Response to Review #2

This paper reviews two fog cases that illustrate some unique fog formation means that have likely not been observed or well studied to date. This research is worthy of publication. There are a few key elements that of which some are critical to denote:

We gratefully thank the reviewer for the careful evaluation of our manuscript and constructive comments.

Review:

Line 35 - Supercooled liquid has been observed to 240 K at South Pole Station during the SPARCLE experiment (see https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021JD035182)…While this was at a higher altitude above the ground, it is possible to have cold temperatures and still have liquid… Hence, this should be considered in what is written here to denote this. Please revise the temperature values at which liquid water can and does exist.

Thank you very much for mentioning this very interesting paper. We have reformulated the corresponding sentence and refer to Rowe et al. 2022 :

Given the low concentrations of INPs over the Antarctic (Belosi et al., 2014), supercooled liquid droplets have been observed at very cold temperatures down to 240 K (Silber et al., 2019; Ricaud et al., 2020; Rowe et al., 2022) and they were shown to be at the origin of fogs over the Antarctic coast (Kikuchi, 1971, 1972).

Line 70 - Averaging data over 30 minutes is a long time. This reviewer is not in favor of this practice as you are smoothing out the data before analysis….which this is less of an issue with slower changing parameters like pressure (not used in this study) but it has a larger impact on faster moving variables such as temperature and wind. As a note, 30 minute averaging is at least 3 times beyond the WMO recommendations which recommend averaging over small time frames (1 minute for temperature, 2 minute or 10 minute for wind) see WMO Publication #8). While we can debate the merits of this, I wonder the impact it would have in interpreting the 25 August case between 6 and 15 LT when the RHi goes above the Koop et al (2000) value. How might the data observations look in this time period without the 30 minute averaging, but instead 10 minute averaging? This non-standard method for handling the data impacts future comparisons likely to be made by others and other observational datasets that do not do this. This contributes to the heterogeneous observing network Antarctic suffers from, and it is not getting any better with divergent observing schemes that are in place.

Thank you for this very relevant comment. In 2009 when the first instruments were deployed on the 45m mast at Dome C, we chose to save 30-min statistics (mean, min, max and variance, see Genthon et al. 2010). 30 min was a good trade-off between the typical time-scales of processes we wanted to characterize and the storage capabilities at that time. Moreover, it should be underlined that the response time of the humicap sensor of the HMP increases well beyond 1 min at T <60°C (Vaisala, personal communication) and a 1-min resolution is very likely not adapted for relative humidity data at low temperature. The temperature, wind and humidity datasets officially published and distributed (Genthon et al. 2021, 2022) thus have a 30-min resolution for consistency of the data format throughout the period of measurements.

Nonetheless, for scientific motivations and to comply with WMO standards, 1-min wind, temperature and humidity data have consistently been saved but only since 2019. Unfortunately, no humidity measurement is available for the period of the second fog event and we are not able to analyse the 25 August fog event using data at higher temporal resolutions. We tried to identify a similar but more recent potential fog event from RHi time series and found one in June 2020. The figure below shows that RHi evolves quite smoothly during the fog formation. Even though a higher time resolution helps identify more accurately the RHi value and the time at which ice crystals nucleate, the general conclusions regarding the evolution of RHi during the fog formation are the same using 10-min and 30-min averages.

