Review of 'Unique Microphysical Properties of Small Boundary Layer Ice Particles under Pristine Conditions on Dome C, Antarctica'

by Adrian Hamel et al.

This article leverages original measurement data from a PPD-2K instrument at Dome C that enables a characterization of ice crystal optical and geometrical properties falling above the Antarctic Plateau. A statistical analysis of ice crystal size and habits over a 2 month period is presented and a particular event of ice fog and diamond dust is analysed in details with the use of additional measurements collected at the meteorological observatory. A comparison with similar measurements collected in Alaska is also presented and discussed, and the paper concludes on the uniqueness of the ice crystal properties in the pristine environment of the Antarctic Plateau.
This is a quite interesting and original study with a serious data processing and analysis. The PPD-2K offers very precious and new information on the microphysical properties of Antarctic fog. The paper is overall well written and has the potential to become a relevant contibution to the scientific literature but I think some work is needed to make the analysis and conclusions more robust before its publication in Atmospheric Chemistry and Physics.

Major comments :

- The measurements cover a summer period, where the Dome C atmospheric boundary layer exhibits a marked diurnal cycle (e.g., Genthon et al. 2010, https://doi.org/10.1029/2009JD012741
). An analysis of the possible influence of local time on the occurrence of fog and diamond dust events would be very valuable.

- Albeit infrequent, blowing snow can occur at Dome C (drifting snow is however quite common).
A more in depth analysis of the possible 'contamination' of the crystal properties's analyses by blowing snow is absolutely needed. Scatter plots showing the crystal concentration as a function of wind speed, Particle size distributions and CNN habit fractions for different wind speed classes, and wind speed time series during the analysed fog events are examples of graph that could be helpful to address this point. In particular, one may wonder to what extent the fog cloud event analysed in Fig 5 and

Sect. 3.2 is not the remobilization of ice particles (from the diamond dust event a few hours before) by the wind.

- It is stated in the paper (l259) that the diurnal cycle boundary layer dynamics only weakly affects the development of the fog. I may be wrong but Fig 5 suggests the contrary to me. The fog layer deepens in local morning associated with the growth of the boundary layer (convective activity, as seen by the vertically homogeneous temperature in panel e) and the optical thinning near local noon and sharp increase in the relative fraction of sublimating particles might suggest a fog sublimation through vertical downward transport of dry air from the top of the convective boundary layer.

- At several places in the paper (especially in the discussion), the authors mention the homogeneous freezing process. However the distinction between homogeneous freezing of – relatively large – pre-existing supercooled liquid water (SLW) droplets at ~ -38°C and the homogeneous nucleation of ice through freezing of aerosol solution particles (at temperature below -38°C) should be distinguished. Vignon et al. 2022 suggested that the ice fog they observed was formes by homogeneous nucleation (freezing of small aerosol droplets), as the events they focused on took place in winter during which the temperature is too cold for SLW to exist at Dome C. Please distinguish the two processes during the analysis and clarify the text because it is confusing at some places and the interpretation might be not always correct.

- This is a comment related to the previous one. I find really unfortunate that the authors do not show an analysis of a liquid fog event (which could possibly lead to homogeneous freezing of supercooled liquid water drops). They mention that this is left for a future work, but the current paper is not that long and can include an additional case study. Such an additionnal analysis would allow to strengthen the interpretation of the spherical habits in relation with relative humidity wrt liquid, and to reinforce the conclusions about the occurrence of homogeneous freezing (of liquid droplets) at Dome C and its role in ice fog formation in summer. I would even say that the paper cannot keep the current message regarding the occurrence of homogeneous freezing without an additional investigation of liquid fog. Please see Ricaud et al. 2025 (https://doi.org/10.1016/j.polar.2025.101256) for additional information of nocturnal liquid fog at Dome C.

- I overall find the interpretation of the small-scale optical complexity parameter k not easy to follow at many places in the paper. Can you provides details about the physical meaning of this parameter and help the reader interpret its evolution.

Minor comments :

l12-13 : This is a quite strong statement given the conclusions from this study only holds for a limited period of time at a single location in Antarctica.

l16 ‘a fraction of about 40 % clear-sky precipitation’ : this number is one estimate from one particular location. The contribution of clear-sky precipitation to the overall Antarctic precipitation is still an open question.

L33 : ‘in a commonly used parameterisation’ : are you sure the Girard & Blanchet parameterisation is ‘commonly used’ ? To my knowledge, I am not aware of many studies leveraging their microphysical parameterisation.

L37 : 2.85 and 2.57 K ? Where do those numbers come from ? How can such close numbers come from very different radiative forcings ? Girard & Blanchet (2001b) quantify the reduction in cooling rate associated with diamond dust and fog. The two types of cloud can lead to very different surface warming only if integrating over different time lengths.

Figure 1 : ‘Time of flight in a.u.’ can you specify the meaning of this label in figure’s caption ?

L112 ‘10%’ How has this number been estimated ?

L130-132 : What should the reader conclude about the difference of maintenance between the two periods ? Should we expect differences in data quality ?

L144 : The proper reference for this 7 m/s wind speed threshold to detect the occurrence of drifting snow is Libois et al. 2014
Libois, Q., Picard, G., Arnaud, L., Morin, S., and Brun, E.: Modeling the impact of snow drift on the decameter-scale variability of snow properties on the Antarctic Plateau, J. Geophys. Res.-
Atmos., 119, 662–681, https://doi.org/10.1002/2014JD022361,2014.

L148 : around → round

L149 aerosol → aerosols

L163 : ‘regularly occurs’ Please refer to Genthon et al. 2017 .

Genthon, C., Piard, L., Vignon, E., Madeleine, J.-B., Casado, M., and Gallée, H.: Atmospheric moisture supersaturation in the near-surface atmosphere at Dome C, Antarctic Plateau, Atmos.
Chem. Phys., 17, 691–704, https://doi.org/10.5194/acp-17-691-2017, 2017.

L163 : for the calculation of saturation vapor pressure.

L181 : The last sentence is awkward. Please reformulate.

L185 and Figure 3c : an additional panel with the relative humidity wrt liquid in x-axis would be helpful.

Figure 5f : please add the time series of RHliq as well. This might give insights into the ice nucleation mechanism at play.

Sect. 3.2 Can you explain why you chose this particular event and not another. Additional motivation and justification are needed.

L210 : 'radiative cooling' : not necessarily. Vignon et al. 2022 show that ice fog formation can be triggered through local cooling of the air associated with turbulent mixing.

L254 : ' layer started to weaken' → ice fog layer depth started to decrease ?

L291 : Can you really qualify a fog event as a 'precipitation event' ?

L294 : please recall the considered time period here.

L302 : 'measurement times are excluded when pollution …' this is a repetition from the Methods section.

L344 : emission → emissions

Appendix : There are too many appendices for a quite short paper (4). In particular, Appendix A and D seem not absolutely critical and can be summarized in a few words in the main text.