Anonymous Referee #2

I find this paper to be a clear discussion of factors contributing to "warm" and "cold" clouds over Dome C. Also, it offers a good comparison of a number of measurement techniques and modelling. The result that advection patterns are a main driver of the differences between the warm and cold clouds is interesting, and I think it is suitable for ACP. The conclusions are mostly well founded. The paper is quite long, but it is very well organized and easy to read except for some small grammatical issues that I include with my following comments.

→ We first would like to thank the reviewer for his/her positive general review. Specific changes have been made in response to his/her specific comments that are described below.

Comments:

1) Line 20-23 – Re-write something like "Episodes of thick cloud and diamond dust during 15 March to 8 April 2011 and 4 to 5 March 2013 in the atmosphere above Dome C (Concordia station, Antarctica, 75 ◦ 06'S, 123 ◦ 21'E, 3233 m amsl) were measured and modelled."
→ Done.

2) Line 23 – "The measurements were obtained from the following instruments: 1) . . ."
→ Done.

3) Line 35 – remove "by all datasets"
→ Done.

4) Line 76 – remove "also"
→ Done.

5) Lines 85-88 – ". . . experiences cloud about 30% of the time at altitudes below 3 km and less than 10% of the time above 5 km. Cloud occurrence over the western continental region is about 50% below 3 km and about 30% from the surface up to 8 km."
→ Done.

6) Lines 109-110 – replace "investigating" with "on". Remove "from" in both places. Replace period after "used" with a semi-colon.
→ Done.

7) Line 121 – please add a reference for the AROME model here.
→ We have inserted the reference to Seity et al. (2011) here instead of in the AROME section 2.6. as requested by the reviewer.

Note that in the AROME section 2.7 we have replaced the reference Bosveld et al. (2014), relevant to GABLS3, by Bazile et al. (2015) that was more appropriate to GABLS4.

Bazile, E., Couvreux, F., Le Moigne, P., and Genthon, C.: First Workshop on the GABLS-4 Intercomparison, GEWEX Newsletter, pp18-19, August 2015.

8) Line 129 – remove first "the".
→ Done.

9) Line 132 – remove first “the”. Remove third “the”.
→ Done.

10) Lines 154-155 – Please clarify the biases. E.g. “Compared with the radiosondes, the radiometer temperatures are biased 1-5 K lower at altitudes below 4 km and 5-10 K higher above 4 km.“ Similarly for the “wet” bias.
→ Based on previous studies and comparisons with radiosondes and space-borne measurements reported in Ricaud et al. (2015), “we can infer three recommendations regarding the HAMSTRAD data. 1) HAMSTRAD IWV measurements from 2009 to 2014 are of excellent quality (linear Pearson correlation coefficients $r > 0.98$) and can be used without retrieving any bias. These 7-minute time resolution data can be suitable for any scientific analysis considering both an absolute comparison (in unit kg m^{-2}) and a relative time evolution of this parameter (e.g. a temporal anomaly). 2) HAMSTRAD temperature measurements are suitable for scientific analyses over the range 0-10 km with a high time correlation ($r > 0.80$) with radiosondes. The time evolution of this parameter over the period 2009-2014 with a resolution of 7 minutes is meaningful. Nevertheless, the vertical distribution of temperature from 0 to 10 km is subject to biases that need to be removed if the scientific analyses require the use of vertical profiling. 3) HAMSTRAD absolute humidity measurements are suitable for scientific analyses over the range 0-4 km. Above 4 km, both the amount of H_2O dramatically decreases and the instrument loses sensitivity. The time evolution of this parameter over the period 2009-2014 and over the range 0-4 km with a resolution of 7 minutes is meaningful ($r > 0.70$). Nevertheless, the vertical distribution of absolute humidity from 0 to 4 km is subject to biases that need to be removed if the scientific analyses require the use of vertical profiling.”

In the revised version, in order to shorten the manuscript, we no longer show IWV HAMSTRAD data and we do not compare absolute humidity HAMSTRAD data with radiosondes anymore. We have thus modified the incriminated sentences accordingly.

> Statistically, it has been shown that, against radiosondes from 2009 to 2014, there is a 1-5 K cold bias below 4 km, and a 5-10 K warm bias above, with a high time correlation (linear Pearson correlation coefficient $r > 0.80$). There is a wet bias of 0.1-0.3 g m^{-3} below about 2 km and a dry bias of ~0.1 g m^{-3} above, with a high time correlation below 4 km ($r > 0.70$). Yearly-averaged vertical profiles of the biases in temperature and absolute humidity are also provided from 2009 to date at the same http address. Note we have not debiased HAMSTRAD data in the present study.

