

## ***Interactive comment on* “Effect of bacterial ice nuclei on the frequency and intensity of lightning activity inferred by the BRAMS model” by F. L. T. Gonçalves et al.**

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As bacteria are the most active ice nuclei found in the atmosphere and intrinsically linked with atmospheric processes, it is crucial to deepen our knowledge concerning those interactions. In order to do so, the present manuscript investigates the effect bacterial ice nuclei have in the Brazilian regional Atmospheric Model System on the formation of hydrometeors and subsequent lightning activity. The authors come to the conclusion that bacteria tend to decrease the amount of rain being produced and increase the lightning activity.

Those are very interesting findings which need to be published. However, the

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manuscript needs some major revisions, notably concerning the ice nucleation part, before it is ready for publication. Chapters 2.1 and 3.1 need expansion and thorough rewriting for clarity and precision of the formulations, especially concerning the data provided in Table 2. Those chapters would also profit from being proofread by a native speaker. Additionally, I suggest altering the title by incorporating the effect bacteria have on the precipitation, as this is also a substantial part of the manuscript. In general, it sometimes feels like the manuscript is divided into two separate papers – one about the effect of bacteria on precipitation alone, and the other about their effect on lightning. That could be remedied by trying to bring those two aspects together.

I can recommend the article for publication, but only after those concerns and the ones listed below have been thoroughly addressed.

## 1 Specific comments

p. 26149 l. 6: What length is the model time step?

p. 26149 l. 26: It is not clear whether bacteria were allowed to act only as IN or also as CCN.

p. 26150 l.18-21: You write that the “IN concentration was assumed to follow 100000 times less the population of bacteria”. What are those other IN you talk about? Is it mineral dust? Also, please rephrase the sentence for clarity, as it’s not clear what is meant by “100000 times less the population of bacteria”.

p. 26150 l. 24-26: Does bacteria concentrations being homogeneous over the whole model domain mean that their vertical distribution is also homogeneous? If yes, this would not be realistic. I find it also problematic that there is no depletion of IN. This would mean that IN-active aerosol do not sediment and are not removed by precipitation. I hope that this is not what the authors had in mind when writing, otherwise it

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would mean that the model is inherently flawed.

p. 26150 l. 27: I am not sure what you mean by this sentence. Do you want to say that you assume in the model that all bacteria act as ice nuclei? As this is probably not the case in nature, I would like to see some discussion on that, or at least your reasoning why all the bacteria in your model act as ice nuclei.

p. 26151 l.12 Please explain here in deeper detail how the ice nucleation is handled in BRAMS, especially the parametrization. Is it assumed to be the same for all IN species? Maybe rephrase here quickly the formula used from Meyers et al. (1992) and Cotton et al. (1986) that you mention. Why are not some more recent parametrizations used? E.g. Hoose et al., 2010: A Classical-Theory-Based Parameterization of Heterogeneous Ice Nucleation by Mineral Dust, Soot, and Biological Particles in a Global Climate Model. *J. Atmos. Sci.*, 67, 2483–2503. doi: 10.1175/2010JAS3425.1

p. 26152 l. 5: Say here already which values you use for C and not just in lines 25/26.

p. 26152 l. 17: This doesn't make sense, why would some ice species like snow be non precipitable? Please explain. Also, I think you are missing a word after "pristine". What is pristine, the ice crystals?

p. 26152 l. 20: What is meant by "pristine masses"?

p. 26152 l. 27: What is the length of the time step used here?

p. 26153 l. 7: You quote the wrong table here, it should be "Table 2" instead of "Table 1".

p. 26153 l. 9 and following: Please use the established units for reporting cloud water and ice water calculated by the model, i.e. liquid and ice water content respectively in  $\text{g/m}^3$  instead of  $\text{g/kg}$  which is a more common unit for the specific humidity. Please check also for conversion errors, as the values given here are three orders of magnitude too high (unless I understood something wrong or you wanted to write  $\text{mg/kg}$  instead of  $\text{g/kg}$ ). Even in the tropics, the average specific humidity is only around 18

