

***Interactive comment on “Impacts from ice-nucleating bacteria on deepconvection: implications for the biosphere-atmosphere interaction in climatechange” by V. T. J. Phillips et al.***

**V. T. J. Phillips et al.**

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## **Overview**

We thank the anonymous reviewer (#2) for the comments and interesting suggestions made.

We note that this reviewer claims to have been influenced by views expressed by the previous reviewer, who is an Editor here. Since

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many of the reviewer's (#2) criticisms are similar to earlier ones, some of our responses to the first reviewer also apply here.

The paper provides a breakthrough in knowledge about biological ice nucleation in the atmosphere. It shows that entire cloud ensembles over a period of several days can be substantially modified by biogenic IN particles emitted from the biosphere. The paper shows how this atmospheric response would be expected to modify their emissions from the biosphere. As far as we are aware, this has never been done before.

Although no model validation is actually presented in the present paper, it will be trivial to include in the revised version of the manuscript. Validation of an earlier version of the model for the same case simulated here (ARM(C)) is referred to in the present BGD paper (Phillips and Donner 2006, QJRMS) in Section 4.1. The ice initiation of the model, and other aspects of it, were comprehensively validated for a tropical ocean case by Phillips et al. (2007, JAS), using aircraft, satellite and ground-based observations.

The validation data presented by Phillips et al. and by Phillips and Donner have been reproduced with similar accuracy by the latest version of the model with prognostic aerosol and an upgraded liq-

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uid phase to be used for the new simulations of all ARM cases. This new validation is being included in the revised paper.

We offer clarification in response to points made by this anonymous reviewer.

## Detailed comments

(i) The reviewer suggests that the paper's content is inconsistent with the title, which "*suggests that general conclusions regarding the impact of ice-nucleating bacteria on biosphere-atmosphere-interactions and climate change can be drawn*". This requires clarification. The implications that the title refers to are qualitative ones and simply feature in the discussion. It is not claimed anywhere in the paper that climate impacts from biogenic aerosol are being quantitatively evaluated. The title will be shortened as suggested.

(ii) The reviewer states that "*there is no validation against observations whatsoever*". This requires clarification. As detailed in our response (point (f) therein) to the first reviewer and as summarised above, an earlier version of the model was validated by Phillips and Donner (2006, QJRMS) precisely for this ARM(C) case. That

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validation is actually cited in the present BGD paper (Sec. 4.1). The more recent version of the CSRM has been validated for other cases (Phillips et al. 2007, JAS), as described in that response. Extra validation is being included in the revised paper for the case simulated and for the ice initiation, as suggested.

(iii) The reviewer suggests that "*preliminary*" simulations ought not to be reported in a journal paper. In the revised version of the paper, we will omit this phrase, since the results to be presented will not then be preliminary.

(iv) More clarification of the definition of a visible cloud will be added, as required.

(v) The reviewer asks, "*What have we learned from the paper?*" If one follows the description of the results and their discussion in the paper, one learns that INA bacteria at realistic concentrations in the free troposphere near land sources can appreciably affect cloud properties by nucleating crystals and cloud-droplets. The cloud-microphysical mechanisms are elucidated. That is a breakthrough in cloud modeling never done before.

(vi) The reviewer's statement that "*the conclusions that you draw would hold for any increase in IN but are not restricted to an increase in INA bacteria*" requires clarification. Other types of IN

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would have very, very different nucleating abilities and other increases in IN-containing particles would give rise to completely different responses of the simulated clouds.

The documented impacts from biogenic aerosol on the simulated clouds are critically dependent on the in-cloud concentration of biogenic active IN. These in-cloud concentrations have not yet been observed directly and so, must be predicted. This necessitates application of a sophisticated CSRM that represents the aerosol-cloud interaction, such as the one we have applied.

Our CSRM predicts the in-cloud IN concentrations aloft corresponding to realistic aerosol loadings and chemistry in the environment. The unique nucleating ability of biogenic IN is represented by the model.

(vii) The reviewer states that "*what we learned is not different from the conclusions that one draws when increasing CCN and cloud droplet number concentration in warm clouds*". The physical mechanisms causing the modification of cloud properties and surface precipitation are different for these biogenic IN aerosols compared to CCN, and involve the ice phase. These mechanisms are explained in the paper. The model has a complete representation of the impact from the cloud on all major aerosol species in

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the environment, and vice versa. The model actually predicts how much biogenic material reaches sub-zero levels, and then predicts how much ice is nucleated by it. This is not trivial to do.

The paper represents a breakthrough in knowledge about biological ice nucleation. For the first time, as far as we are aware, the paper proves how biological ice nucleation significantly modifies cloud properties and meteorological conditions, for realistic yet high loadings of biogenic aerosol in the troposphere.

(viii) The reviewer states that "*your study would be more useful if you compared the uncertainty in radiative fluxes and precipitation of IN stemming from INA bacteria with uncertainties in radiative effects of anthropogenic CCN*". While in theory this would seem a good idea, it will increase the length, which is already more than ample.

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