Response to RC1

General comments:

The authors present a technical study to retrieve conversion factors for the well-established POLIPHON (Polarization Lidar Photometer Networking) method at sites that are not as close to deserts to experience pure dust outbreaks, though, are still affected by mineral dust mixed with anthropogenic pollution aerosol (i.e. mixed dust). The presented method uses column-integrated sun photometer data which would not fulfill the usual criteria for the retrieval of pure dust conversion factors (based on Ångström exponent and AOD). Instead, to additionally confirm the presence of (mixed) dust, ground-based and, for a case study, space-based polarization lidar observations were used together with auxiliary tools like backward trajectories and the GRASP algorithm.

As the authors rightly state, the POLIPHON method is a powerful tool to comparably easy (via remote sensing) assess and potentially quantify dust/aerosol effects on cloud formation and glaciation and therefore, weather and climate. Nevertheless, the method is only as good as its input parameters and various ongoing validation efforts. This study provides a useful although error-prone method to retrieve further needed input parameters (conversion factors) and therefore, can be recommended for publication in AMT after revisions especially focusing on a discussion of these errors/uncertainties.

Response: We appreciate the reviewer's thoughtful review and constructive comments. All of the comments have been addressed in the revised manuscript, and the responses to the individual comments are given below. It should also be mentioned that $c_{250,d}$ value has been modified after correction to a programming mistake.

Specific Comments

Comments: The usage of the GRASP algorithm does not substantially support the presented method. It could also be omitted or more clearly stated as auxiliary in the single case study.

Response: Thank you for pointing out this issue. Indeed, the usage of the GRASP algorithm does not substantially support the presented method and it is just an auxiliary applied for deriving the particle size distribution from sun-photometer-measured spectral AODs. This is only a step between dust-case data-set selection and dust-related conversion factors obtainment. For clarity, we have added a methodological diagram and the following statements in section 3 to show that auxiliary function is provided by the GRASP algorithm (please see line 159-161 and figure 2).

'…The methodological diagram is given in Fig. 2. The related data or algorithms applied for each step are showed. In particular, it should be emphasized that GRASP algorithm is only used in the step of deriving the particle size distribution from spectral AODs.'

Comments: The main argumentation in this study, why one could also use cases of mixed dust to retrieve the POLIPHON dust conversion factors, is that Chen et al. (2018)

did not find a significant impact of urban pollution on ice nucleation in the immersion mode. This does not necessarily mean that the optical properties of pollution do not have an impact in the retrieval of the conversion factors.

I understand that you took the “most dusty” cases you could find at your site for your retrieval. Nevertheless, I suggest to add a more comprehensive analysis of your sun photometer data by also calculating the conversion factors for continental aerosol at your site as described in Mamouri and Ansmann (2016) ($c_{290,c}$). This provides the opportunity to compare your “dusty” conversion factors with the continental ones and to discuss the possible effect of the continental aerosol/pollution on your retrieval.

Response: For the first issue, to state the motivation of this paper more clearly, we have modified the following sentence in the introduction (please see line 72-76).

‘**Urban air pollution generally cannot affect the atmospheric INPC (Chen et al., 2018); however, their optical properties may have an impact on the retrievals of the dust-related conversion factors, and then the INPC for mixed dust situations in a megacity influenced by long-range transported dust plumes (Córdoba-Jabonero et al., 2018; Mamouri and Ansmann, 2017; Wang et al., 2021).**’

For the second issue, we have obtained the conversion factor $c_{290,c}$ (0.11±0.02 Mm cm^{-3}) for continental aerosols (Ångström exponent >1.6), which has been added in the updated figure 6. The related analysis and discussions have also been added. Moreover, when calculating the $c_{290,c}$, we found a programming mistake that APC_{280} was used for the original $c_{250,d}$ calculation rather the APC_{250} (as seen in Mamouri and Ansmann, (2015)), leading to an underestimate of $c_{250,d}$ (0.11 Mm cm^{-3}) in our original manuscript. As a result, the $c_{250,d}$ value has been replaced by 0.19±0.05 Mm cm^{-3} in the revised manuscript. We are sorry for the carelessness. Considering this modification, some results and discussions as well as Fig. 12c have also been revised as follow (please see line 20-26, 264-289, 352-353, 360, 394).