11) Line 178 – remove first “the”.
→ Done.

12) Lines 224-226 – “AROME was used within the GEWEX Atmospheric Boundary Layer Study 4 (GABLS4) to study the meteorological evolution over the Dome C station (Bosveld et al., 2014).”
→ Done.

13) Lines 269-271 – Can you offer any explanation for this large difference?
→ We no longer show a comparison between HAMSTRAD and AROME temperature in a planetary boundary layer in the revised manuscript. This line and the associated Figure have been removed.

14) Lines 309-311 - AROME is wetter than the radiosondes in the figure. I think your respective values here should be reversed.
→ Done.

15) Line 316 – remove "much"
→ Done.

16) Line 322 – Change "Consistently" to "Consistent", replace "drawn with" with "concerning" and remove the last "the".
→ Done.

17) Line 340 – remove "much"
→ Done.

18) Line 347-348 – Change to "There was no abrupt increase of longwave downward radiation as during the warm and. . ."
→ Done.

19) Line 395 – Change to "We gain more insight into the vertical structure. . ."
→ Done.

20) Lines 423-424 – Please elaborate on why mixing of the air beneath the inversion causes the supersaturation w.r.t. ice.
→ We have rewritten the incriminated sentence into:

> In the Eastern Antarctic Plateau over all the seasons except summer, a strong surface-based temperature inversion persists in which small ice crystals referred to as diamond dust/ice fog form in the boundary layer (Walden et al., 2003).

21) Lines 433-435 – Change to "The second episode, which is much shorter than the first, relies on the same datasets presented in Section 3. The only difference is that the model analyses are only from the meteorological operational model ARPEGE that. . ."
→ Done.

22) Lines 443-444 – Please elaborate on ". . .with a explain transition propagating in the HAMSTRAD data up to 4 km altitude, probably due to the vertical resolution of the microwave measurements." Are you saying that the transition (and please define transition) reaches 4 km because the vertical resolution is poor? You mention that the resolution is 500 m. Does that mean the transition height might be 3.6 km instead of 4 km?
→ The reviewer is right. Due to the vertical resolution of the microwave radiometer a "transition height" of 4.0 km should be labelled as 4.0 ± 0.5 km. The "transition region" we were referring to was the 0-K temperature anomaly isoline delimiting the warm period on 4 March to the cold period of 5 March in the lower troposphere. Along the vertical, the 0-K temperature anomaly isoline is located around 2.4 km on 4 March in the ARPEGE dataset whilst it is higher up around 4.0 ± 0.5 km in the HAMSTRAD data set. We have rephrased the incriminated sentence in the new version of the manuscript.

> Considering the 0-K temperature anomaly isoline, both datasets show a warm period on 4 March followed by a cold period on 5 March from the surface to about 2.4 km altitude on 4 March by ARPEGE and to about 4.0 ± 0.5 km by HAMSTRAD. The 1.6-km difference between the altitude of the 0-K temperature anomaly isoline in HAMSTRAD and in ARPEGE data sets on 4 March might be due to the poor vertical resolution of HAMSTRAD compared to ARPEGE.

23) Line 474-475 – "Consequently, this 12 hour period on 5 March can neither be attributed to clear sky nor to thick cloud episodes."
→ Done.

24) Line 482-483 – Change "The ARPEGE simulation indicates an ice cloud from the surface to near 4 km on 4 March with the top altitude decreasing. . ."
→ Done.

25) Lines 494-495 - What is the temperature in this regime? You show no temperatures for episode 2, only tendencies. The reduced polarization may indicate water droplets, but it could also be due to change in the crystal ice habit. Your statement needs to be supported by appropriate temperatures or changed to read that there is a discrepancy in the interpretation between the reduced polarization and the temperature.
→ Both temperature and absolute humidity anomalies decrease over the period 00:00-10:00 UTC on 5 March (Figs. 10 and 11, respectively). We now can consider the time evolution of the number of ice crystals measured by the ICE CAMERA integrated over one hour from 4 to 5 March 2013 above the Dome C station (Fig. R7). We notice that, over the concomitant period, the number of ice crystals detected by the ICE CAMERA dramatically decreased from ~700 to ~200, whatever the crystal ice habit size greater than 20 µm. In the presence on liquid particles, there is a strong Lidar raw signal together with a low depolarization signal as it is visible on Figure R8 around 100 m. Consequently, the reduced polarization detected in Fig. 14 reflects the presence of supercooled liquid water and not ice crystals.