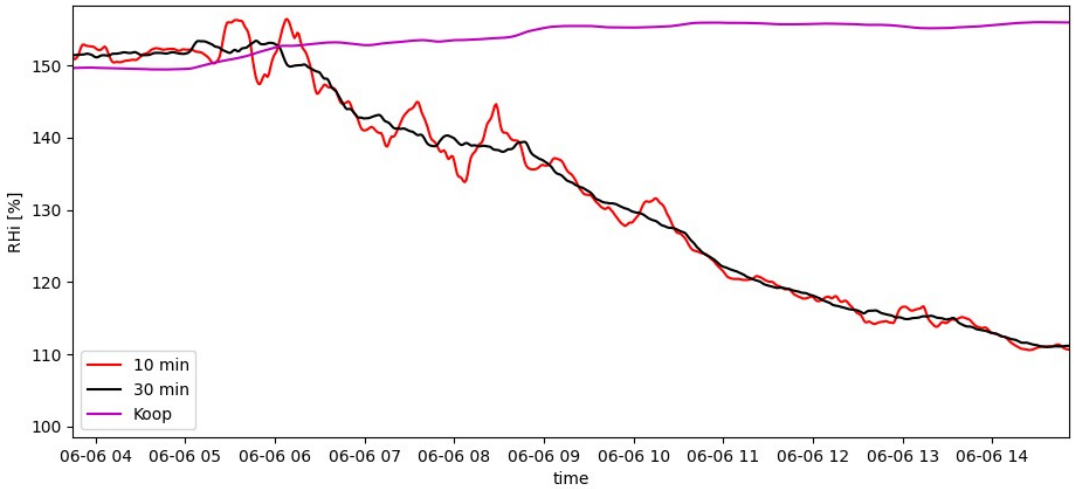

Figure : 18-m RHi time series in June 2020. The red (resp. black) line show 10-min (resp. 30-min) moving averages of 1-min resolution data. The purple line shows the Koop (2000)'s threshold.

Genthon C, Town MS, Six D, Favier V, Argentini S, Pellegrini A. 2010. Meteorological atmospheric boundary layer measurements and ECMWF analyses during summer at Dome C, Antarctica. J. Geophys. Res. 115: D05104, doi: 10.1029/2009JD012741

Genthon, C., Veron, D., Vignon, E., Six, D., Dufresne, J. L., Madeleine, J.-B., Sultan, E., and Forget, F.: Ten years of wind speed observation on a 45-m tower at Dome C, East Antarctic plateau, https://doi.org/10.1594/PANGAEA.932513, 2021

Genthon, C., Veron, D., Vignon, E., Madeleine, J.-B., and Piard, L.: Water vapor observation in the lower atmospheric boundary layer at Dome C, East Antarctic plateau, https://doi.org/10.1594/PANGAEA.939425, 2022.

Line 80 - As I read through the cases, I wonder if it would help the reader to know more about the Murphy and Koop methodology, as seeing an RH value of over 100% seems unexpected (but it is fine, correct?).

We refer to Murphy and Koop here as they provide state-of-the-art formulae for the saturation vapor pressure with respect to liquid and ice phases. We guess you mean that further details are needed to explain the Koop (2000)'s (nor Murphy and Koop's) approach to explain the homogeneous freezing at high supersaturation values. Following your recommandation and the one from the editor, we have therefore added the following paragraph in Sect. 2.2 :

To detect the possible occurrence of homogeneous freezing of solution aerosols, we will compare our RHi measurements with the so-called Koop et al. (2000)'s threshold. In the approach of Koop et al. (2000), solution particles spontaneously freeze when RHi exceeds a threshold value that primarily depends on temperature. As a first approximation, we calculate the RHi threshold value (RHi_T , in %) using the analytical fit of Koop et al. (2000)'s experimental results derived in Ren and Mackenzie (2005):

$$RHi_T = (2.349 - T/259) \cdot 100$$

where T is the temperature in Kelvin. This fit has been performed for solution particles in equilibrium with the ambient vapor that have a typical radius of 0.25 µm and that can freeze homogeneously within 1 min (see also Kärcher and Burkhardt, 2008). The exact value of the threshold also depends on the size of the particle as well as on the composition thereof and on theformulation and uncertainties of water activities and saturation vapor pressure. Individually, those effects make RHi_T vary by about 1 to 5 % (see Baumgartner et al., 2022). An envelop of 5 % has therefore been added around the Koop's curve in our graphs. This envelop is only intended as a rough indicator of the uncertainty and to guide the eye.

Also, the RHi vs. RHl seem to be the same curves with an offset (?) Using RH overall is a terrible measure of actual moisture anyways…and RHi clearly shows that you are saturated or supersaturated with respect to ice.