‘…As seen in Fig. 6, a good correlation between $n_{250,d}$ and α_d was found with a linear Pearson correlation coefficient of 0.976 for the period of 2011-2013. Each green point represents a pair of daily averaged values for the dust-occurring period of a dust-intrusion day (taking the day of 28 April 2011 shown above as an example). Note that these points represent the same dataset (i.e., the same 33 dust-intrusion days) as those green points in Figure 5. The $c_{250,d}$ value was 0.19±0.05 Mm cm^{-3} as computed by the equation below:

$$c_{250,d} = \frac{1}{J_d}\sum_{j=1}^{J_d}\frac{n_{250,d,j}}{\alpha_{d,j}} \quad \textbf{(11)}$$

The standard deviation of 0.05 Mm cm^{-3} is similar to those obtained from other AERONET sites (0.02-0.05 Mm cm^{-3}) by Ansmann et al. (2019b). The $c_{250,d}$ value of 0.19 Mm cm^{-3} is approximately 27% larger than the value of 0.15 Mm cm^{-3} obtained at Lanzhou SACOL (36.0°N, 104.1°E) AERONET site as well as at Dalanzadgad, Mongolia (see Fig. 1), which are very close to the source region of Asian dust (Ansmann et al., 2019b). Mamouri and Ansmann (2015) mentioned that this dust-related conversion factor can almost be invariable from dust source (Morocco and Cape Verde) to downwind regions (Barbados). Therefore, this discrepancy indicates that Wuhan may not be only influenced by Asian dust. Note that the conversion factor 0.19 Mm cm^{-3} is more like the values of 0.16-0.20 Mm cm^{-3} for the North Africa (Saharan dust) and Middle East, suggesting that dust aerosols from these two sources are also possibly involved in the dust events observed over Wuhan. This

conjecture can be verified to some extent since the dust plumes over Wuhan can often be traced back to these two sources by HYSPLIT model simulation (He et al., 2021a). Kojima et al., (2006) confirmed that dust particles that have not undergone substantial aging or a cloud-processing event can be present thousands of kilometers from source regions. Furthermore, to analyze the potential impact of local emissions on $c_{250,d}$, the conversion factor for continental aerosols $c_{290,c}$ was also calculated for the period during 2008-2013 as seen from the purple points in Fig. 6 (Mamouri and Ansmann, 2016). The $c_{290,c}$ value of 0.11±0.02 Mm cm^{-3} for Wuhan is similar to those of around 0.10 Mm cm^{-3} for the two city sites, Limassol, Cyprus (34.7°N, 33.0°E) and Leipzig, Germany (51.4°N, 12.4°E) (Mamouri and Ansmann, 2016), meaning that this value depicts a typical conversion factor for the urban aerosol situations. Similar to the results in Limassol and Leipzig (Fig. 7b in (Mamouri and Ansmann, 2016)), $c_{250,d}$ is almost twice larger than $c_{290,c}$ in Wuhan, indicating lesser large particles are included in the local pollutions. This comparison suggests that there is no significant influence of urban aerosols on the retrievals of dust-related conversion factor $c_{250,d}$ in Wuhan, at least for the 'most dusty' cases which we selected for $c_{250,d}$ calculation in this study.'

Reference:

Ansmann, A., Mamouri, R.-E., Hofer, J., Baars, H., Althausen, D., and Abdullaev, S. F.: Dust mass, cloud condensation nu-clei, and ice-nucleating particle profiling with polarization lidar: updated POLIPHON conversion factors from global AERONET analysis, Atmos. Meas. Tech., 12, 4849-4865. doi.org/10.5149/amt-12-4849-2019, 2019.

Córdoba-Jabonero, C., Sicard, M., Ansmann, A., del Águila, A., and Baars, H.: Separation of the optical and mass features of particle components in different aerosol mixtures by using POLIPHON retrievals in synergy with continuous polarized Micro-Pulse Lidar (P-MPL) measurements, Atmos. Meas. Tech., 11, 4775-4795. doi.org/10.5194/amt-11-4775-2018, 2018.

Kojima, T., Buseck, P., Iwasaka, Y., Matsuki, A., and Trochkine, D.: Sulfate-coated dust particles in the free troposphere over Japan, Atmos. Res., 82, 3-4, 698-708, doi.org/10.1016/j.atmosres.2006.02.024, 2006.

