

# ***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 #2**

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In this work the authors develop a new parameterization of heterogeneous ice nucleation targeted specifically to Arctic clouds. The authors use classical nucleation theory, CNT, to estimate ice nucleation rates. A novel aspect of this work is the usage of the degree of neutralization of the aerosol to parameterize the contact angle used in CNT. The authors apply the parameterization in the simulation of two cloud formation cases during the Indirect and Semi-Direct Aerosol Campaign (ISDAC). Compared to the reference parameterization, the new approach leads to a better agreement between the observed and simulated ice crystal number concentration. This is an interesting work,

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of interest to the atmospheric community. The authors should expand on the rationale behind the proposed parameterizations. The presentation needs some work. After these issues have been addressed, that manuscript would be suitable for publication.

General comments.

My main concern is related to the lack of a proper justification for the proposed parameterizations. The authors base their development on CNT which accuracy for heterogeneous ice nucleation is still matter of debate, although it has been applied before. However the authors make some assumptions that need to be justified. Ice nucleation is assumed to occur mainly in the deposition mode or by immersion in solution. As mentioned by another reviewer only expressions for deposition ice nucleation are used. Moreover, why are these considered the main paths of ice nucleation in the stratiform clouds? Droplet freezing is probably more significant. If not, the authors should show some evidence or at least reports suggesting otherwise. Also, a control simulation where CNT is used but with no acidity dependency considered should be added to discriminate the effect of the later.

Minor comments.

Lines 16-19. Please split this sentence.

Line 26. Should be “specific”.

Line 29. Remove the comma.

Line 33. Number density is however a function of temperature.

Line 34. CNT is not a requirement of the stochastic hypothesis. Please rephrase.

Lines 36-39. Most atmospheric models use time-independent formulations. In fact, all of these references correspond to time-independent formulations.

Line 41. Please explain the significance of the contact angle. Also isn't this the approach used in this work? A single contact angle, dependent on the acidity?

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Line 45. Say INP (ice nucleating particle) instead of IN.

Line 55. Is dust internally mixed with sulfuric acid?

Line 103. Is this assumption appropriate for small ice particles?

Line 133. Why is immersion freezing of cloud droplets (which is likely the dominant path of ice formation) not treated in a more rigorous way?

Line 159, Eq. 13. Is this the total surface area? Shouldn't this equation be weighted by the aerosol size distribution? Also, when applying this to the immersion case, shouldn't it be only valid for the dust particles immersed within the haze aerosol droplets?

Line 170. This seems wrong. Is it maybe  $10^{26}$ ?

Line 174. The surface tension between ice and vapor is a function of temperature. Also, this would be invalid for immersion within haze particles.

Line 176. This is not the expression for an infinite plane surface. This is in fact the expression for small INP when the size is comparable to the size of the ice germ.

Line 203, Eq. 19. Is this for the dust particles internally mixed with sulfate and nitrate, or the overall composition? The latter would not seem very rigorous. Please explain.

Line 215-220. What is the rationale behind the proposed functional forms in Eqs. 20 and 21? Why would the contact angle depend on the acidity?

Line 233. There are no equations 20a and 20b.

Line 265. If ice nucleation occurs at cloud top why would it be on haze aerosol instead of cloud droplets immersed with dust?

Line 285. Is this the total aerosol number for all species?

Line 327. This is a confusing sentence? What do the authors mean by the same  $f$ ?

Line 349-350. Can you show this in a plot?

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Lines 384-385. Please show this.

Line 402-403. What about using no  $f$ , i.e., Just a fixed contact angle?

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Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2020-50>, 2020.

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