We would like to thank the reviewer for their valuable comments and suggestions which have improved this manuscript. We have modified the manuscript to include the proposed changes along with step-by-step answers to their suggestions.

Reviewer #2

The authors present a study to retrieve extinction-to-microphysics conversion parameters of pollen aerosol. These conversion parameters can be applied to profiles of pollen aerosol-optical properties derived by polarization lidar observations in order to estimate profiles of cloud-relevant properties, in this case pollen cloud condensation nuclei concentrations. The presented method is analogous to the well-established POLIPHON (Polarization Lidar Photometer Networking) method, however it is using ceilometer with polarization capability and ground-based in situ observations instead of long-term AERONET sun photometer observations to link particle extinction with particle size distributions. This link is then exploited to retrieve abovementioned conversion parameters.

Such novel (in terms of aerosol type) conversion parameters are always sought-after for the application to lidar profiles all over the world, either from ground-based long-term observations or networks, or from space-borne lidars, which allows to retrieve climatologies of microphysical and cloud-relevant properties. Furthermore, very special observations periods at specific sites equipped with appropriate instrumentation are needed to perform such correlation studies.

Therefore, the manuscript is suited for publication in Atmospheric Chemistry and Physics and can be published almost as is after addressing rather minor comments/questions listed below.

Major comment:

My main question following hereafter is with regard to wavelengths and wavelength conversion. 355 and 532 nm are much more common lidar wavelengths (of ground-based but also space-borne systems, which you mention in your conclusion), especially concerning polarization capability. I believe it would be worth adding some statements to the manuscript regarding this topic.

Thank you for your suggestion. In addition to the 910 nm wavelength from CL61 ceilometer, we have added PollyXT observations and provided the number, mass and CCN-related conversion factors at 532 nm, as well. Similar to CL61 ceilometer observations, we have performed the Klett inversion (backward) to PollyXT 532 nm observations since the combination of background light, overlap height and boundary layer height impairs the Raman retrieval and limits the availability and diversity of cases in terms of pollen loads. Note that observations at 355 nm are omitted due to the high overlap which is at 800 m which together with the birch PDR which is close to the background PDR in this wavelength, introduces high uncertainty in the retrievals and limits the availability of cases. As an outcome, a new section has been added to the manuscript and Figs. 5, 6 and 7 have been updated.

There is a PollyXT is at this site (Line 75)? Does it have near-range Raman capability? Its data are obviously not used in this study. Is there a specific reason for that? I see that there would be potentially two problems: first, the pollen being present at very low ranges below the overlap region of that larger lidar; and second, potentially the polar day at these high latitudes in summer (already in May?) impairs Raman retrieval due to background light.

At least in e.g., Bohlmann et al. (2019, 2021), this seemed to be not a significant problem, and at least backscatter and depolarization profiles down to low ranges at low vertical averaging would be retrievable by Raman method (at nighttime), even lower using near-range capability, including extinction, however missing depolarization, if I understand the (obviously various) PollyXT setups correctly.

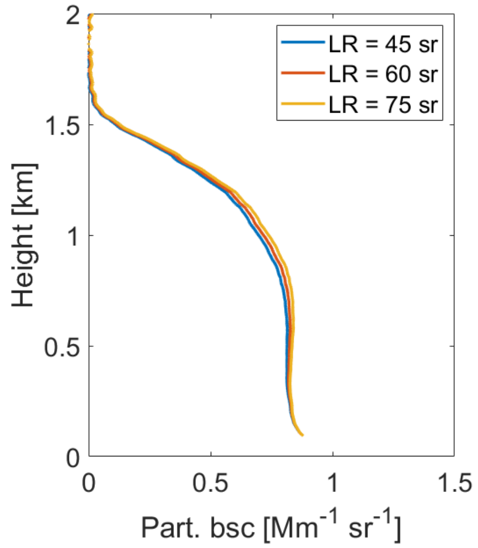
Could/did you compare nighttime Raman extinctions (at 355 and 532 nm) to the Klett-retrieved extinction (from backscatter, at 910 nm)? What about somehow verify the choice of the lidar ratio (of 60 sr at 910 nm) or discuss the sensitivity of the retrieved conversion parameters on that choice?

As Bohlmann et al. (2019, 2021), Shang et al. (2020, 2022) and Filioglou et al. (2023) nicely discussed pollen lidar ratios, depolarization ratios, however, for 355 and 532 nm wavelength, and maybe most importantly in this context here, also some Ångström exponents (also backscatter-related 532/1064 and 532/910, respectively), it would be very beneficial at least to discuss/provide some more literature values or methods/ideas/suggestions helping in the wavelength conversion of your results.