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g/kg max. For example, I would expect the in-cloud cloud water content to be around 0.2 g/kg. You might also want to use the cloud droplet number concentrations (in number per  $m^3$ ) or the liquid water path (in  $kg/m^2$ ) to describe the amount of rain and ice produced by your model. Additionally, I find it troubling that here (and in Table 2) you give values obtained by summing up the variables, as this is not how those data are usually handled. See also my comment on Table 2 below.

p. 26154 l. 8: What do you mean by pristine ice crystals? Those formed by homogeneous freezing and thus containing no ice nuclei?

p. 26153 l.14: Why do you compare the reduction in rain with the results from the Levin et al. (2005) study, as you used bacteria as ice nuclei in your simulation and they did not?

p. 26154 l. 15: As stated previously, it is important to know the vertical dispersal of bacteria. If it is the same everywhere, one would expect the peak of ice crystal production to be the same in all simulations, as stated. This is why it's also important to know the freezing parametrization of the model.

p. 26154 l. 19: As bacteria freeze at relatively high sub-zero temperatures, I would have expected the heterogeneous nucleation peak to take place at lower heights.

p. 2153-26155: I suggest to add information about how different aerosols in your model contribute to the freezing. For example, do bacteria take over when they are added? Also, it is not clear from this chapter, whether there are different aerosol species contained in the model, or just one IN species.

p. 26155 l. 11: I think it's very interesting that the simulations with bacteria produce three times more hail. You might want to cite here the work by Michaud et al. who observed that centres of hailstones contain much more bacteria than the surrounding air. Michaud, A. et al.: The Role of Ice Nucleating Bacteria in Hailstone Formation. 11th General Meeting of the American Society for Microbiology, New Orleans, 2011.

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p. 26156 l. 9: Why did the S2, S3 and S5 simulations produce non comparable values? Please discuss.

p. 26156 l.14: This is the first time that we learn that the model has a 2-min time step. Please add this information already to chapter 2.1.

p. 26157 l.14-18: Please rephrase the sentence starting with “These authors...”. You make it sound like you looked at the horizontal cloud coverage and incident solar insolation as well, but you didn’t mention those aspects at all in your manuscript.

## 2 Tables

Table 1: Instead of deposition write deposition freezing. Delete “and” from “Condensation and Freezing” as well as “Contact and Freezing”. If none of these heterogeneous freezing mechanisms take place in simulation 1 to 4, how does ice form then? By immersion-freezing only? What other IN are acting as heterogeneous ice nuclei in S5?

Table 2: The way those values are presented here is very unusual and confusing. Instead of summing up the variables in the entire domain (horizontal and vertical) for the whole duration of the simulations, I strongly suggest, that the more common liquid/ice water content (in  $\text{kg}/\text{m}^3$ ) or liquid/ice water path (in  $\text{kg}/\text{m}^2$ ) are used. This makes the results comparable to other models and simulations.

Table 3: Please give a unit for the hydrometeor mixing ratios (usually, it’s  $\text{g}/\text{kg}$ ).

Table 4: The ice mass flux seems to not vary much between simulations. Please explain why this is so. Also, there is a formatting error in the table: “lightning flashes” should come below “Total estimated”.

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### 3 Figures

Fig. 1a. A map showing the topography (and maybe surrounding vegetation) would be helpful to get a better understanding of the study area.

Fig. 1b. This figure would be much easier to understand, if it were plotted as a common skew-T log-p diagram, including lines for dry and moist adiabats, as well as isotherms, isobars and constant mixing ratio. It would also be interesting to see where the lifting condensation level and cloud top are, and compare this to the model results.

Fig. 2: It would be more logical to plot the concentration (on x-axis) against height (on y-axis). Why is it plotted against temperature? It would be interesting to see how many bacteria are available for freezing at the specific model levels.

Fig. 3: Please bring the pictures of the simulations S1-S5 in a logical order, from left to right and top down (i.e. top row: S1, S2, middle row: S3, S4, bottom row: S5, S6).

Fig. 4: I suggest that instead of writing “231” etc. you just write the total number of lightning flashes occurring in each scenario.

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