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Interactive comment on "A new parameterization of ice heterogeneous nucleation coupled to aerosol chemistry in WRF-Chem model version 3.5.1: evaluation through the ISDAC measurements" *by* Setigui Aboubacar Keita et al.

Anonymous Referee #1

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The authors present a new parameterization for ice crystals formation by heterogeneous ice nucleation coupled to aerosols chemistry in the WRF-Chem model. They conclude that "the new parameterization is, thus able to represent TIC1 and TIC2 microphysical characteristics at the top of the clouds where heterogeneous ice nucleation is most likely occurring even knowing the bias of simulated aerosols by WRF-Chem over Arctic." This paper could represent a valuable addition how to better represent ice formation in Arctic clouds. But I am sad to say that the paper is currently in a poor shape as far as its presentation is concerned. I also have some major comments about

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Discussion paper

the new parameterization and some of the results. However, if the following comments are thoroughly addressed within this review process I would suggest publishing this paper in GMD.

1 Major comments

The first major comments concern the condition of the paper presentation. Usually this would be part of the minor comments section. However, several presentation errors popped up while reading through the paper, which is the reason why it is already mentioned here. My impression is that the paper was not checked at the end for typos, bracket errors, consistency of parameter notation/writing style (regular vs. italic), description of abbreviations, etc. I will give some examples:

Abstract, line 1, 6 and 10: What do the abbreviations TIC, WRF-Chem and IWC stand for?
Line 25: It should read "... understand fundamental processes...".
Line 26: Delete one "are" in "...which are are particularly...".
Line 239 and 240: There are no Eqs. (20a) and (20b), only Eqs. (20) and (21).
Line 273: There is no Table 5. It should be Table 4.
Line 352: There is a "10-3" too much between -8.1 10^{-3} g/kg.
There are more of such errors. Please check the paper thoroughly.

If you use a citation as a constituent part of the sentence (e.g. grammatical subject) then please check your brackets. For example, line 52: It should read "In Keita et al. (2019), the parameterization of Girard et al. (2013) based upon CNT..."

Some of the parameters used are not / differently introduced or differently written, etc. Some examples:

N_i vs Ni, S_i vs Si, f vs f, U vs $\boldsymbol{U}$, etc.
'Ri' is not introduced (from the context it is ice particle radius), but in the model description you use diameter.
Line 101 -103: Please avoid the brackets around 'α_x', 'λ_x', etc.
Please also check your equations. For example Eq. (2): There is the wrong 'dot' in the scalar product. And what does '*TURB*' stand for or in other words how does this term including '*TURB*' look like?

The second major comments concern the new parameterization and some of the results.
You mention on page 6, starting line 151: "The new parameterization focuses on deposition ice nucleation for uncoated IN and to immersion freezing of sulphuric acid coated IN, i.e. IN immerged in an acid aqueous solution." Here I wonder that for ΔG in the presentation of the nucleation theory you only consider the case of deposition nucleation. If you look into the literature, e.g., Lamb and Verlinde (2010, pages 313-318) you can see that there is a difference between the Gibbs free energies between the case of deposition nucleation and immersion freezing due to e.g. the differences in the interfacial free energies. Finally, you would end up with different nucleation rates even if identical contact angles would be used in the nucleation rate equation. What about the freezing point depression when the particle is immersed in an aqueous solution? Could you please comment on that?

Concerning the parameterization of the contact angle: Why do you use the quadratic and biquadratic forms? Eastwood et al. (2008) show the ice nucleation behavior of various minerals and the respective contact angles. Why did you choose the contact angle of kaolinite? Note that Eastwood et al. (2008) used a different (simplified) equation of the reduction factor in contrast to your Eq. (17). What are the consequences when using contact angles based on Eastwood et al.? Have you also considered checking other papers for contact angles? For my impression the contact angles given

in Eastwood et al. are smaller compared to other studies of kaolinite (e.g. Welti et al. (2012), with $\theta \approx 90^\circ$ for kaolinite particles in the immersion freezing mode)

Concerning the representation of the IWC by MYKE2 and MYKE4: Looking on figure 6, the IWC for F29 is well reproduced by MYKE2 and MYKE4. However, looking on Figs. 7 and 8, which show the vertical distribution of the ice particle number concentration and the ice particle radius (the combination of both at the end leads to IWC), you can see that MYKE2 and MYKE4 overestimate ice particle number concentration and underestimate ice particle radius for F29. Putting these two factors now together lead to a good IWC, however, to my impression just by chance. Actually, for the vertical distribution of the ice particle number concentration alone, REF does a better job. In my view, MYKE2 and MYKE4 are not able to correctly represent the TIC2 microphysical characteristics. Could you please comment on that?

2 Minor comments

Following the recommendation of Vali et al. (2015), I would suggest to use "ice nucleating particles (INPs)" instead of "ice nuclei (IN)".

The year in the citation "Pruppacher and Klett (1998)" should either be 1997 or 2010. 1998 refers to a review of that book.

Line 95 and Eq. (4): Why is this equation explained and written in such a complicated way? For me it looks like to simply be density times volume for the hydrometeors considered: $m_x(D) = \rho_x V_x = \pi/6 \rho_x D^3$

Line 124 -124: You only consider homogeneous ice nucleation of pure supercooled water droplets. What about haze droplets and the resulting freezing point depression?

Eqs. (20) and (21) and Fig.1: Could you please make clear in the text, when introducing Eqs. (20) and (21), that Eq. (20) belongs to MYKE2 and Eq. (21) to MYKE4? It is mentioned in Fig. 1 but not in the text at the end of section 2.1.1.

3 References

Lamb, D. and Verlinde, J.: Physics and chemistry of clouds, Cambridge University Press, Cambridge, UK, 2011.

Vali, G., DeMott, P. J., Möhler, O., and Whale, T. F.: Technical Note: A proposal for ice nucleation terminology, Atmos. Chem. Phys., 15, 263–270, https://doi.org/10.5194/acp-15-10263-2015, 2015.

Welti, A., Lüönd, F., Kanji, Z. A., Stetzer, O., and Lohmann, U.: Time dependence of immersion freezing: an experimental study on size selected kaolinite particles, Atmos. Chem. Phys., 12, 9893–9907, https://doi.org/10.5194/acp-12-9893-2012, 2012.

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