Response to Review #1

The authors report on the observation of two cases of ice fogs formed at Dome C, Antarctica. Both ice fogs formed at very cold temperatures which are typical for cirrus clouds in the upper troposphere. In particular, these fogs formed in-situ, most likely due to the homogeneous nucleation of ice crystals, i.e. the freezing of pre-existing aerosol solution particles. This aspect makes this study particularly interesting since in contrast to aircraft based observations of natural (i.e. outside of the laboratory) cirrus clouds the authors are able to show timeseries of key parameters at a stationary location, hence within the forming cloud itself.

The manuscript is very well written and fits well into the scope of ACP. After adressing my comments and questions I have listed below, I recommend the acceptance of the manuscript.

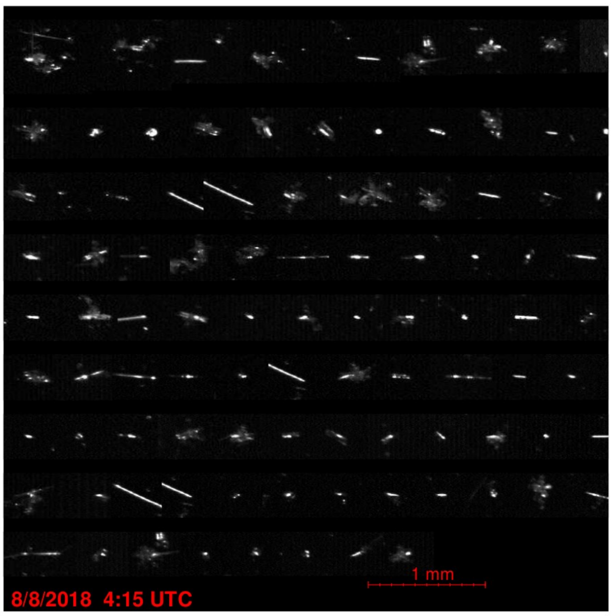
We gratefully thank Reviewer #1 for his/her review our paper and for recommanding its acceptance after revision. We answer his/her line by line comments herebelow :

Comments:

(1) I find it a pity that no data is presented that can shed some light on the nucleated ice crystals within the two fogs, such as their shape, mass, number density. If there is such data available, I strongly recommend to include that.

We completely agree with you, it is a pity that no measurements of the shape, mass and density of ice crystals at Dome C is available during our two fog events. That is why one prospect of this work is to collect sedimenting ice crystals during ice fog events and establish formvar replicas in the manner of Santachiara et al. (2016). Note that an 'ice camera' has been operating for several years at Concordia : http://lidarmax.altervista.org/englidar/Antarctic%20Precipitation.php

It takes pitures of snowflakes and an algorithm classifies them according to their size and geometrical properties (see an example in the figure below). While the camera provides interesting information during synoptic precipitation event, no crystal photograph was available during the two fog events because the size of the tiny fog particles was below the detection limit of the instrument.



(2) Line 21-22: You state that the ice crystal properties "such as their size and their number concentration" are different for an ice fog or diamond dust. I suggest adding a sentence to clarify these differences.

We have added the following sentences :

'Ice fogs can be distinguished from another surface ice cloud type called `diamond dust' through visibility criteria - fogs are optically deeper - or ice crystal properties. For instance, Girard & Blanchet (2001) distinguish ice fog from diamond dust by the high concentration of ice crystals of small diameters as the particles' number concentration in fog clouds generally exceeds 1000 L^{-1} and their size is below 30 µm.'

(3) Line 30-32: To me it seems that the formation process you describe here is the freezing of supercooled liquid droplets which are already as large as cloud droplets. In other words it is the freezing of a pre-existing liquid cloud. I suggest to refer to this process as a liquid-origin cloud, since the term "homogeneous freezing" is usually understood as the freezing of much smaller solution aerosol particles (you describe this process in line 41-44).

You are right we describe here the main formation processes described in Gultepe et al. (2017) which correspond to liquid-origin fogs. We have added 'liquid origin' where it is relevant in the text.