Mamouri, R. E. and Ansmann, A.: Potential of polarization/Raman lidar to separate fine dust, coarse dust, maritime, and anthropogenic aerosol profiles, Atmos. Meas. Tech., 10, 3403-3427. doi.org/10.5194/amt-10-3403-2017, 2017.

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. doi.org/10.5194/acp-16-5905-2016, 2016.

Wang, T., Han, Y., Hua, W., Tang, J., Huang, J., Zhou, T., Huang, Z., Bi, J., and Xie, H.: Profiling dust mass concentration in Northwest China using a joint lidar and sun-photometer setting, Remote Sens., 13, 1099. doi.org/10.3390/rs13061099, 2021.

Comments: Similarly, you need to provide uncertainty ranges (standard deviations) for the retrieved conversion factors as in Mamouri and Ansmann (2016). These need to be compared and discussed in detail as well. In addition, you state that your sun photometer has a substandard precision in compared to AERONET. How does this influence your retrievals with respect to the uncertainties?

Response: The standard deviations for the retrieved conversion factors and related comparison and discussion have been added in the revised manuscript (please see line 20-21, 24, 267-271, 299, 305-208 and 381-385). The updated conversion factors are $\mathrm{c}_{250,\mathrm{d}} = 0.19 \pm 0.05\ \mathrm{Mm\ cm^{-3}}$ and $c_{v,d} = (0.52 \pm 0.12) \times 10^{-12}\ \mathrm{Mm\ m^3 m^{-3}}$.

Our AOD measuring errors are given under the optical air mass of 1.0 (Zhang et al., 2021), which is corresponding to the summer solstice in the Northern Hemisphere. Considering the 33 dust-intrusion days are selected from spring and winter, those AOD errors should be divided by a factor of 1.6 and 2.4, respectively. Therefore, the AOD errors for our sun photometer should be similar as those for AERONET instruments. Torres et al. (2017) analyzed the influence of AOD errors on the aerosol size distributions (in subsection 3.4 therein). The tests with random simulated errors showed that the uncertainties in the GRASP bimodal log-normal size distribution parameters increase as the aerosol loads decreases. Considering the averaging AOD_{440} value of 0.92 for the 33 days selected in our study, we use the uncertainties in bimodal log-normal size distribution parameters from the coarse-mode aerosol prevailing case cluster with AOD_{440}=0.9 (i.e., 'SOLV3' in Table 2 and 7 therein) to estimate the uncertainty involved in APC_{250} and total volume concentration. The same AOD errors for each wavelength as AERONET instruments were introduced. Taking the simulated uncertainties of GRASP bimodal log-normal size distribution parameters into account, the uncertainties in APC_{250} and total volume concentration caused by AOD errors are estimated to be <3.2% and ~0%. The uncertainty in AOD_{500} is ~2%. Torres and Fuertes (2021) compared the aerosol size properties derived by GRASP-AOD application with those obtained by AERONET retrieval algorithm. When AOD_{440} >0.4, the uncertainty in total volume concentration was estimated to be 23%. Mamouri and Ansmann (2015) mentioned that the uncertainty in AERONET algorithm derived APC_{250} is 10-15%. Propagating all the uncertainties above into the conversion factors obtained in this study, the final uncertainties in $\mathrm{C}_{250,\mathrm{d}}$ and $\mathrm{C}_{\mathrm{v,d}}$ are conservatively estimated to be both <28%. The related statements have been added in the revised manuscript (please see line 110-114 and 308-320).

Reference:

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. doi.org/10.5194/acp-15-3463-2015, 2015.

Torres, B., Dubovik, O., Fuertes, D., Schuster, G., Cachorro, V. E., Lapyonok, T., Goloub, P., Blarel, L., Barreto, A., Mallet, M., Toledano, C., and Tanré, D.: Advanced characterisation of aerosol size properties from measurements of spectral optical depth using the GRASP algorithm, Atmos. Meas. Tech., 10, 3743-3781. doi.org/10.5194/amt-10-3743-2017, 2017.

Torres, B. and Fuertes, D.: Characterization of aerosol size properties from measurements of spectral optical depth: a global validation of the GRASP-AOD code using long-term AERONET data, Atmos. Meas. Tech., 14, 4471-4506, doi.org/10.5194/amt-14-4471-2021, 2021.

Zhang, Y., Zhang, Y., Yu, C., and Yi, F.: Evolution of aerosols in the atmospheric boundary layer and elevated layers during a severe, persistent haze episode in a central China megacity, Atmosphere, 12, 152. doi.org/10.3390/atmos12020152, 2021.