The PollyXT version installed in Vehmasmäki does include a near-field Raman capability, but polarization measurements are available only in the far-field view. Related to the Raman inversion, pollen activity usually peaks during daytime which prohibits the use of Raman channels while during nighttime, the boundary layer height is low, limiting the availability and diversity of cases in terms of pollen loads. An added difficulty is the geographical location of the station which from May and on there is no night with the sun staying between 6 and 12 degrees below the horizon at the darkest hours. In fact, the PollyXT cases added in the manuscript are during daytime (between 06 and 16 UTC) with only 2 cases at 18 UTC (21 local time).

Having said that, in the link below you can find Raman retrievals for the 12th of May 2021 for PollyXT instrument available online at PollyNET. Targeting the darkest hour at the station, which is around 21-23 UTC (the last two rows of graphs in the provided link), we can see lidar ratios fluctuating between 50 and 80 sr in the lowest 1 km. It is evident that the Raman-shifted wavelength at 607 nm is noisier compared to the 387 nm. A similar solution but applying a vertical smoothing window of 21 bins which translates to 157 m and averaging between 21 and 23 UTC, can be found below. In addition to the PollyXT optical products, the CL61 ceilometer particle backscatter coefficient and particle depolarization ratio have been added. We have also used the decomposition method to derive the ratio of birch pollen in the mixture. Accounting for the overlap and vertical smoothing, profiles above 400-500 m can be considered. At 500 m, the particle depolarization ratio value is 0.20 at 532 nm (0.13 at 910nm) and Angstrom exponents are in the range of 0.45-0.86 pointing to mixtures of pollen and background aerosols. This can also be seen in the birch share profiles. At the moment this is the best guess of the lidar ratio as already mentioned in the studies above but surely more efforts should be put for deriving the lidar ratio of birch pollen.

The lidar ratio selection introduces negligible uncertainty in the boundary layer for the forward inversion. This is visualized in the example below, where a forward Klett inversion has been performed for a variety of lidar ratios (LRs). In the backward Klett inversion the LR induces greater variability as shown in Shang et al., (2021). Note that all other parameters are kept constant except the LR. Since the lidar ratio is decisive for converting the particle backscatter to extinction coefficient regardless of the inversion method, we have included a sensitivity study summarized in the tables below which show how the conversion factors change depending on the selection of the lidar ratio. The tables have been included in the manuscript as well.



Shang, X., Mielonen, T., Lipponen, A., Giannakaki, E., Leskinen, A., Buchard, V., Darmenov, A. S., Kukkurainen, A., Arola, A., O'Connor, E., Hirsikko, A., and Komppula, M.: Mass concentration estimates of long-range-transported Canadian biomass burning aerosols from a multi-wavelength Raman polarization lidar and a ceilometer in Finland, Atmos. Meas. Tech., 14, 6159–6179, https://doi.org/10.5194/amt-14-6159-2021, 2021.

