temperature uncertainty of the DSC experiments? E.g., in line 284, you state a value of -0.2 k for ΔT_{het} which could be within the uncertainity of the experiment. What are significant changes in values for ΔT_{het} or rF_{het}?

Reply: DSC has in fact a high precision. To clarify this, we add the following sentence to the manuscript on line 239:

“The average precision in T_{het} is ±0.2 K. Uncertainties in F_{het} are on average ±0.05, but may be much larger when heterogeneous freezing signals are weak or overlap (forming a shoulder) with the homogeneous freezing signal.”

- Are there studies investigating the impact of carbonate removal and salt removal on the ice nucleation ability of dust particles or is your study the first one investigating this?

We are not aware of other studies that investigated the effect of carbonate and salt removal. It would be interesting to see more such studies. Yet, soluble salt removal is only meaningful for salty soils, which might be rare for desert dusts.

- Lines 336-337: it might be interesting to the reader to compare your results in a more quantitative way to these studies.

The strength of the DSC method is to give a qualitative overview over the IN activity of a sample, which is provided by the whole DSC thermograms. We decided to break their rich information down to T_{het} and F_{het}. Another way of quantifying the curves would also have been possible. We would like to keep to this method, as we have evaluated the DSC thermograms in this way also in previous studies (e.g. Kumar et al., 2018; 2019a; 2019b).

- Line 553: the heterogeneous freezing temperature range of 236-248 k is very broad and includes not only the freezing temperature of clay minerals but also other mineral types.

We agree with the reviewer. We therefore revise this statement:

“This is supported by the heterogeneous freezing range (236–248 K) of the LUP samples after OMR removal, which is in general agreement with the freezing temperatures of clay minerals, although it is not specific for them as other mineral types are IN active within the same temperature range.”

Technical comments

- Title: should it not be,,….. as a source?

Reply: corrected

- Line 163: it should be mentioned in the table header that it is taken from the first part of this work (Hamzehpour et al., 2022).

Reply: corrected

- Line 251: abbreviation,, rFhet” is not explained.

Reply: it is now explained in the text

- Line 310: I recommend increasing the marker size and to indicate the dust and soil samples with different markers.

- Figure 11: I assume that the blue dashed line corresponds to T_{het} and F_{het} of the pure minerals, as described in Figure 12?

Reply: to explain the blue dashed line, we add the following text to the figure caption of Fig. 8 (former Fig. 11):

“The blue dashed line in panel (a) represents the freezing temperature according to the water activity criterion, in panel (b), it marks the frozen fractions of the minerals in pure water.”

- Figure A is not specifically mentioned in the text. Also, the labels are too small.

Reply: Figure A is now Figure A4 and is mentioned in line 354.

References

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