Comments: Furthermore, it has to be made clearer in the whole manuscript that these parameterizations (DeMott et al. 2010, 2015) are for immersion mode INP, than just the one sentence stating the Ullrich et al. (2017) parameterization is valid for deposition nucleation. This is important as Ullrich et al. (2017) indeed provide a deposition nucleation parameterization also for soot aerosol.
Response: Thank you very much for pointing out this issue. Considering most dust layers over Wuhan appear at relatively low altitudes with warmer condition, we only considered the immersion nucleation in this study. Indeed, as the reviewer mentioned, U17 is an important parameterization, especially for the deposition freezing regimes as well as the soot-aerosol-related parameterization scheme. For clarity, we have added the following statements about the U17 and have also emphasized that we obtained the dust-related immersion-mode INP concentration in abstract, section 4, and section 5. (please see line 26, 211-216, 351, and 391).

'Note that these two parameterizations (D10 and D15) are used for immersion freezing. Ullrich et al. (2017) developed another important parameterization for heterogeneous ice nucleation that quantifies the INPC as a function of ice nucleation active surface site density (related to temperature and ice saturation ratio). This parameterization included both desert dust and soot aerosol and was applicable for both immersion nucleation and deposition nucleation. Most dust layers over Wuhan appear at relatively low altitudes with warmer meteorological conditions; hence, immersion nucleation takes place more generally. Therefore, we only applied D10 and D15 parameterizations in this study.'

Comments: Some textual suggestions in the attached PDF.
Response: The related texts have been revised according to your suggestions.

Response to RC2

General comments:

This is an interesting study, with a substantial contribution to scientific progress within the scope of AMT. It is based on ground-based lidar observations from Wuhan and provides regionally-tailored parameterizations for dust and cloud-relevant lidar-retrievals. The new methodology proposed, could be applied to different regions to provide regionally-tailored parameterizations for dust and cloud-relevant concentration retrievals. The paper is well written and the overall presentation is well structured and clear. It is recommended for publication in AMT after a few revisions. The specific comments are given below. The more important comments are connected with the discussion of the associated uncertainties of the retrieved products from the presented methodology.
Response: We appreciate the reviewer's thoughtful review and constructive comments. All of the comments have been addressed in the revised manuscript, and the responses to the individual comments are given below. In particular, the associated uncertainties of the retrieved products have been added in the revised manuscript. Moreover, $c_{250,d}$ value has been modified due to a programming mistake.

Specific Comments

Comments: Page 2, line 38: "...except for the occurrence of ice multiplication mechanism (also named Hallett-Mossop process) at temperatures of -3 to -8 °C [Hallett and Mossop, 1974]". As more secondary ice production mechanisms have been proposed in the literature (see for example Field et al., 2017), consider revising this sentence accordingly.

Response: Thank you for providing this newer literature regarding the secondary ice production effect. We have added it into the revised manuscript as follow (please see line 42-43)

'**…, which can rapidly enhance the number concentration of the ice population following initial primary ice nucleation events (Field et al., 2017).**'

Comments: Page 2, line 38: "This agreement was substantially verified by a closure study …". the same agreement was found in Marinou et al., (2019) paper using spaceborne lidar-radar retrievals. Consider including their findings in the reference also.

Response: We have added the following sentence that introduces the same comparison between INPs (derived by CALIPSO) and ICNCs (derived by DARDAR) in Marinou et al. (2019). (please see line 46-48)

'**Moreover, good agreement between INPC derived by the measurements of CALIPSO spaceborne lidar and ICNC derived by the synergistic measurements of spaceborne raDAR and liDAR (DARDAR) was also found by Marinou et al. (2019).**'

Comments: Page 3, line 65: "Urban air pollution generally cannot affect the atmospheric INPC [Chen et al., 2018]". Consider including also the recent references of Kanji et al. (2020) and Schill et al. (2020) which found out that soot in a bad immersion freezing INP (at temperatures > -30 C) with < 10% contribution to the total INPC.

Response: Thank you for providing these two relevant papers. We have added them into the revised manuscript as follow (please see line 73-74)

'**Similarly, Kanji et al. (2020) and Schill et al. (2020) found that soot also is not an effective aerosol type serving as INP.**'

Comments: Page 4, line 104: "The fine mode fraction (FMF) of 500 nm...". Till this point you provided the uncertainties of all the other products discussed. Consider including in the text the uncertainty on this product also.