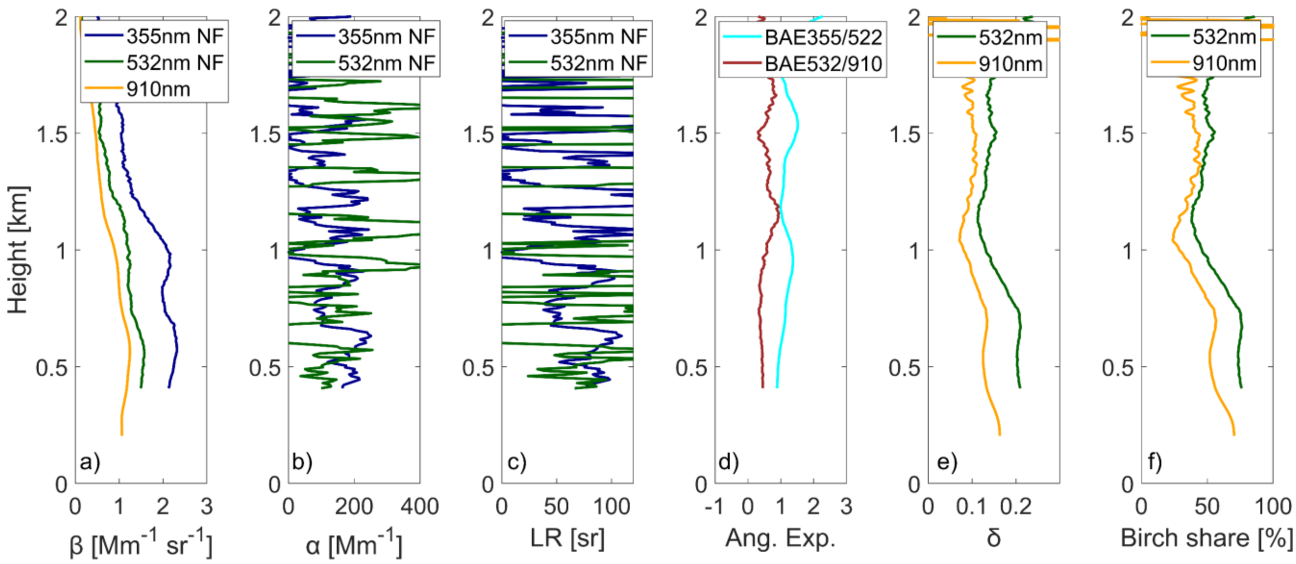


Figure: a) Raman-estimated particle backscatter coefficients at 355, 532 and 1064nm from PollyXT lidar. For 355 and 532 nm, the near-field (NF) signals have been used. Particle backscatter coefficient at 910 nm from CL61 ceilometer is shown in solid orange line. b) Particle extinction coefficient at 355 and 532 nm. c) Lidar ratio profiles at 355 and 532 nm. d) Backscatter-related Angstrom exponents. e) Particle depolarization ratio at 532 and 910 nm. f) Estimated birch share in the total backscatter from 532 nm and 910 nm using the decomposition method.

		LR = 50 sr		LR = 60 sr		LR = 70 sr		LR = 80 sr	
Mass	Number, c_n ($Mm \cdot m^{-3}$)	324 ± 24		270 ± 20		232 ± 17		203 ± 15	
	Volume, c_v ($10^{-12} Mm \cdot m^{-3} \cdot m^{-3}$)	2.15 ± 0.18		1.79 ± 0.15		1.53 ± 0.13		1.34 ± 0.11	
CCN-related		c (cm^{-3})	x	c (cm^{-3})	x	c (cm^{-3})	x	c (cm^{-3})	x
	CCN (0.13-35 um)	0.02 ± 10.29	2.93 ± 0.68	0.01 ± 11.63	2.93 ± 0.68	0.008 ± 12.89	2.93 ± 0.68	0.005 ± 14.10	2.93 ± 0.68
	GCCN (1-35 um) (10^{-3})	3.2 ± 0.3	-	2.6 ± 0.3	-	2.3 ± 0.2	-	2.0 ± 0.2	-
	UGCCN (10-35 um) (10^{-4})	3.73 ± 0.43	-	3.11 ± 0.36	-	2.26 ± 0.31	-	2.23 ± 0.39	-

Table 1. Birch conversion parameters essential to convert the particle extinction coefficient of birch, α_{birch}, at 532 nm into microphysical properties for different lidar ratios (LR).

		LR = 50 sr		LR = 60 sr		LR = 70 sr		LR = 80 sr	
Mass	Number, c_n ($Mm \cdot m^{-3}$)	326 ± 15		272 ± 12		233 ± 10		204 ± 9	
	Volume, c_v ($10^{-12} Mm \cdot m^{-3} \cdot m^{-3}$)	2.33 ± 0.11		1.95 ± 0.10		1.67 ± 0.08		1.46 ± 0.07	
CCN-related		c (cm^{-3})	x	c (cm^{-3})	x	c (cm^{-3})	x	c (cm^{-3})	x
	CCN (0.13-35 um)	0.65 ± 3.14	1.98 ± 0.33	0.45 ± 3.33	1.98 ± 0.33	0.33 ± 3.50	1.98 ± 0.33	0.26 ± 3.66	1.98 ± 0.33
	GCCN (1-35 um) (10^{-3})	3.4 ± 0.3	-	2.7 ± 0.3	-	2.3 ± 0.2	-	2.0 ± 0.2	-
	UGCCN (10-35um) (10^{-4})	3.45 ± 0.17	-	2.87 ± 0.14	-	2.46 ± 0.12	-	2.17 ± 0.11	-

Table 2. Birch conversion parameters essential to convert the particle extinction coefficient of birch, α_{birch}, at 910 nm into microphysical properties for different lidar ratios (LR).

