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Review of Liu et al. - Multi-dimensional satellite observations of aerosol properties and aerosol types over three major urban clusters in eastern China

Anonymous Referee #2

Referee comment on "Multi-dimensional satellite observations of aerosol properties and aerosol types over three major urban clusters in eastern China" by Yuqin Liu et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2020-1278-RC1>, 2021

The paper "Multi-dimensional satellite observations of aerosol properties and aerosol types over three major urban clusters in eastern China" by Liu et al. present and discuss the temporal and spatial variation of aerosol properties over the Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta regions, and the vertical distribution of the different aerosol subtypes, based on nine-years (2007-2015) of MODIS-Aqua and CALIOP-CALIPSO observations, together with meteorological parameters provided by ERA-Interim reanalysis. The study falls within the scope of ACP. The manuscript is well-written and structured, the presentation clear, the language fluent and the quality of the figures high. The authors have done a thorough job and the results support the conclusions. I recommend publication in ACP, however I recommend the following revisions before it can proceed to be published.

Comments:

- In the framework of the study CALIPSO nighttime observations are used. The authors justify their choice through the illumination conditions and the related lower daytime SNR. However, I would suggest to extend their justification through CALIPSO daytime and nighttime performance, as provided in the literature.
- In the end of Section 2.1, a map encompassing East China, delineating the three BTH,

YRD, and PRD study regions, would be practical for the reader.

- I would suggest to the authors to break down Section 2.2 - "Data sources" into three distinct sub-sections: "MODIS/Aqua", "CALIOP/CALIPSO" and "ERA-Interim".
- Whenever a web-link is provided, please follow the formalism on adding in a parenthesis the "last visit:" information (e.g. line 137).
- Lines 141-143 "Over China, the differences between the C6 and C6.1 AOD are small, except over certain areas like the Tibetan Plateau, Sichuan Province and the NW of China". Please include related references.
- Why have the authors selected MODIS AOD 1.5 and CALIPSO AOD 3? Please include references. Moreover, regarding comparison methodology, I would argue the use of similar CALIPSO and MODIS upper AOD limits.
- Please include information of the pre-processing of MODIS/Aqua. Which Quality Assurance procedures and flags are used? Based on Figure 2, the authors have used a re-gridding procedure in MODIS L2 AOD, which is not mentioned. Is any final smoothing applied to the data? Moreover, Figure 2 has same "blank" areas, without AOD values. Please discuss these aspects/address in the manuscript.
- "CALIOP is the first space-borne near-nadir dual-wavelength lidar (532 nm and 1064 nm)". This is not correct (e.g. ICESat). Please revise.
- Lines 155-161: The authors discuss the different levels of processing in CALIPSO algorithms. Please mention which refer to L1B and which to L2, and also that the study is based on L2. Moreover, add the word "Version" beside the "4.1".
- The authors mention that AOD is the vertical integration of extinction. However, it is not discussed in the manuscript how the mean AOD is calculated. The official and more robust way, as discussed in Amiridis et al. (2013) and Tackett et al. (2018), is calculating the mean quality-assured extinction coefficient profile at the overpass level - based on L2 profiles per overpass, and accordingly using all overpass-mean profiles to calculate the seasonal or annual profile. Not following this approach results in weighting effects, thus in not representative results. Please provide in the manuscript the methodology followed in the processing of CALIPSO profiles at mean-extinction-coefficient and AOD at 532nm, and if the methodology is different, make necessary corrections.
- Lines 168-169: "This is further illustrated ...". Add in the end the Section/Figure that support this sentence.
- Lines 174-180: Profiles of RH are provided in CALIPSO L2 Aerosol and Cloud Profiles, based on MERRA-2 model, which is used in the algorithms of CALIPSO in order to produce the different optical products. Possible use of ERA-Interim may results in some point of model-intercomparison. Have the authors considered the use of RH from CALIPSO datasets?
- Line 182: "cloud-free pixels". What is a pixel? Please define clarify in the manuscript. Is it the L2 Profile, the grided L3 profile, or the region (e.g. BTH region) to be cloud-free?
- It is not clear why the authors have used the limited period between 2007 and 2015. Since this period has already been discussed in Proestakis et al. (2017), it would be interesting and of added-value to include more years in the analysis. Expanding the timeseries would be of added value for timeseries analysis, especially due to the special orbital characteristic and overpass frequency of CALIPSO. Moreover, extending the observational period would address the question whether emissions have increased after 2015 or whether they are still declining due to regulations applied.
- In Section 3.1, please provide in the manuscript the trends, the related statistical significance, and discuss the outcomes.
- In Figures 1b and 1c please include vertical error-bars/uncertainty-bars. Moreover, what is missing is the information on the number of overpasses/profiles used for the calculation. Discuss in the manuscript the outcomes in combination with the number of overpasses/profiles, with respect to the representativeness of the results.
- In the figures, please add the sensor name. For instance in Figure 1, modify the caption to "CALIPSO annually (a), ...".
- Although the language is fluent and the manuscript smooth, at some points the

language could be more formal (e.g. line 253: "The monsoon brings heavy rains which effectively washout aerosols").

- Throughout the manuscript, in the framework of the discussion of the different types of aerosols, the related sources, and atmospheric mass origin, phrases such as "likely", "maybe" and more are frequently used. To this end, of high value would be to add aerosol backtrajectories cluster analysis, to strengthen the discussion, and avoid hypothesis used, especially in this extend.
- In Figure 2 add annual figures and corresponding discussion.
- Figure 3: use the CALIPSO official colors if possible, to the aerosol subtypes.
- It would be of added value to the reader of the manuscript and to the manuscript itself to add a brief discussion and description on the CALIPSO aerosol classification algorithm (Kim et al. 2018) and to possible errors in the classification (Burton et al. 2013), since the aerosol subtyping is a cornerstone to this study.
- Lines 324-325: Include AOD limits of the different "moderately polluted", "polluted" and "heavily polluted" conditions. A histogram of the AOD values delineating the different categories would be nice also.
- Figure 4: Please add variability-bars, and maybe "number of cases-used" to the right-axes, to provided to the reader a degree of representativeness. Moreover please explain to the manuscript the feature of extinction coefficient increasing close to the surface (0 km).
- FO is not explained clearly. Is it the "number of a specific aerosol subtype to the total number of aerosol", the "number of a specific aerosol subtype to the total number of aerosol including Clear-Air", or something else? For instance in the FO figures, the aerosols subtypes is between 0 and 1. Have the authors converted the FO to percentage? If not the FO is very unexpectedly/unphysically low.
- In Figure 5 please add the "Annual figures".
- Lines 483-484: The use of Layer A, B, C, is not very convenient for the reader. Please consider the use of alternative ways of formalism.
- What I am missing in the manuscript is a connection between observations and physics. Observations are discussed, but the study does not go deeper. For example the authors could discuss that polluted dust and smoke are hydrophilic aerosols, in presence of high RH the act as effective CCN aerosols, releasing Latent Heat and contributing to instability, while dust aerosols act as effective IN aerosols, having significant effects in higher altitude, ... Please consider improving the manuscript in relation to physical interpretations of the outcomes.
- In the end, conclusion section, what is missing is a section of the way the observations can be used and their added value. Some examples for the authors could be effect on human health, transport, deposition, and more, to extend and discuss them.