Response: Details of error expressions are given in Appendix A of O'Neill et al. (2003). There are assumptions of the coarse-mode Ångström exponent, spectral derivative coarse-mode Ångström exponent, and relationship between the fine-mode Ångström exponent and spectral derivative fine-mode Ångström exponent (O'Neill et al., 2001) included in FMF calculation. The uncertainties of these assumptions depend on the actual atmospheric condition. Therefore, it is not easy to provide a specific value of uncertainty in FMF. Considering FMF values just qualitatively assess the presence of dust plume and are not involved in conversion factor derivation, it would be acceptable not to give a specific uncertainty in FMF. To address the reviewer's concern, we have added the following statements in the revised manuscript (please see line 115-118)

'**The uncertainty in FMF mainly depends on the assumptions of the coarse-mode Ångström exponent, spectral derivative coarse-mode Ångström exponent, and relationship between the fine-mode Ångström exponent and spectral derivative fine-mode Ångström exponent (O'Neill et al., 2001), which are related to the actual atmospheric condition.**'

Reference:

O'Neill, N., Dubovik, O., and Eck, T. F.: A modified Ångström coefficient for the characterization of sub-micron aerosols, Appl. Optics, 40(14), 2368-2375, doi.org/10.1364/AO.40.002368, 2001.

O'Neill, N., Eck, T., Smirnov, A., Holben, B., and Thulasiraman, S.: Spectral discrimination of coarse and fine mode optical depth, J. Geophys. Res., 108(D17), 4559. doi.org/10.1029/2002jd002975, 2003.

Comments: Page 5, line 130: "In this study, the CALIOP Level-2 vertical feature mask (VFM) product was used to validate the presence of dust layers over Wuhan". As this validation could be done with the depolarization measurements of the ground-based system only, consider rephrasing to highlight the synergy of the two measurements, from ground and space, to provide the 3D dust presence.

Response: We have added the following statements to highlight the ability of CALIOP measurement for providing the 3-D structure information of the dust plume. (please see line 146-148)

'**…the CALIOP Level-2 vertical feature mask (VFM) product was used not only to validate the presence of dust layers over Wuhan (Omar et al., 2009) but also to provide the three-dimension structure information on the dust plume combining simultaneous ground-based measurements (i.e., vertical distribution and horizontal extension).**'

Comments: Page 6, line 160: "The uncertainty for α_d is on the order of 20% [Mamouri and Ansmann, 2014; Tesche et al., 2009]". This uncertainty is provided in relation to the total extinction coefficient and not in relation to the retrieved dust extinction coefficient from the formula, and is representative for the uncertainty on the α_d in case of dust dominated aerosol layer (with d_p approximatelly 30% or higher, aka 100% presence of dust). When the pure dust component is less, the uncertainty of the retrieved a_d is higher. Indicatively a_d uncertainty is reaching >90% in layers with d_p = 10% (see for example section 3.2 in Marinou et al. 2019). I suggest describing the uncertainties more accurately.

Response: Thank you very much for the comments. As discussed by Mamouri and Ansmann, (2014) and Marinou et al., (2019), the uncertainty in α_d depends on the contribution of pure dust component. Low dust contribution with δ_p <0.1 can cause a very large uncertainty of >94%. Since δ_p values are mostly observed to be 0.14-0.43 over Wuhan during the dust-related heterogeneous nucleation events (He et al., 2021a), we only consider the well-detected desert dust layer (δ_p ~0.3) and less pronounced aerosol layer (δ_p ~0.2) when estimating the uncertainty. Mamouri and Ansmann (2014) estimated the uncertainty in β_d to be 15-20% for well-detected desert dust layers and 20-30% for less pronounced aerosol layers. Considering the uncertainty of ~10% in dust lidar ratio (an updated value of 47±4 sr for Asian dust is obtained by pure rotational Raman lidar observation at our site, according to Peng et al. (2021)), the uncertainty in α_d is estimated to be 18-32%, which is more conservative than the value of 15-25% given by Ansmann et al. (2019b). We have added the related discussions about the uncertainty in α_d. (please see line 179-186)

