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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Saharan dust and ice nuclei over Central Europe" *by* H. Klein et al.

H. Klein et al.

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Reply to Reviewer 1

This is a well written and interesting article in which Klein and co-workers describe a study in which they correlate natural ice nuclei numbers with mineral dust from a Saharan source. They clearly demonstrate that Saharan mineral dust is a major ice nucleating species at their site in Central Europe. The subject of this paper is appropriate for ACP and once my comments below are addressed, I recommend it for publication.

The authors thank the reviewer for his/her valuable comments.

Comment: 1) Abstract. Add in a line on the experimental technique used here.

Reply: This was done.

Comment: Also, the correlation coefficients for mass and surface area were similar (0.8 and 0.78). Perhaps alter this sentence to 'A correlation is found between dust surface area and IN concentration' or something similar.

Reply: Following the suggestion, the sentence was changed to "Ice nuclei and mineral dust are significantly correlated, in particular IN number concentration to aerosol surface area.".

Comment: 2) P14994, ln 25. Replace 'good' with a more descriptive and less subjective word. Perhaps 'efficient'.

Reply: We have replaced "good" by "efficient".

Comment: There are a number of new lab studies appearing in the literature at the moment which could be cited: Niedermeier, D., S. Hartmann, R. A. Shaw, D. Covert, T. F. Mentel, J. Schneider, L. Poulain, P. Reitz, C. Spindler, T. Clauss, A. Kiselev, E. Hallbauer, H. Wex, K. Mildenberger, and F. Stratmann (2010), Heterogeneous freezing of droplets with immersed mineral dust particles – measurements and parameterization, Atmos. Chem. Phys.,10, 3601–3614.

Reply: Was included in the references.

Comment: And also B. J. Murray, T. W. Wilson, S. L. Broadley, and R. H. Wills, Heterogeneous freezing of water droplets containing kaolinite and montmorillonite particles, Atmos. Chem. Phys. Discuss., 10, 9695–9729, 2010.

Reply: Was included in the references.

Comment: 3) P14996, ln 16. Replace 'top' with 'highest'.

Reply: Done

Comment: 4) P14997, ln 9. Replace 'is' with 'was' or 'has been'.

Reply: Done, was changed to "was".

Comment: 5) Section 2.1. More details for the experimental technique are required here. The following details need to be included: i) Number of samples analysed with FRIDGE.

Reply: The number of IN samples (Fig. 8) is n=18, and is now given in the caption. In addition the samples that went into the various regression analyses (Table 2) were coded by symbols and colors in Figure 8, as requested also by reviewer G. Vali. The number of samples collected during the course of one year is 352, and is given in the caption of Figure 10.

Comment: ii) Typically how many IN were there per sample?

Reply: On average about 200-400 ice crystals grow on a substrate and are counted. We try to adjust the sample volume somewhat according to the expected concentration, if this information is available from previous analysis. During the dust event the air sample volume was reduced to avoid overloading.

Comment: iii) How many particles were there per sample?

Reply: In FRIDGE we cannot see particles on the substrate, but only ice crystals. The mean number of ice crystals (i.e. IN) on the wafers is 2082 for the dust event samples and 242 over two years.

Comment: iv) What were the size of the particles?

Reply: We cannot measure this. We could only infer this from the measured size distribution and collection efficiency.

Comment: v) How efficient is the electrostatic precipitator.

Reply: Efficiencies are higher than 96.7% for our operating conditions. Detailed data of the efficiency of the precipitator as function of particle size and sample flow rate (including 2 Figures) are given in the paper of Klein et al., 2010, which is cited in chapter 2.1. We thus prefer not to repeat these data in the revised manuscript.

Comment: Is there a dependence on material type?

Reply: We have not investigated this explicitly. Our tests of sampling efficiency (Klein et al., 2010) were done with ambient aerosol.

Comment: vi) How long were the samples exposed to a particular RH?

Reply: For each analysis at a specified temperature and vapor pressur a sample is first cooled to the desired temperature (approx. 5 minutes, in vacuum), then water vapor is inflated and ice is grown, after 90 seconds the number of ice crystals is stable, and counted. This procedure is described in more detail in chapter 2.1 in the paper by Klein et al. 2010.

Comment: vii) How was the position correlated between the optical microscope and the ESEM.

Reply: We have added the following sentence in the method section in chapter 2.1: “The unambiguous identification of the analyzed particles as ice nuclei was enabled by a high precision laser engraved coordinate system on the substrates. The positions on the substrates, where ice nucleation was observed by the CCD camera of FRIDGE, can be recovered in the ESEM with a lateral resolution of approximately 5 μm.”

Comment: viii) Was EDX analysis used to obtain the composition? This needs to be stated.

Reply: EDX was used, and we have added this in the manuscript. The new sentence reads: “The elemental composition of individual particles found at those coordinates on the substrate where ice nucleation was observed in the images by FRIDGE, was measured by energy-dispersive X-ray microanalysis (EDX).”

Comment: 6) Phillips et al. [2008] suggest there is a discrepancy between lab and field measurements whereas Klein et al suggest there is agreement between their natural dust measurements, other natural dust experiments and lab experiments (Field et al). I would like to see a comment on this apparent discrepancy between Phillip’s

conclusions and Kelin's?

Reply: Good point: Unfortunately the initial agreement of our activated fraction to lab data (Field et al., 2006) was lost, as we discovered an error in our calculation (see our response to reviewer Gabor Vali on 15003/13). The data (and interpretation) were corrected, and are now much lower than the cited lab data of Field et al. (2006), but lie within the enormous range spanned by different lab data. Phillips et al. (2008) identify the unknown representativeness of the artificial lab aerosol (either manufactured or collected from the earth's crust) for atmospheric IN as a source of discrepancy, and this may be true.

Comment: 7) P15005 ln 6. I think Klein et al are referring to the empirical relationship from Phillips et al who was in collaboration with the Colorado people. Phillips is from Hawaii, hence this sentence needs to be corrected.

Reply: The reviewer is right. We replaced "CSU group" by "CSU instrument"

Comment: 8) In calculating the number of IN per surface area, it is not clear to me if the total surface area is of all aerosol or only specifically of the dust.

Reply: We have added the requested information and say now: " . . .ratio ξ of activated IN to the surface area of 0.5 – 20 μm diameter particles (derived from APS measurements) . . ."

Comment: 9) DeMott and co-workers have published a new parameterisation of ice nuclei number based on the number of aerosol which are larger than 0.5 um. This should be cited and possibly compared to your data. The reference is: DeMott at al. PNAS, 107, p11217, 2010.

Reply: We have added a sentence on the parameterization by DeMott et al. (2010). This parameterization somewhat underpredicts the IN relative to our measurements in the dust plume. As this intercomparison is probably inappropriate, because their data do not cover dust events like the one that we encountered, it was not included.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 14993, 2010.