We have inserted the Figure R4 in the new version of the manuscript and have rephrased the incriminated sentence into:

> We now can consider the time evolution of the number of ice crystals measured by the ICE CAMERA integrated over one hour from 4 to 5 March 2013 above the Dome C station on Figure 15. We notice that, from 00:00 to 10:00 UTC on 5 March, the number of ice crystals detected by the ICE CAMERA dramatically decreased from ~700 to ~200, whatever the crystal ice habit size greater than 20 µm. There is also a strong Lidar raw signal (not shown) together with a low Lidar depolarization signal (Fig. 7) around 100 m, signature of liquid particles. Consequently, the reduced polarization detected in Fig. 14 reflects the presence of supercooled liquid water and not the presence of ice crystals.

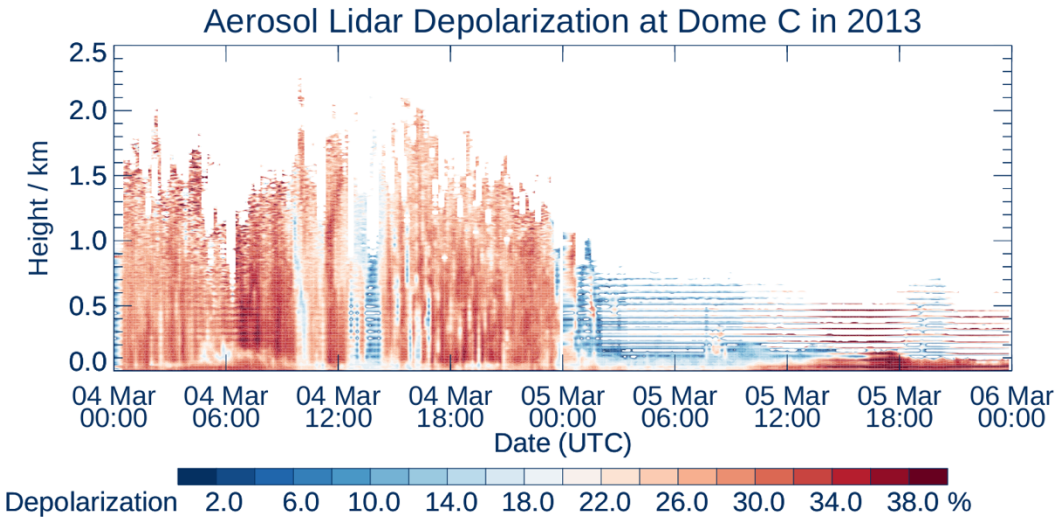

Fig. 14: Time evolution of the Depolarization ratio (%) from 4 to 5 March 2013 above the Dome C station as measured by the aerosol Lidar installed at Dome C.

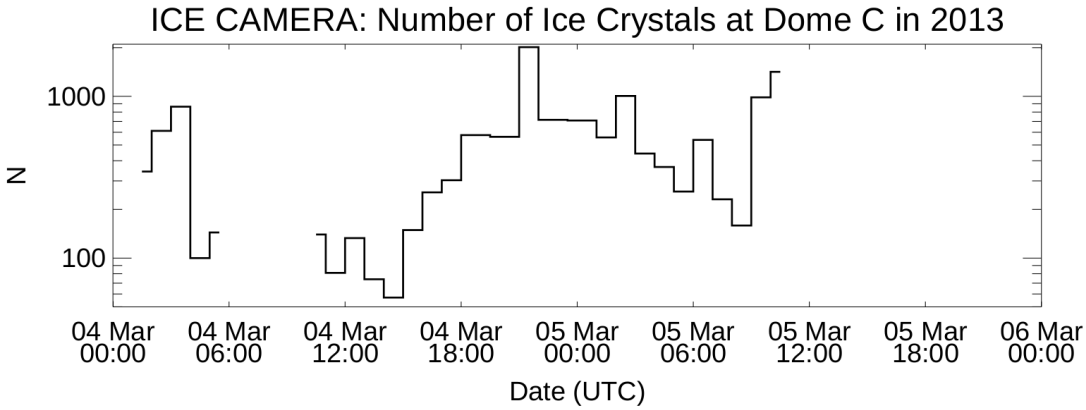

Figure R7: Time evolution of the number of ice crystals measured by the ICE CAMERA integrated over one hour from 4 to 5 March 2013 above the Dome C station.