'…The uncertainty in α_d mainly depends on the contribution of dust component within an aerosol layer. Very low dust contribution can cause a very large uncertainty in α_d (Marinou et al., 2019). Since δ_p values are mostly observed to be 0.14-0.43 over Wuhan during the dust-related heterogeneous nucleation events (He et al., 2021a), we only consider the well-detected desert dust layer ($\delta_p \approx 0.3$) and less pronounced aerosol layer ($\delta_p \approx 0.2$) when estimating the uncertainty in α_d. Mamouri and Ansmann (2014) estimated the uncertainty in β_d to be 15-20% for well-detected desert dust layers and 20-30% for less pronounced aerosol layers. Considering the uncertainty of ~10% in updated dust lidar ratio (Peng et al., 2021), here the uncertainty in α_d is estimated to be 18-32%, which is more conservative than the values of 15-25% given by Ansmann et al. (2019b).'

Reference:

Ansmann, A., Mamouri, R.-E., Hofer, J., Baars, H., Althausen, D., and Abdullaev, S. F.: Dust mass, cloud condensation nu-clei, and ice-nucleating particle profiling with polarization lidar: updated POLIPHON conversion factors from global AERONET analysis, Atmos. Meas. Tech., 12, 4849-4865. doi.org/10.5149/amt-12-4849-2019, 2019b.

He, Y., Yi, F., Yi, Y., Liu, F., and Zhang, Y.: Heterogeneous nucleation of midlevel cloud layer influenced by transported Asian dust over Wuhan (30.5°N, 114.4°E), China, J. Geophys. Res.-Atmos., 126(2), e2020JD033394. doi.org/10.1029/2020JD033394, 2021a.

Mamouri, R. E. and Ansmann, A.: Fine and Coarse dust separation with polarization lidar, Atmos. Meas. Tech., 7, 3717-3735. doi.org/10.5194/amt-7-3717-2014, 2014.

Marinou, E., Tesche, M., Nenes, A., Ansmann, A., Schrod, J., Mamali, D., Tsekeri, A., Pikridas, M., Baars, H., Engelmann, R., Voudouri, K.-A., Solomos, S., Sciare, J., Groß, S., Ewald, F., and Amiridis, V.: Retrieval of ice-nucleating particle concentrations from lidar observations and comparison with UAV in situ measurements, Atmos. Chem. Phys., 19, 11315-11342. doi.org/10.5194/acp-19-11315-2019, 2019.

Peng, L., Yi, F., Liu, F., Yin, Z. and He, Y.: Optical properties of aerosol and cloud particles measured by a single-line-extracted pure rotational Raman lidar. Opt. Express, 29(14), 21947-21964, doi.org/10.1364/OE.427864, 2021.

Comments: Page 6, line 165 and line 171: "The uncertainty of M_d is ≤ 60% [Mamouri and Ansmann, 2014]" ... "The overall uncertainty for α_250, is estimated to be on the order of 30% [Mamouri and Ansmann, 2015]". Similarly with the above comment, these uncertainties are representative for a dust dominated case (100% dust presence). Please rephrase accordingly.

Response: According to the response above, we have updated these two uncertainties to be 29-64% for M_d and 27-40% for n_(250,d). As a comparison, these two values are also more conservative than the values of 20-30% for M_d and 25-35% for n_(250,d) given by Ansmann et al. (2019b). (please see line 191 and 196)

Comments: Page 8, line 1, and Figure 3 and 4: The AE of the first time period this day (09:00-11:00) is even lower than the time used (12:00-16:00). Why is only the second time period considered dust relevant and is used? Could the authors provide additionally the size distribution of the first period in Figure 4? Or the first period is not included in this methodology due to some criteria it cannot fulfill?
Response: Thank you very much for pointing out this issue. The selection of time period is based on whether a dust aerosol layer is observed by the polarization lidar simultaneously. Ground-based lidar began to operate at 1000 LT this day and the thick dust layer was observed all day long. Therefore, we should also take the sun photometer datasets during 1000-1100 LT into consideration. Figure 5 has been updated in the revised manuscript. It should be mentioned that although the shape of particle volume size distribution shows a slight change (see figure 5a), $n_{250,d}$ is almost unaltered compared with the original value. Thus, we can conclude that this modification has neglectable impact on the obtained conversion factors. (please see line 249, 252, and figure 5)