Automatically Raman-retrieved profiles of backscatter and extinction coefficients and lidar ratios from both near- and far-field can be seen here:

https://polly-tmp.tropos.de/datavis/location/3/25/2/?dates=[2021-05-12T00:00:00,2021-05-13T00:00:00]

Minor comments:

Line 58: I urgingly suggest to add e.g., in front of He et al. (2023), or add other studies. It has been done many more times and before than only He et al. (2023).

Thank you for your suggestion. We have added the following studies:

Shinozuka, Y., Clarke, A. D., Nenes, A., Jefferson, A., Wood, R., McNaughton, C. S., Ström, J., Tunved, P., Redemann, J., Thornhill, K. L., Moore, R. H., Lathem, T. L., Lin, J. J., and Yoon, Y. J.: The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, Atmos. Chem. Phys., 15, 7585–7604, https://doi.org/10.5194/acp-15-7585-2015, 2015.

Mamouri, R. E. and Ansmann, A.: Estimated desert-dust ice nuclei profiles from polarization lidar: methodology and case studies, Atmos. Chem. Phys., 15, 3463–3477, https://doi.org/10.5194/acp-15-3463-2015, 2015.

Mamouri, R.-E. and Ansmann, A.: Potential of polarization lidar to provide profiles of CCN- and INP-relevant aerosol parameters, Atmos. Chem. Phys., 16, 5905–5931, https://doi.org/10.5194/acp-16-5905-2016, 2016.

Ansmann, A., Mamouri, R.-E., Hofer, J., Baars, H., Althausen, D., and Abdullaev, S. F.: Dust mass, cloud condensation nuclei, and ice-nucleating particle profiling with polarization lidar: updated POLIPHON conversion factors from global AERONET analysis, Atmos. Meas. Tech., 12, 4849–4865, https://doi.org/10.5194/amt-12-4849-2019, 2019.

Line 133/Fig. 3: Is this software what is used to produce these blue lines in Fig. 3? It is not clear from the caption what these lines are (indicated length and text are written in a much too small font). Please, include it.

That is correct. The lines indicate the geometrical diameter of the birch pollen grain where up to 40 diameters per sample were measured in order to extract the statistical population of the birch pollen. The following information has been added to the caption: 'The Olympus cellSens Entry imaging software was used to mechanically measure the diameters of the particles (blue lines) identified as birch pollen grains for up to 40 individual grains.'

Line 360: Concerning the log-log regression in the relationship between number concentration and extinction, usually Shinozuka et al. (2015, https://doi.org/10.5194/acp-15-7585-2015) is given as a reference. At least log-log regression is nowadays commonly done when using AERONET to retrieve conversion parameters (for number concentrations), however, usually rather for the smaller particles (r>50 nm and 100 nm, i.e., marine, continental/pollution) than for the larger particles (r>250 nm, i.e., dust) (e.g., Mamouri and Ansmann, 2016).

Indeed! We have revised Section 2.8.2 and replot Figures 6b-c and 7 regarding the GCCN and UGCCN. We have kept the log-log relationship for the CCN retrievals only.

It is correctly stated in the abstract and in Sect. 3.2.1. that the conversion parameters are only retrieved from 2021 measurements. This becomes clear as ICEMET data were only available in

2021 and 2023 (Line 160), but missing in 2022, and on the other hand, ceilometer data were not available in 2023 (Line 104). It might be helpful to make this fact a bit clearer by explicitly stating that, despite the fact that impressive multiyear pollen observations are available, the concurrent measurements are only available for 2021.

We have added the following statement: 'Despite the multiyear pollen observation availability on site, the conversion factors for the number/mass concentrations from PollyXT are extracted from 2-year observations during 2021 and 2023 while equivalent factors from CL61 ceilometer consider 2021 observations due to the instrument availability of the sensors involved. For the CCN–related conversion factors, the datasets used for CCN and GCCN are during 2021 for both lidars while UGCCN dataset for PollyXT includes both 2021 and 2023. For CL61, UGCCN conversion factor is extracted from the 2021 dataset'

Line 416: Here, I would recommend to repeat that statement from the abstract regarding ceilometer-networks. Of course, they are meant inclusively in lidar-networks, but one could highlight the advantage of the dense coverage of such systems/networks, even if they are not yet throughout equipped with polarization capability.

Thank you for your suggestion. We have added the suggested statement.

Also Line 416: There is no reason to restrict it to space-borne backscatter lidars. I see that this could be meant as the minimum requirement, but I suggest to just state "space-borne lidars".