(4) Section 2.2: At very cold temperatures close to 200K, a new formulation of the saturation vapor pressure over liquid water was recently presented by Nachbar et al. This formulation differs from the formulation given in Murphy and Koop (2005), in particular at cold temperatures. What happens to your RHl-values if you use this new formulation? Although Nachbar et al state that their parameterization is only valid for temperatures above 200K, it seems that such a comparison is applicable for observed fog in the case 1. Of course, such a comparison might also affect the results in Appendix A.

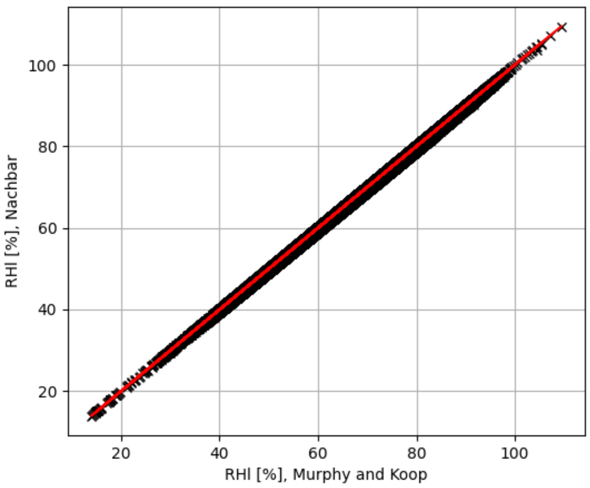
Reference:

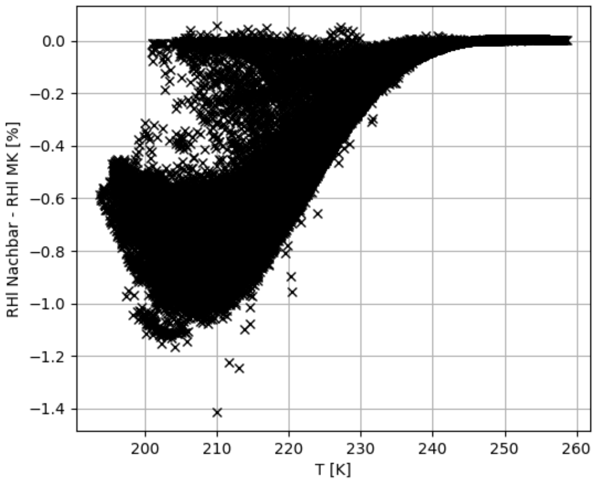
Nachbar, M., Duft, D., and Leisner, T.: The vapor pressure of liquid and solid water phases at conditions relevant to the atmosphere, J. Chem. Phys., 151, 064504, https://doi.org/10.1063/1.5100364, 2019.

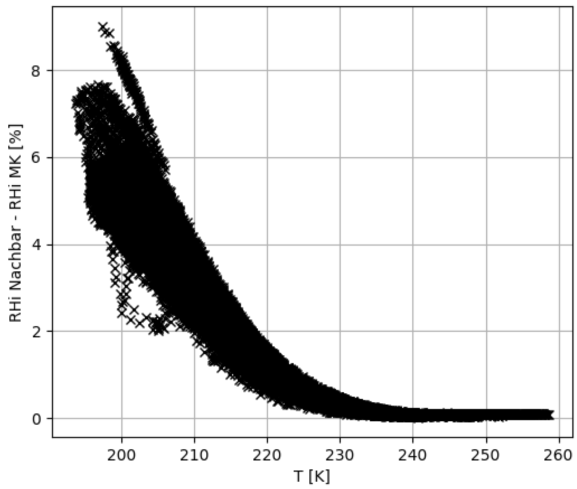
Thank you very much for raising this point and for refering to this paper we did not know. We have calculated RHl following Nachbar et al. (2019) and compared the results with the calculations using Murphy and Koop's esl formula.

The first figure herebelow compares the RHl estimations at the three levels and over the whole year 2018. One can notice that the two formulae overall give similar results.

The second and third figures shows the difference in RHl and RHi using the two formulae (at the three levels and over the whole year 2018) versus the ambient air temperature. Differences are almost always lower than 1.2 % (in magnitude) for RHl but reach a few percents at very low temperatures for RHi (as the difference in esl and esi is very small). Even if those small RH differences do not affect our overall results and conclusions regarding the fog initiation and evolution, we want to show the most accurate RH estimations as possible. Following your recommendation, we have therefore recalculated the RHl and RHi value using Nachbar's esl formula, recomputed the observational uncertainties in Appendix A and updated the figures 2,3,4,5,8,9,A0 and A1 (and the numerical RHl and RHi values given in the paper).