Comments: Figure 2: As the δ and a_d profiles from this case are discussed in the manuscript to demonstrate the methodology, it is advised that the authors include in this figure these profiles also, during the period used. It would be good, for completeness, also if the authors mention the D selected for the demonstration case (which height region is averaged for the mean a_d in this case).
Response: According to the reviewer's suggestion, to demonstrate the identification of dust occurrence by mean of polarization lidar observation, we have provided the profiles of volume depolarization ratio during four cloud-free periods in the updated figure 3 and have also added the related expressions as follow (please see line 239-242)

'…**Besides, four cloud-free periods (1000-1030 LT, 1220-1250 LT, 1400-1430 LT, and 1530-1600 LT) were selected to show the vertical distributions of δ as seen in Fig. 4c, 4d, 4e, and 4f. The δ values were larger than 0.06 throughout the whole lower troposphere (from surface to around 5.5 km). Considering the thresholds of δ and thickness that we defined, all these periods can be identified as 'dust occurrence.**'

Comments: Page 8, line 228: "In total, we screened 32 dust-intrusion days from the sun photometer observation during 2011-2013." Shouldn't this be rephrased as: "In total, we used 32 dust-intrusion days from joint lidar and sun photometer observations during 2011-2013." ?
Response: We have rephrased this sentence as follow (please see line 263-264)

'**In total, we used 32 dust-intrusion days from joint lidar and sun photometer observations during 2011-2013.**'

Comments: Figure 5: You should skip "by sun photometer" in the end of the sentence. See also the above question.
Response: The caption has been revised and 'by sun photometer' is removed.

Comments: Page 8, line 234: Please also provide the uncertainty or, if not possible,

the standard deviation of the proposed conversion factor.
Response: The standard deviations for the retrieved conversion factors have been added throughout the revised manuscript.

Comments: Page 8, line 239: "Moreover, two other AERONET sites were reported to also have...". Consider rephrasing as: "These results are in line with conversion factors reported in two other AERONET sites…."
Response: Considering the value of conversion factor are updated, we have completely rewritten this paragraph, including new conclusions as well as the related discussions.

Comments: Page 9, line 249: "Each point in Figure 6 …" please comment in the manuscript if these points are from the same set of lidar layers and AERONET retrievals as the ones in Figure 5.
Response: We have added the following statement
'**Note that these points represent the same dataset (i.e., the same 33 dust-intrusion days) as those green points in Figure 6.**'

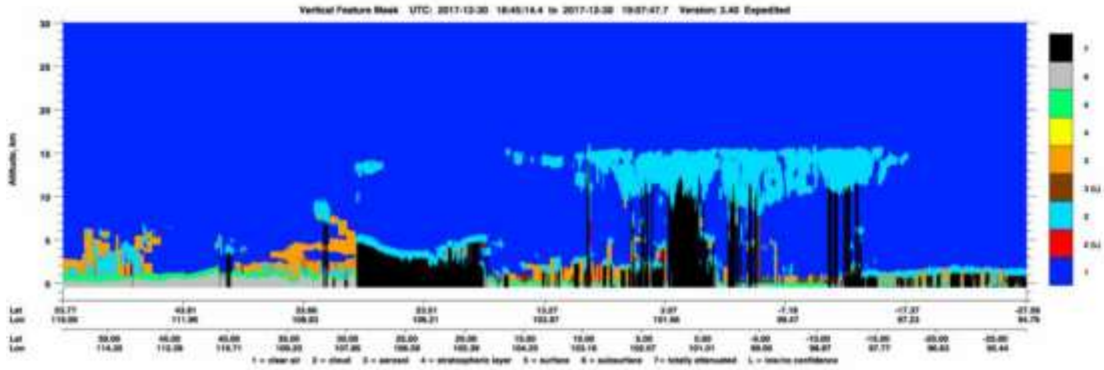
Comments: Page 9, line 253: Please also provide the error or, if not possible, the standard deviation of this conversion factor.
Response: The standard deviations for the retrieved conversion factors have been added throughout the revised manuscript. (please see line 20-21, 24, 267-271, 299, 305-208 and 381-385)