Corrected according to reviewer's suggestion.

Minor comments on style and spelling:

There are many cases of missing dots after Fig. etc., not abbreviated Section or Figure(s), missing s for plural Equations/Figrues, one missing ~ or \, after Sect. (Line 100-101), comma after "e.g.". Generally, it would also be beneficial to make figure and section references clickable by using \ref{label}.

Thank you for your suggestions, we have now corrected the manuscript accordingly.

There are many hyphens mixed up. Use "--" for intervals, maybe for things like aerosol--cloud interaction, but not for things like aerosol-type-dependent.

Thank you for your comment. Corrected accordingly.

In equations/formulas, generally, do not use italics for indices, use for example $_{\mathrm{index}}$. I suggest to do the same as well for units, only put the exponents in math mode cm^{-3} (consistently), and use \textmu for micrometer.

Thank you for your suggestions, the equations and formulas have been corrected accordingly.

Line 103: I suggest to add "those": "therefore those data were omitted". The sentence before is also quite incomprehensible. I suggest to change it like that by adding two commas: "We only considered observations during 2021 and 2022, since during the birch pollen period in May 2023, the instrument experienced…".

Thank you for your suggestion. The text was corrected accordingly. Also, the previous sentence has been reformed for clarity.

Line 114: use \citep[e.g.,][]{Vakkari_2015} to avoid double)).

Thank you, corrected as suggested.

Line 139: Kaikkonen et al. (2020) refers to ICEMET only? Then, also add it like this: \citep[hereafter ICEMENT; University of Oulu, Finland][]{Kaikkonen_2020}.

Thank you for your suggestion. Yes, it referes to ICEMET only. Corrected accordingly.

Line 207: Tesche et al. (2009) with \citet{} instead of \citep{}.

Corrected as suggested.

Line 374: "CCN concentrations […] are caused" instead of "is caused".

Corrected as suggested.

Line 378: "model-based" instead of "modeled--based".

Corrected as suggested.

Line 379: Wozniak et al. (2018) with \citet{} instead of \citep{}.

Corrected as suggested.

Line 388: "coastal" instead of "Coastal".

Noted and corrected.

Fig. 1: Last access date of that web page has to be stated. And a comma added: "In close proximity,".

Last access information added.

Figs. 2 and 7: I would state “number concentration” and “Mass concentration”, respectively, at least in the captions.

Captions are corrected as suggested.

Fig. 4: Add spaces or hyphens between 2 and h, “2-h” or “2 h” (actually, in the whole manuscript). Furthermore, I would not write “perfect fit” but “1:1 reference line”, “identity line” or “line of equality”.

Noted and correct in Fig. 4 and throughout the manuscript.

References:

Generally, it would be useful to have the references clickable in the text (copernicus class should do this automatically, though).

Generally, consistently use either full journal name or abbreviation (e.g., Lines 496, 520, 546, 556, 654).

Generally, remove all double https://doi.org/ in https://doi.org/https://doi.org/.

Thank you for the thorough review. We have removed the repetition of https://doi.org/ and opted for the full journal names.

Lines 454 and 455: some strange line breaks (in Baars et al., 2016).

Noted and corrected.

Lines 466, 507, 587, 590, 593: no space between pages and hyphen.

Noted and corrected.

Line 479: In Buters et al. (2018), Galán is not correctly parsed.

Corrected as suggested.

Line 486: The degree sign in the title is missing (Cholleton et al., 2022).

Added as suggested.

Lines 521, 522: Why are two urls given? And last access date of both should be given.

Noted and last access date added.

Lines 553, 554 and 579, respectively: Last access dates have to be stated in the same format.

Noted and corrected.

Line 561: In Lewis and Schwartz (2004), the doi seems to be not working (besides the issue with double https://doi.org/), even though it is stated as well on this url: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/9781118666050.ch5. I do not know how to deal with this issue. I leave it to the copy editors.

Noted and corrected.

Line 627: Journal name has to be written in capitals, or as abbreviation (also in capitals).

Noted and corrected as suggested.

Line 629: In Tesche et al. (2009), Müller is not correctly parsed.

Noted and corrected.

Line 635: Fernández Rodríguez and Ángela Gonzalo Garijo are not correctly parsed, and no hyphens in the names should be written. (author={Tormo Molina, R. and Maya Manzano, J. M. and Fern\'andez Rodr\'iguez, S. and Gonzalo Garijo, \'A and Silva Palacios, I.})

Corrected as suggested.