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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Bacteria in the ECHAM5-HAM global climate model" *by* A. Sesartic et al.

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We would like to thank Pierre Amato for the helpful comments and careful evaluation of the manuscript. The referee's comments and our responses follow.

1 Major comments

Emission fluxes of bacteria are considered similar for all forest types.: As mentioned in our manuscript, we obtained the data for bacterial emission fluxes from the Burrows et al. literature review. As the available bacteria observations do not sufficiently distinguish between the different forest types, Burrows aggregates the data into one forest category and this is what we use in our simulations. We are aware that this is a very crude representation of the reality, but it is limited due to the current lack of data. We therefore strongly encourage future research to focus on better observations of bioaerosol emissions.

No real criticism about the parameterization of the emission of bacteria has been made.: This has been now added to the manuscript. It is currently the best we can assume, as more detailed emission flux data are lacking (see comment above).

More details should be given concerning the experimental data used for parameterization of bacteria as ice nucleators. [. . .] I wonder how the authors converted a fraction of frozen drops into INA/cell at a given temperature [...]. Such issues and the parameterization of ice nucleation by bacteria have to be explained more precisely in the manuscript.: These concerns have now all be addressed in the manuscript. Please note that the parameterization by Diehl et al. does not consider INA/cell, but uses the number concentration of bacteria as the input.

Referenced paper by Santl Temkiv: This is an extended abstract for the 18th International Conference on Nucleation and Atmospheric Aerosols (ICNAA), that took part in Prague in 2009, as noted. However, as it was a late submission it does not appear in the official conference proceedings. It has now been forwarded to the referee and can be procured from Tina Santl Temkiv via e-mail tit@dmu.dk We corrected the amount of the bacterial cells from 9% to the observed 12%. This value is related to the total number of bacterial cells in the sample. Unfortunately, information about the number of IN per cell and temperature dependence was not available.

The paper by Christner et al. (Science, 2008) is mentioned (p 1460, line10) but apparently not reported correctly: This has now been corrected; see minor comments Page 1460, line 9, for details.

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2 Minor comments

Remark about only a limited number of bacteria species being active IN: corrected.

Page 1459, line 12: corrected.

Page 1459, line 17: corrected.

Page 1459, line 17: corrected.

Page 1459, line 18: corrected.

Page 1459, line 19: The cell size indeed does not depend on the composition of the membrane, but we are writing here about the cell's surface area. The protruding lipopolysaccharides enlarge a cell's surface area, thus making it bigger than it would be if one were to assume a simple spheroid.

Page 1459, line 25: Has been rephrased to "Pseudomonas sp. is a bacterial strain which is an excellent IN", as we only look at bacterial IN activity in our research. However, Levin et al. (1987) found that Pseudomonads can also act as CCN. The same finding might be extrapolated from the fact that other gram negative bacteria like Mycoplana bullata for example have been found by Bauer et al. (2003) to be activated as CCN at 0.1% supersaturation.

Page 1460, line 4: Corrected.

Page 1460, line 9: The statement "500 biogenic nucleators per litre of snow" stems from Phillips et al. (2009) where they cite Christner et al. (2008). Upon further review, it was found that Phillips et al. cites two papers by Christner et al. which both were published in the year 2008, however, they did not distinguish between them in the text of the article. The reference has now been corrected to refer to the Chrisnter et al. (2008) PNAS paper (and not the one in Science), where such values - and even higher ones - can be found (e.g. in Fig.1 of the paper).

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Page 1460, line 25: As Möhler et al. (2008) is an experimental study in a cloud chamber, we excluded this citation, and added three new ones by Ariya et al. 2009, Diehl Wurzler 2010 and Sun et al. 2010 which are dealing with numerical models.

Page 1463, line 10: The modal structure of ECHAM5-HAM was developed and described in detail by Stier et al. (2005), which we cite. An additional bioaerosol mode was included in order to simulate the distribution of large bioaerosol particles – bacteria, to start with, and later on fungal spores and pollen. A table was added to the corrected manuscript (Table 1) where the sizes of the different modes are referenced.

Page 1463, line 24: The mass used for bacteria [. . .] discuss quickly. Bacteria are generally considered to be around 1 μm in diameter [. . .].: This has now been discussed in the manuscript.

Page 1465, lines 6-7: Has been rephrased for clarification: "However, as the observational data used for model input relies only on point measurements, it does not reproduce the variability inherent in nature."

Page 1465, line 29, Why does the presence of bacteria impact homogeneous freezing (fig 5)?: Ice crystals formed by bacterial IN below the homogeneous nucleation threshold can grow by water vapour deposition, thus changing the environmental supersaturations. Model studies (e.g. Spichtinger Cziczo, 2010) and freezing chambers experiments (e.g. Möhler et al., 2005) have shown that heterogeneously formed ice crystals can change or suppress a subsequent homogeneous freezing event via changing supersaturations, thus impacting the ice crystal number concentrations. This explanation is now added to the manuscript.

Page 1466, line 22: corrected.

Figure 4: We are aware that the concentrations of bacteria in the literature were obtained using various methods (i.e. culture or microscopy) and showing different parameters (i.e. total cells, viable cells). However, including this figure is the only way of

validating our model bacteria emissions, which is why we left it in. Also it could serve as a motivation to conduct more observations.

Figure 6: The figure in the discussion version of the manuscript was wrong. We now corrected it. Figure 6 shows the difference of the different simulations to the reference simulation. Therefore, we do not show the total amount of condensed water (LWP+IWP) but the difference to the reference simulation. If there are more IN active bacteria, freezing occurs more often and the IWP increases at the cost of the LWP. Ice formation leads to a more efficient precipitation release and on average reduces the lifetime of mixed-phase clouds, hence the reduction in the total water path when more bacteria are active as IN. The LWP reduction is more pronounced in the storm track regions due to a more efficient precipitation release.

3 References

Ariya, P.A. et al. (2009) Physical and chemical characterization of bioaerosols - implications for nucleation processes. Int. Rev. Phys. Chem., 28 (1), 1-32.

Bauer, H. et al. (2003) Airborne bacteria as cloud condensation nuclei. J. Geophys. Res.-Atmos., 108.

Diehl, K. and S. Wurzler (2010) Air parcel model simulations of a convective cloud: Bacteria acting as immersion ice nuclei. Atmos. Environ., 44, 4622–4628

Christner, B.C. et al. (2008) Geographic, seasonal, and precipitation chemistry influence on the abundance and activity of biological ice nucleators in rain and snow. PNAS, 105(48), 18854–18859.

Levin, Z. et al. (1987) Possible application of bacterial condensation freezing to artificial rainfall enhancement. J. Clim. Appl. Meteorol., 26, 1188–1197

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Möhler, O. et al. (2005) Ice nucleation on flame soot aerosol of different organic carbon content. Meteorologische Zeitschrift, 14 (4), 477-484

Phillips, V.T.J. et al. (2009) Potential impacts from biological aerosols on ensembles of continental clouds simulated numerically. Biogeosciences, 6, 987–1014.

Spichtinger, P., and D. J. Cziczo (2010), Impact of heterogeneous ice nuclei on homogeneous freezing events in cirrus clouds, J. Geophys. Res., 115, D14208

Stier, P. et al. (2005). The aerosol-climate model ECHAM5-HAM. Atmos. Chem. Phys., 5(4), 1125–1156

Sun, J. et al. (2010) Mystery of ice multiplication in warm-based precipitating shallow cumulus clouds. Geophys. Res. Lett., 37, L10802

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 1457, 2011.