Thank you for this comment. The ratio between RHi and RHl is a function of temperature only (esl(T)/esi(T)). In Fig. 4 and 8, as temperature does not substiantially vary, the RHl curve looks shifted from RHi but this is physically consistent. We agree with you that RHi is the most informative variable for our work but the examination of RHl informs about the potential degree of deliquescence of aerosols (and possible subsequent homogeneous freezing). This is why we show both RHi and RHl in Figures 4, 8 and B1.

Figure 2 - Is this for the March 8th case? Some indication of dates/times in the caption would be helpful.

We have reformulated the caption as follows :

Panel a: Time-height plot of the lidar backscattering signal intensity during the first fog event between 12 LT, 8 March to 00 LT, 10 March 2018. The red line indicates the radiosonde launching time. Panel b shows the vertical profile of temperature (blue) and potential temperature (calculated with a reference pressure of 10^5 Pa, red) from the radiosounding. The black arrow indicates the top of the boundary layer. Panel c shows the vertical profile of relative humidity with respect to ice (RHi, red) and with respect to liquid water (RHl, blue) from the same radiosounding.

Figure 3 - So this case, you have wind speeds clearly over the threshold for blowing snow, yet it is not reported nor happening? (Also see lines 125 through 130…)

To our knowledge, blowing snow has never been reported at Dome C but snow drift does occur when the wind is sufficiently strong. We cannot report the occurrence of drifting snow as the lowest lidar reliable gate is at ~ 20 m a.g.l. i.e at a height much higher than a typical drifting snow layer depth. Moreover, no instrument specifically designed to detect blowing snow such as Flowcapts or SPCs have been deployed at Dome C so far.

A Campbell SR50 acoustic depth gage measures the local variation of the snow surface at Dome C (see Genthon et al. 2015) but the surface footprint of the SR50 is very small and no robust conclusions regarding the occurrence of snowdrift can be drawn from the measurements of a single instrument. We have therefore specified in the text that snow drift is possibe when the wind speed exceeds the threshold value :

'Note that at 2200 LT, 7 March and after 0600 LT, 8 March, the 3-m wind speed exceeds the threshold and some snow drift is therefore possible during those periods.'

Genthon, C., D. Six, C. Scarchilli, V. Ciardini, and M. Frezzotti (2015), Meteorological and snow accumulation gradients across Dome C, East Antarctic plateau, Int. J. Climatol., 36, 455–466, doi:10.1002/joc.4362.

Line 120 - Reference Figure 4 here with the RHi value referenced…

This paragraph portrayed the overall evolution of the fog from the lidar measurements. The evolution of the relative humidity from the hygrometers data is thoroughly described in subsequent paragraphs. To avoid any confusion, we prefer not to refer to Fig. 4 in this paragraph.

Line 150-155 Is it fluxing downward and the atmosphere is not decoupled at all above?? *** Unlikely there is decoupling?***

Thank you for raising this point. Indeed the 3-m level is not decoupled from the atmosphere above. However, the vertical gradient of partial pressure is stronger near the surface, one can therefore reasonably assume that the divergence of the flux at 3-m is positive (leading to a decrease in moisture content). We now specify in the text that we speaking about the 'net' flux.

Line 205 - Is the 20 meters from human observation?

We now specify 'above ground level' in the text.

Line 217 - This stray sentence should be combined with the paragraph above.

Done

Line 243 - This stray sentence should be combined with the paragraph above.

The paragraph has been reformulated to answer a comment from a second reviewer. There is no stray sentence anymore.

Figure 10 is really helpful - just too small. Is there anyway it can be published to be larger to see the red text??

Following your recommandation, we have increased the size of the figure.

Figure B2 is too small to see - hopefully this can be improved in publication

The size of this figure has also been increased.

Minor langage/English:

Line 5 - Remove “To our knowledge” is not really needed… Just say “This is the first time…”

Corrected.

Line 40 - Remove “hitherto” as it is not needed

Corrected.

Line 256 - Correct the line “To our knowledge, this our study presents…” to simply say “This study presents…”

Corrected.

Line 262 - Remove “ we raised in the Introduction” as it is not needed

Corrected.

Line 285 - Add “thermometer” at the end of this bullet point.

Added.