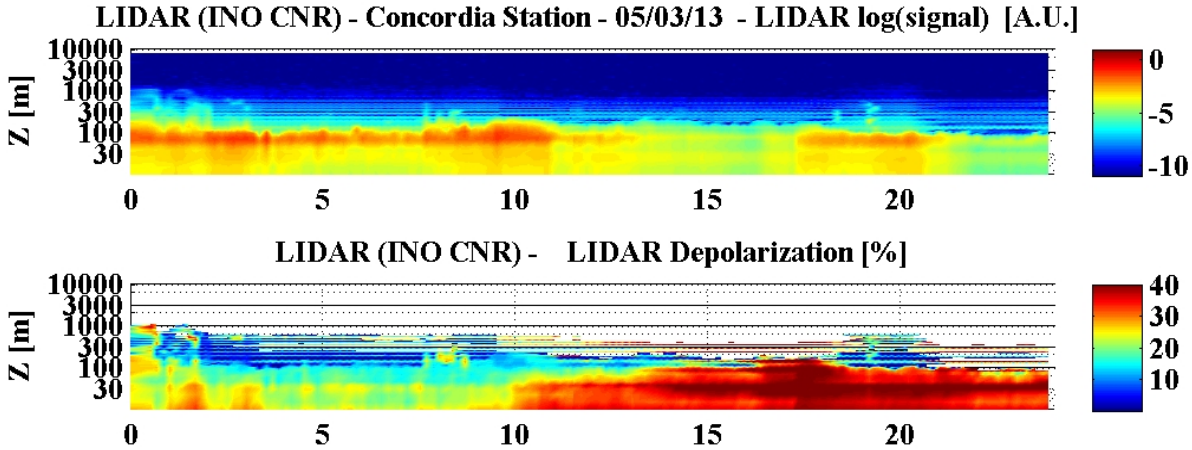

Figure R8: Time evolution of the Lidar raw signal (top) and depolarization (bottom) measured on 5 March 2013 above the Dome C station.

26) Lines 496-498 – What vertical structure are you referring to? There is considerable vertical structure in the depolarization across the time period 1000-2400 on March 5 and within the lower few hundred metres. You can't say with any certainty here that there was no precipitation of ice crystals. Even diamond dust is large enough to fall out unless there is sufficient vertical wind to maintain their suspension. Please revise.

→ Indeed, the reviewer is right. When considering the depolarization ratio measured on 5 March 2013 (Figure R9) in the lowermost troposphere (0-500 m), some traces of vertical structures are present around 18:00 UTC, signature of precipitation. In the literature, it is not easy to estimate the fall velocity of ice crystals depending whether we consider ice fog or diamond dust. Bürgesser et al. (2016) refer to small (ice fog) particles; whilst Böhm (1989) refer to large ice crystals (diamond dust). From Bürgesser et al. (2016), the fall velocity for columnar ice crystal with lengths ranging 20-160 µm is ranging 1-6 cm s^{-1}. From Böhm (1989), the terminal velocity for radiative assemblage of dentrites, unrimed plates, side planes, bullets and columns is ranging 0.35-0.75 m s^{-1} for diameters ranging 0.2-1.0 mm and the terminal velocity of unrimed side planes with diameters ranging 0.4-1.0 mm is ranging 0.65-0.85 m s^{-1}. But it is beyond the scope of the present paper to discuss the fall velocity of the ice crystals.