(5) Section 2.5: Does the Global Data Assimilation System employ a rotated grid to avoid a pole-singularity in the Antarctica area? If not, does this singularity affects data that is used to compute the backward trajectories?

The Global Data Assimilation System is based on the Global Forecast System model which uses the Finite Volume Cubed Sphere (FV3) dynamical core. The latter is a finite-volume core with no singularity at the poles :

https://www.gfdl.noaa.gov/fv3/fv3-grids/

Our back-trajectories are thefore not affected by singularity-related effects.

(6) Figure 4 and 8: I suggest to indicate the two time periods which you describe in the following subsections with "Initiation" and "Growth+Decay" within the figures, e.g. by adding two vertical arrows below the panels. In addition, I suggest to indicate the time which corresponds to each of the vertical lines shown in the panels (e.g. by adding the times at the top of the first panel). What is the meaning of the solid black horizontal line?

Thank you for this comment. We have modified Figures 4 and 8 with your suggestions. We also specify in the caption that the solid black line highlights the 100 % RHi value.

(7) Line 151: Note that Baumgartner et al (2022) describe that the homogeneous freezing of the solution particles already starts at values of RHi below the threshold given in Koop et al (2000). The rate of ice crystal nucleation increases as the values of RHi approach that threshold, but the threshold is not to be understood as a switch. In essence, as long as RHi comes close to the critical value (e.g. the threshold), the homogeneous nucleation starts and there might have been some homogeneous nucleation also at 3m height during your observation.

Thank you very much for raising this point. We agree that the Koop's threshold should not be interpreted as a binary switch. First of all, following the review by the editor M. Krämer, we have added a ± 5 % enveloppe around the Koop's curve in our graph (see the explanation in our response to her comments). Moreover and following your recommendation, we have reformulated the paragraphs analysing situations for which RHi is below but close to the Koop et al (2000)'s threshold :

For the first event :

'Given the maximum RHl and RHi values attained, the aerosol deliquescence and solution droplet freezing at 3-m a.g.l. are not very likely but their occurrence cannot be completely excluded since Baumgartner et al. (2022) show that homogeneous freezing can start at RHi values slightly lower than the Koop et al. (2020)'s threshold.'

For the second event :

'At 42-m, RHi approaches the Koop et al (2000)'s threshold between 0400 and 0500 LT 25 August and some preliminary crystal nucleation can already occur at this time.'

Minor and technial comments:

(1) Line 27: It should read "pre-conditioned"

Corrected.

(2) Line 59: "...data at Dome C, a site particularly…"

Corrected.

(3) Line 104: "droplets"

Corrected.

(4) Line 114: "to track the trajectories of the air masses probed above Dome C."

Corrected.

(5) Line 120: It should read "0600 LT" ?

Yes indeed. This has been corrected.

(6) Line 149: It should read "0800 LT, 8 March (Fig. 4)." and "2230, 7 March, at the"

Thank you. This has been corrected.

(7) Line 209-210: What is the maximum value of Rhi?

The maximum RHi value attained along the radiosounding is 113 % . We have added this information in the text.

(8) Line 213: "measurements"

Corrected.

(9) Line 247: "precipitation"

Corrected.

(10) Line 256: Delete "this"

Done.

(11) Appendix A: I found it quite hard to understand what exactly is shown in figure A1. Please state this more explicitly. It would also be helpful to add a sentence on how one should "read" these plots.

Following your suggestion, we have added the following sentence :

'Panel a (resp. b) of Fig A1 shows how the uncertainty in the RHl (resp. RHi) estimation depends on temperature. For each temperature bin on the x-axis, the dependence is explored for different RHl (resp. RHi) values below liquid saturation (color shading).'

(12) Line 281: It should read "RHl and Rhi"

Corrected.

(13) Equations A1, A2 and line 290: Please substitute the asterisk by a centered dot to indicate multiplication.

Done.

(14) Equation A2: The numbers of the regression coefficients should appear as an index.

Done.