Comments: Page 9, line 255: "In particular, those more dispersed points below the dashed line seem to be more affected by anthropogenic aerosols". Would it make sense to calculate one conversion factor for the elevated aerosol layers and a seperate one for the PBL layers? Would the retrieved factors be better representative for the different mixing conditions expected in the PBL and in the free troposphere?
Response: Thank you very much for the valuable suggestion. Obviously, as the reviewer mentioned, it will be better if we can separately calculate the conversion factors for the elevated aerosol layers in free troposphere and the aerosols within the PBL; because the elevated aerosol layers usually contain purer dust particles and do not suffer the mix with other aerosol sources. If this solution is feasible, a more accurate conversion factor for dust over Wuhan can be expected. However, the core thought of the POLIPHON method is using the sun-photometer-measured column-integrated AOD spectrum (wavelength-depended AOD) to calculate the particle size distributions and thereby fit the conversion factors. Therefore, we can hardly derive the dust-related conversion factors by separating the respective AOD contribution from PBL and free troposphere. This is also the reason why Ansmann et al. (2019b) only calculate the dust-related conversion factors for those AERONET sites near the dust desert regions or over the cities with relative clean atmospheric environment (to diminish the impact of anthropogenic aerosols as much as possible). As for our study, we also have to use the column-integrated AOD spectrum measured by sun photometer to derive the dust-related conversion factors; hence the possible influence of anthropogenic aerosols within the PBL cannot be completely avoided.

Comments: Page 9, line 263: "Another slight dust layer with an enhanced δ of ~0.04

occurred up to ~8 km”. Please include the time of observation in the plot.
Response: The time **‘after ~0230 LT’** has been added.

Comments: Figure 8: Consider including additionally the CALIPSO feature type plot of this case, for a complete overview of the scene. The elevated aerosol/cloud layer above the station at 7-9 km is visible here also.



Response: As the reviewer suggested, we have added the simultaneous CALIOP level-2 vertical feature mask into the updated figure 10b so that the classification of cloud and aerosol layer also can be indicated. (please see line 331, 334 and figure 10)

Comments: Figure 9 & 10: Please include also the error bars of the derived parameters.
Response: We have added the error bars of the derived parameters in the updated figure 11 and 12.

Comments: Summary and conclusions: The authors could consider including in their conclusions a comment on the evaluation approaches that could be used/followed to validate the proposed methodology.
Response: We have added the following comment in section 5. (please see line 387-389)

‘**In the future, we expect to validate the obtained conversion factors by comparing with unmanned aerial vehicles (UAVs) in situ measurements (Marinou et al., 2019).**’

Technical corrections:

Comments: All manuscript: The reference brackets for ACP is () instead of [].
Response: All the reference brackets have been revised to ().

Comments: Page 2, line 47: “...Marinou et al...”
Response: The spelling mistake has been corrected.

Comments: Page 2, line 51: “...in sit**u**...”
Response: The spelling mistake has been corrected.

Comments: Page 3, line 83 & 91: “...particle **linear** depolarization ratio...”
Response: The repression **‘particle depolarization ratio’** has been revised to **‘particle linear depolarization ratio’.**

Comments: Page 6, line 147: “...dy multiplying with a typical dust...”

Response: ‘multiplying the typical dust…’ has been revised to **‘multiplying with a typical dust…’.**

Comments: Page 7, line 189: “...the filtered out all…” out should be deleted, as these are the values kept.
Response: The word **‘out’** has been removed.

Comments: Page 7, line 190: “Considering the AERONET sites selected in Ansmann et al. [2019b] mostly located in/near the desert regions, the pure dust cases following the criteria given above can be found more easily (with adequate data sets >2500 for each site”. Consider rephrasing to: The pure dust cases following the criteria given above can be found more easily (with adequate data sets >2500 for each site) in/near the desert regions, as presented in Ansmann et al. (2019b).
Response: According to your suggestion, this sentence has been revised to ‘**The pure dust cases following the criteria given above can be found more easily (with adequate data sets >2500 for each site) in/near the desert regions, as presented in Ansmann et al. (2019b).**’

Comments: Page 7, line 195: “...observed here generally reflect a characteristic of mixed dust (dust particles mix...”. Consider rephrasing to “...observed to generally reflect characteristics of mixed dust (dust particles mixed...”.
Response: According to your suggestion, this sentence has been rephrased.

Comments: Page 7, line 197, 198: “...properties **above** Wuhan…” “... different from those **in** near-desert sites”.
Response: The first sentence has been revised to **‘…properties above Wuhan’**. As for the second sentence, we have rephrased it as follow **‘Thus, the dust-related conversion factors differ from those of near-desert sites.’**

Comments: Page 11, line 324 “is derived at 2.0 L^-1”
Response: ‘**reached**’ has been revised to **‘is derived at ’**.