

Interactive comment on “Investigations of the impact of natural dust aerosol on cold cloud formation” by K. A. Koehler et al.

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In this article, Koehler et al. describe an experimental laboratory study of ice nucleation by natural and surrogate mineral dust samples and also report results in which the surrogate dust was coated with organic material. The natural dusts were collected from regions broadly around North Africa and the surrogate was Arizona Test Dust (ATD). The most striking and important conclusion is that at temperatures below about -40°C coating of SOA deactivated ATD, such that it only nucleates ice at RH similar to those expected for homogeneous nucleation in aqueous solution droplets. Hence, the implication is that dust with sufficiently thick coated would not play an important role in cirrus cloud formation. It is also very exciting (and surprising) that the coated ATD apparently suffers no deactivation above about -36°C where ATD nucleates ice in the

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condensation/immersion mode.

This is a very interesting paper, in which new and important results are presented and once the comments below have been addressed I recommend it for publication.

1) Title: This title implies that the authors have investigated the impact of ice nucleation on clouds. Before I read the abstract, I was expecting a modelling study rather than a lab based study. Also, the reference to ‘natural dusts’ is inaccurate since a number of the experiments have been done with ATD. I suggest something more like: ‘Laboratory study of ice nucleation by coated and uncoated mineral dusts’ or something similar.

2) Abstract ln 15. I think it is actually show that there is a significant difference between ATD and the other dusts between -40°C and -60°C, contrary to what is stated here.

3) 19347, ln7-10. In addition, Murray et al. (ACPD, 10, 9695–9729, 2010 recently explored the ice nucleating properties of different mineral types. They showed that kaolinite and montmorillonite have different nucleation characteristics.

4) 19347, ln 18. Forschungszentrum Karlsruhe has changed its name to Karlsruhe Institute of Technology.

5) 19348, ln 21-24. What are the dominant minerals in this size grade of North African dust? A brief discussion on this would be helpful and informative.

6) 19352, ln 4. The word ‘hereafter’ doesn’t make sense here. Revise the sentence.

7) 19353, ln 2-4. Mohler et al (ERL, 2008) also show that the SOA from alpha pinene does not nucleate ice – see their fig 6. This citation backs up the author’s argument.

8) 19357, ln 17-23. I would not say the results are in ‘excellent’ agreement. The numbers are not identical and the quoted conditions are not identical. I suggest replacing with ‘good’.

9) 19358, ln 5. I do not understand what is meant by ‘balance’ here. Revise.

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10) 19359, In 24, Do the authors mean hydrophilic surface rather than hydrophobic surface?

11) 19359, In 26-29. This sentence needs to be rewritten. It reads that Archuleta did experiments with 10-55 μm sized droplets, which is incorrect. I also, do not understand what the authors are attempting to say in this paragraph. Please revise.

12) 19359, 1st para. You should also discuss the results of Zobrist et al. (J. Phys. Chem. A 2008, 112, 3965-3975). They observe a significant immersion heterogeneous effect below -40°C .

13) Discussion on 19362. Can the authors comment on why the SOA should deactivate ice nuclei in the deposition mode, but not in the condensation/immersion mode? Zobrist et al and also Zuberi show that when the 'coating material' is soluble and in an aqueous state heterogeneous nucleation is still active. Eastwood et al. (GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L02811, doi:10.1029/2008GL035997, 2009) show that when kaolinite is immersed in sulphuric acid and ammonium sulphate droplets it nucleates at a much higher RH than when uncoated, but is still active (i.e. nucleates below homogeneous). This seems relevant and should be discussed.

14) The difference between Koehler et al.'s data and the previous work is that the coatings in the previous studies were soluble. SOA may have a low solubility and may physically block the access of water vapour to the dust particles rather than binding to active sites etc. However, if this is the case it is unclear why nucleation above -36°C remains active in the presence of SOA. One thought is that maybe the SOA solidifies or becomes very viscous or sticky at lower temperatures or maybe becomes insoluble at lower temperatures. This discussion doesn't necessarily need to be included in the revised version, but I mention it because I'm interested!

15) One thing that is not discussed and should be is why at around the threshold for homogeneous nucleation of pure water droplets the characteristics of ice nucleation apparently shift. Above about -36°C it is always immersion or condensation freezing

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(the liquid state is involved), but below -40°C it is clear deposition nucleation on the 'clean' dusts. Is the match with the homogeneous freezing temperature of water just a coincidence or is there some physical basis for this?

16) P19364, In 27. I disagree, based on fig 6 the activation is not complete. In the homogeneous case it is only getting to 20%, and in the heterogeneous case it is getting to about 50%. Why is it not complete?

17) I like the discussion on the importance of not assuming a single threshold nucleation RH for all IN in models. I fully agree with this. In fact, nucleation on glassy aerosol also occurs over a wide range of RH conditions (Murray et al. Nat. Geosc. 2010).

18) P19365, In 24. SOA is referred to as being hygroscopic. Is this material really hygroscopic? I think of sulphuric acid or NaCl as hygroscopic, but I would imagine most of the components of SOA generated from alpha pinene are relatively insoluble and therefore non-hygroscopic.

19) P19366 In 27. Eastwood (2009, see above) and Dymarska (JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D04204, doi:10.1029/2005JD006627, 2006) both show that larger kaolinite particles (supermicron) can nucleate ice at lower RH.

20) P19367, In 3. (also in other places). Mineral dust particles are referred to as 'freezing'. Mineral dust particles can nucleate ice and cause liquid to freeze. Please correct.

Specific editorial comments:

1) 19346, In 4. The word 'ability' is in the wrong place in the sentence. Revise. 2) 19347, In 1. Delete 'grown'. 3) 19360, In 5. Delete extra 'an'. 4) P19366, In 19. Insert a new paragraph after 'DeMott et al. (2010).'

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 19343, 2010.

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