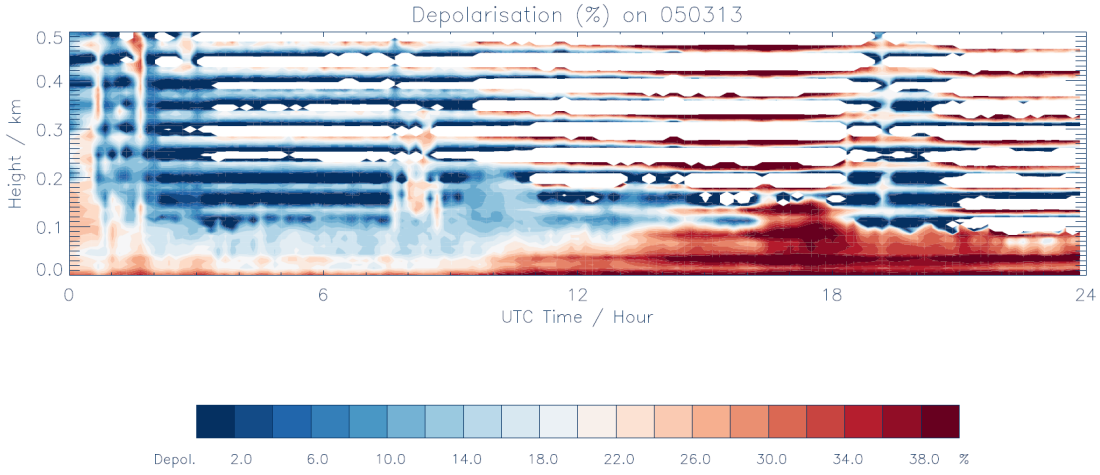

Figure R9: Time evolution of the Depolarization Ratio (%) measured on 5 March 2013 above the Dome C station from the surface to 500 m above the ground.

Böhm, H. P.: A general equation for the terminal fall speed of solid hydrometeors. J. Atmos. Sci., 46, 2419-2427, 1989.

Bürgesser, R. E., Ávila, E. E. and Castellano, N. E.: Laboratory measurements of sedimentation velocity of columnar ice crystals. Q. J. R. Meteorol. Soc., 142, 1713-1720, 2016. doi:10.1002/qj.2766.

Note that when considering the depolarization ratio measured on 4-6 April 2011 (Figure R10) in the lowermost troposphere (0-500 m), some traces of vertical structures are also present, signature of precipitation. Consequently, we cannot mention, as we did L. 411 of the previous

version, “there is no trace of precipitation”. Therefore, we have rephrased the sentence in the revised version of the manuscript.

> The high depolarization ratio shows that the cloud is constituted of ice crystals and, since there are no other layers higher in the troposphere (as during the warm and wet period), there is little trace of precipitation.

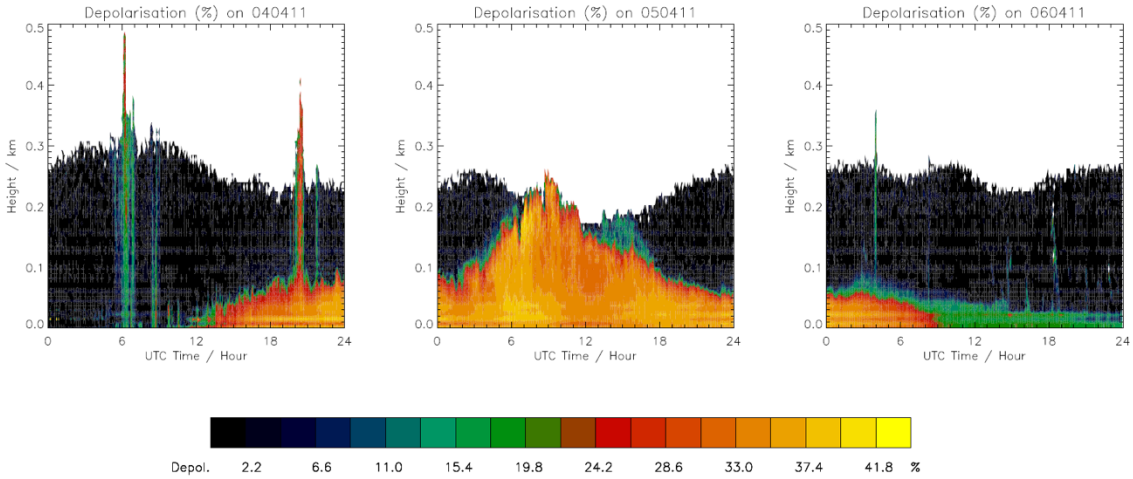

Figure R10: Time evolution of the Depolarization Ratio (%) measured on 4-6 April 2011.

27) Line 510 – Please revise to “. . . of ice crystals with a longer suspension time in the air.”
→ Done.

