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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Urediospores of *Puccinia* spp. and other rusts are warm-temperature ice nucleators and harbor ice nucleation active bacteria" *by* C. E. Morris et al.

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This study of ice nucleation by urediospores is a welcome addition to the range of microorganisms whose role in atmospheric ice initiation is being intensely researched. The fact that there is a documented relationship between rainfall and the spread of these organisms lends added importance to the study. The measurement results presented in the paper are quite convincing in spite of some sampling limitations.

Based on the measurements, combined with their experience with ice nucleation by other microorganisms and with the presence of those in precipitation, the authors make the general observation that atmospheric sampling of these microorganisms and mea-

surements of their ice nucleating potential are still insufficiently detailed for reliable assessments of their impacts. This is undoubtedly true. They also suggest that the observed low concentrations of ice nucleating species at cloud heights is a selective advantage. The main argument presented in the paper in support of this thesis, namely that higher numbers would lead to excessive competition, is not well founded; see the comment below for 26158/6-12.

Minor points, as well as more important ones are listed below with reference to page and line numbers.

26145/2 (also, in the title of the paper.) While the meaning is clear to those used to thinking about ice nucleation, the term "warm temperature ice nucleators" should probably be avoided. Alternatives may be "minimal supercooling" or "slightly below 0°C" or "small supercooling". Another option is to clarify (in a footnote) what is meant by "warm temperatures" in this paper.

26145/17 Simple dry dispersion of P.syr. seems to be left out here.

26147/24-28 This is an unexpected and significant statement. The words "life history" seem to indicate some narrowing of the scope of the sentence. Perhaps this is not intended.

26148/7-8 Is there some way to evaluate the efficacy of this washing? How clearly does this step really separate bacteria associated with the spores from others? How much was the number of associated bacteria reduced?

26149/8 A point of caution about the applicability of this equation. For the sample dilutions used here the activity per spore is «1, otherwise this equation couldn't have been applied. In other words, this equation is valid only for K«1. This type of calculation cannot account for the possibility that more than one ice nucleus might be located on a single spore. Physically that is clearly imaginable but would have to be evaluated differently.

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26150/22, 24 The -1 exponent could easily be misread as indicating a footnote.

Figs. 2, 3, 4. Onset temperature appears to be defined as the temperature of the first drop freezing. The simplicity of this parameter is of obvious advantage, but onset temperature is of dubious value on several counts. It does not normalize for the number of spores per drop, nor for the number of drops available for testing. In Fig. 1, there is at least an order of magnitude spread between the INA/spore at the onset temperatures of different samples. A more meaningful parameter would be the temperature at which the activity reaches a certain level, for example 10ˆ-4 nuclei per spore. Some extrapolation of the curves in Fig 1 would be needed for this, or the sample dilutions would have to be adjusted. Ordering of the samples by this parameter would alter the patterns in Figs 2, 3 and 4.

26154/13 Were washed or unwashed spores looked at?

26155/25 The rapid fall-off in concentration for surface-source aerosol is typical of clear-air conditions. Updrafts can carry near-surface concentrations into clouds. This point is made later on (26157) but should be mentioned here as well.

26156/20 It would be helpful if some details of this calculation were shown. The values and the range of 100 for the results are not surprising, but it should be supported by giving the basis and the assumptions that go into making this deduction. Since these numbers are based on one set of data, how much more variation could be expected in rains from different areas and different times?

26156/24 Comparing total population count with ice nucleus concentration jumps over the step of what fractions are IN active.

26156/26 The phrase "conducive to precipitation" needs some clarification. In fact the whole sentence leaves one wonder just what the authors mean.

26157/19-23 The Hallett-Mossop process depends on riming taking place at the temperature range -3 to -8°C, not on ice initiation at those temperatures. The graupel on

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which riming takes place may originate, and indeed it must, higher in the cloud.

26158/6-12 While competition as a limiting factor to precipitation development is a clear concept, there is little evidence for this to be of practical importance at temperature higher than about -15°C Supercooled water is present at these higher temperatures in the overwhelming majority of clouds (e.g. Korolev et al., 2003, Quart. J. Roy. Meteor. Soc., 129, 39-65), even without selecting for freshly formed clouds. Thus, there is no limitation to growth by additional ice particles under those conditions. The point made by the authors may still be valid regarding the existence of a point of optimum concentration of ice particles for maximum precipitation efficiency. However, precipitation efficiency is a very difficult quantity to define and to evaluate. It would be reaching very far, I think, to argue that the natural evolution of varieties of microorganisms led to their ice nucleating ability to be at, or near that optimum point for large ranges of different meteorological conditions. That does not detract from the important contribution these ice nuclei make to precipitation initiation. Perhaps their presence is not the overwhelmingly dominant factor but they do fill a unique role. Most decidedly so in prompting some precipitation from slightly supercooled clouds that otherwise would not produce any. Much work has been done, but much more will be needed to quantitate the contribution of biological ice nuclei to local or global precipitation.

26158/12 I sense that "questions" could be replaced by "notions" or something like that. None of the points in following sentences are phrased as questions.

26160/1 See earlier comment about ice multiplication.

A useful additional reference: "Intercontinental Dispersal of Bacteria and Archaea in Transpacific Winds" by David J. Smith, Hilkka J. Timonen, Daniel A. Jaffe, Dale W. Griffin, Michele N. Birmele, Kevin D. Perry, Peter D. Ward, and Michael S. Roberts. Appl. Environ. Microbiol. AEM.03029-12; doi:10.1128/AEM.03029-12

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