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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Biological residues define the ice nucleation properties of soil dust" *by* F. Conen et al.

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General Comment

This is a nice contribution to the literature framing the potential role of organic ice nuclei within soils in contributing to atmospheric ice nuclei, with clear implications for cloud ice formation and modeling ice nuclei emissions that deserve to be explored. It would be good to see a little more tie in with research in this area 40 years ago, some additional discussion to frame the potential atmospheric implications (just not too speculative), and acknowledgment that the actual source of the organic IN (my preference to terming them "biological residues") remains to be identified.

Specific Comments

1. Introduction

Page 16586, lines 22-23: DeMott et al. (2010) note a modal diameter of IN a little larger than 0.5 microns, but they chose to correlate with particles larger than 0.5 microns because it is less likely that larger particles reflect the influence of pollution and other aerosols as they grow into the accumulation mode.

Page 16587, line 5: In fact, Schnell and Vali (1972) first raised the issue of IN association with organic content in soil, and this is not made crystal clear here or later. It should be. Schnell and Vali state that, "The starting point for this research was the finding[4] that soils having higher contents of organic matter are better ice nucleators than pure clays or sands." Reference 4 in this case is a science report by Vali from McGill University. The 1972 Nature paper also features a figure (Fig. 1 therein) showing IN versus organic content of soils. The present study suggests that a simple global relation such as shown in Fig. 1 of Schnell and Vali (1972) was not valid, though little emphasis is placed on this. Instead, the present study finds a clear relation with organic content only in single regions. Since this has strong implication to the generality of results and their application in models, it should be emphasized that a simple global relation may not be possible based on the new results.

2. Materials and methods

Page 16587, line 25: Please explain wet sieving to those of us who do not use such a technique. Does that mean that the particles are put into liquid and then filtered? If this is the case (please be more explicit), doesn't this offer the possibility for organic material to be redistributed among the soil particles, perhaps more evenly than might exist? Or is it the case that the organics are fully insoluble and cling to the more numerous soil particles?

Page 16588, line 5: This statement regarding the predominance of immersion freezing nucleation is based on a numerical model, and therefore depends on the validity of its assumptions regarding how to quantify ice nucleation. A classical theoretical approach

is taken, which provides a physical basis for quantifying ice nucleation, but may not well represent the actual behavior of atmospheric ice nuclei. This must be discerned by measurements. Therefore, I suggest changing this sentence to ". . .has been estimated theoretically to represent the vast majority. . ." Another relevant recent paper that comes to a similar conclusion, albeit by an indirect observational means, is Westbrook and Illingworth (2011; Geophys. Res. Lett, paper in press 2011GL048021).

3. Results and discussion

Page 16589, line 9: Can you mention here or in methods how organic content was measured?

Page 16589, lines 15-16: Is "of biological origin" different from a source from biological residues? This comment addresses the present ability or not to distinguish the types of biological IN in the present work. This section is concluded with a back of the envelope calculation of the potential contribution of intact bacteria. Can you ascribe an uncertainty to such a calculation, since an order of magnitude could explain the IN activity at -8°C of three of the soils?

Page 16590, lines 12-19: This might be another place to highlight similarities and differences with the studies of Schnell and Vali.

Page 16591, lines 7-9: The association of the biological residue with the mineral particles, rather than as distinct particles that are released to the atmosphere, would be more convincingly proven if the particles could be generated dry and condensation forced on them. With the introduction of a wet sieving process, and even with the immersion freezing method alone, if more than one particle enters each liquid volume, it would seem difficult to disentangle the roles of residues on dust from the possible free release of residues.

3. Conclusions

This is a general comment on this section. It would be helpful to the atmospheric

community to say a little more to put the results in context of expected atmospheric concentrations, if there is any way to do that. I could only think of the following. Since Fig. 1 shows concentrations per microgram of soil dust, one could consider the situation of all of the dust present at any time being of such soil dust origin (e.g., not mineral dust). For example, if dust mass concentration in air is 1 microgram m^{-3}, then the scales in Fig. 1 would represent numbers of IN m^{-3} of air. Thus, at this soil loading, soil D would activate 1 IN per liter at -12°C, while all others give values lower by nearly two orders of magnitude at this temperature. Results for the other soils imply 0.1 per liter IN (per microgram m^{-3}) at or colder than -16°C. This is useful for discussing the atmospheric implications if one knows soil dust loading based on emissions at any time. For example, over the Western U.S., inspection of data from the IMPROVE (Interagency Monitoring of Protected Visual Environment) monitoring sites at higher altitudes suggest a range of soil dust mass concentrations from below 0.1 (winter values) to sometimes in excess of 10 micrograms m^{-3} (Spring Asian dust transport period), and annual average values are at or below 1 microgram m^{-3}. Other U.S. sites in the high plains or closer to agricultural regions have annual averages at around 0.5 microgram m^{-3} and with a smaller range than the Western sites. It might be possible to find such data from other monitoring networks around the world, to reflect other regions with different annual cycles. In any case, the number concentrations for the Western U.S. are perhaps not out of line with explaining the range of at least some reports of ice nuclei concentrations active at temperatures warmer than -16°C in the atmosphere.

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