28) Lines 520-523 – change “were presented” on line 522 to “is discussed”. You are discussing the “impact”.
→ No, the subject is not “the impact” but both “the impact” and “the high correlation”. We modified the incriminated sentence into:

> Both the impact of the origin of air masses on the short-term variability of H_2O and temperature and the high correlation coefficient (greater than 0.90) between water vapour and temperature at Dome C over the entire year 2010 were presented in Ricaud et al. (2012 and 2014c) based on 5-day back-trajectory calculations.

29) Line 564 – Replace “If we consider the” with “The”. Remove “as”.
→ Done.

30) Line 565 – Remove the first “the”.
→ Done.

31) Line 566 – Replace “, we obviously remark” with “show”.
→ Done.

32) Line 569 – Remove “indeed”.
→ Done.

33) Line 575 – Replace “slight” with “smaller”.

→ Done.

34) Line 578 – "thick-cloud episodes"
→ Done.

35) Line 580 – ". . . the diamond dust episodes occurred during. . ."
→ Done. We have rephrased the incriminated sentence into:

> Consequently, considering episodes 1 and 2, the thick-cloud episodes observed during the warm and wet period above Dome C are attributed to air masses with an oceanic origin whilst the diamond dust/ice fog episodes occurred during the cold and dry period are attributed to air masses with continental origins.

36) Line 584 – "Here, we attribute the tendencies of . . ."
→ Done.

37) Line 585 and 586 – Replace "into" by "among"
→ Done.

38) Section 5.3 – Please explain why this attribution was not be done for episode 1?
→ The budget computation is done during the model integration on a pre-defined area around Dome C. It requires a large-scale area to estimate the advection tendency but can be done only over a short period, as during episode 2 with the ARPEGE global-scale model. AROME is a meso-scale model and can provide this parameter only to within its domain (250x250 km) and for a long period (episode 1). So the advection tendency is not meaningful for AROME during episode 1.

39) Line 604 – remove "a". change "on" to "in"
→ Done.

40) Line 607 – what are "small precipitations"?
→ The term "weak precipitations" has been used instead of "small precipitations".

41) Line 609-610 – Does this sentence, which refers to dehydration of the PBL and includes "precipitation", contradict your statement at the end of section 4.4 that the diamond dust does not precipitate? See also above comments 26 and 27.
→ You are right. There are indeed traces of precipitation. See discussions 26.

42) Lines 600-610 – You refer to microphysics as the one of the factors influencing the water vapour budget. I know you are using the model with microphysics, but it is not clear from your discussion if the influence on the water budget is truly microphysics or just the presence of cloud. Please clarify in Section 5.3.
→ The negative tendency of Qv only means condensation so water vapour transforms to liquid or ice droplets. Clouds have only impact on the temperature budget through the radiation.

43) Line 650 – "Since both downward and upward longwave radiation are greater than. . ."
→ Done.

44) Line 665-666 – ". . . suggesting that the cloud consisted of smaller ice crystals that may remain suspended in the air longer."
→ Done.

In conclusion, 5 new references have been inserted in the revised manuscript:

Bazile, E., Couvreux, F., Le Moigne, P., and Genthon, C.: First Workshop on the GABLS-4 Intercomparison, GEWEX Newsletter, pp18-19, August 2015.

Girard, E. and Blanchet, J. P.: Microphysical parameterization of Arctic diamond dust, ice fog, and thin stratus for climate models. J. Atmos. Sci., 58, 1181-1198, 2001.

Gultepe, I., Kuhn, T., Pavolonis, M., Calvert, C., Gurka, J., Heymsfield, A. J., Liu, P. S. K., Zhou, B., Ware, R., Ferrier, B., Milbrandt, J. and Berstein, B.:Ice fog in Arctic during FRAM-ICE Fog project: Aviation and Nowcasting Applications, Bull. Am. Meteor. Soc., 95, 211-226, 2014.

Lazzara, M.: Diagnosing Antarctic fog, 5th International Conference on Fog, Fog Collection and Dew, Münster, Germany, 25-30 July 2010. Vol. 1, p. 150. (http://meetingorganizer.copernicus.org/FOGDEW2010/FOGDEW2010-150.pdf)

Vié, B., Pinty, J. P., Berthet, S., & Leriche, M. : LIMA (v1. 0): A quasi two-moment microphysical scheme driven by a multimodal population of cloud condensation and ice freezing nuclei. Geosci. Model Dev., 9, 567-586, 2016.