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Comments on "Multi-dimensional satellite observations of aerosol properties and aerosol types over three major urban clusters in eastern China" by Yuqin Liu et al.

Anonymous Referee #1

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-RC2, 2021

General comments

The authors use MODIS/Aqua and CALIOP/CALIPSO observations to retrieve the temporal, horizontal and vertical variation of aerosol properties (AOD/extinction and aerosol type) over the regions of Beijing-Tianjin-Hebei (BTH), Yangtze River Delta (YRD) and Pearl River Delta (PRD) in the period from 2007 to 2015. The paper is comprehensive, well written and suitable for ACP. However, there are several methodological issues that must be tackled before the manuscript can be accepted. There are deficits in the understanding of the vertical information provided by the CALIPSO retrievals, and the paper suffers from a tendency to overinterpret the results. My major concerns are:

1) It is stated (in Sec. 2.3) that MODIS AOD greater than 1.5 were discarded. However, mean values in areas with high pollution (see Fig. 2) seem to be close to 1.5, and even white pixels appear in the red areas where the mean AOD is larger than 1. These findings clearly hint to a bias that is introduced by discarding any AOD > 1.5. The entire study provides only long-term mean values, without any statistical investigation regarding the range of values, standard deviation, median, percentiles etc. to underline the significance of the findings and to detect potential biases. Therefore, conclusions, e.g., about trends in AOD are not trustworthy.

2) The study aims at the synergetic use of aerosol products from passive and active sensors. However, the results are presented just next to each other, without fully exploiting the synergy. A comparison of AOD values retrieved from imager and lidar is missing, and it remains unclear whether the results are consistent (see also previous comment on possible biases).

3) Background information on the original satellite retrievals and their limitations is missing. Overinterpretation of results and even circular reasoning are the consequence. The interpretation of the appearance of aerosol types in the vertical column above the three regions requires the understanding of the decision tree for assigning an aerosol type to aerosol layers detected in the CALIOP signals (see Kim et al., 2018, Fig. 1). The aerosol subtype selection depends, e.g., on the surface type and the aerosol layer height. In the paper, atmospheric "findings" are discussed that actually originate from the CALIPSO retrieval input and threshold parameters. One should always keep in mind that the CALIPSO aerosol typing is a pre-condition for the L2 algorithms (to select a proper lidar ratio for the extinction retrieval) and is relying only on L1 data and auxiliary information.

4) There is a contradiction in the discussion of CALIOP daytime vs. night-time data. First, it is stated that the study is restricted to night-time observations because of the lower SNR and corresponding biases at daytime (L165 ff.). Later, day- and night-time results are directly compared, and the differences are solely related to atmospheric processes, without considering any biases in the retrievals. A corresponding error estimation is not provided.

5) It is unclear why the investigation is restricted to the period 2007-2015. Several more years of data are available until today.

Specific comments

L38, "Aerosol effects depend on particle size distribution": Very generic. Which effects concretely?

L40, "... important role in Earth's climate change": Very generic. How exactly do aerosol particles change the climate (and not just influence the energy balance)?

L41, "…serve as cloud condensation nuclei": Why only condensation nuclei? What about ice nuclei?

L35 vs. L44 etc.: "Aerosol" is defined in singular (L35), but then often used in plural. What exactly do you mean with "aerosols" (aerosol particles or aerosol types or something else)?

L48, "…aerosol indirect effects are strongly influenced by aerosol types": What about the direct effects? How do direct and indirect effects depend on the aerosol type?

L168, "This is further illustrated…": What is illustrated and where?

L181 ff.: The description of data processing is too brief. What does "cloud-free pixels" exactly mean? To which instrument and which cloud-detection scheme does it refer? Does it only hold for MODIS? What is about CALIOP? How is aerosol-cloud discrimination considered (e.g., are aerosol layers in cloudy profiles included or are only fully cloud-free profiles considered)? How is the AOD from CALIOP calculated? What do the quality control flags mean, i.e., which lidar data are discarded? Are the AOD retrievals from imager and lidar equivalent (e.g., in terms of coverage) and how do the values compare?

L200 ff.: Does the description refer to MODIS or CALIOP AOD?

L227 ff.: "…larger boundary layer heights … allow for mixing over a deeper layer resulting in elevated AOD": Why? Usually, mixing leads to a dilution of aerosol in the BL while AOD remains constant.

L231 ff.: Trajectory analysis and source attribution are needed instead of speculations about the sources of high AOD. Aerosol removal processes like washout and deposition must be considered in the discussion as well.

Fig. 1: What is the data source, MODIS or CALIOP? More statistical information is required (e.g., box plots). At least the standard deviation must be provided and explained for all panels.

Fig. 2: What is the data source? What do white pixels mean? How can mean values close to 1.5 be explained, if all AOD values larger than 1.5 are discarded?

L285 ff.: It is stated that the relative contribution of each aerosol type to the aerosol burden is calculated. However, for such an investigation it would be necessary to weight the aerosol type occurrence with the layer mean extinction. Using only the occurrence does not say anything about the contribution to the aerosol burden.

Sec. 3.2.2 and 3.3: See major comment no. 3. It is important to understand the CALIPSO typing scheme for the interpretation of the findings.

L317, “The vertical profiles of the aerosol extinction coefficients describe the variation of the attenuation of the laser light…”: Vice versa. The aerosol extinction coefficient profile is the atmospheric property that causes variations in the attenuation of laser light, which can thus be used to describe the extinction.

L321, “…modulated by the boundary layer”: What does it mean?

L323, “…soothes the features and results in rather smooth profiles”: What does it mean?

L323 ff.: Which AOD is used and what are the concrete intervals? Please provide numbers!

L333 ff.: This discussion is strange (input = output).

Fig. 4: Figure caption is wrong.

Fig. 4: Please provide the variance and the AOD values for each profile.

L355: The definition of “layers” in this context is a bit misleading, since the retrieval is originally starting from distinct layers detected by CALIOP. It would be better to speak of “height ranges” here. These height ranges should also be indicated in the figures, in order to guide the reader in the discussion. It should be discussed if and how the CALIPSO typing scheme artificially introduces the boundaries of these height ranges.

L381 ff.: Please explain, under consideration of the CALIPSO typing scheme, where marine and dusty marine profiles come from. Also explain the occurrence of smoke in view of the typing scheme.

Fig. 5: Figure caption is wrong.

L437, “dusty marine aerosol”: From Fig. 6, it seems that it is clean marine aerosol. Again, please consider the surface-dependent typing in the interpretation.

Fig. 6: Figure caption is wrong.

Sec. 3.4.1: What does the RH at 950 hPa have to do with the vertical distribution of aerosols up to 8 km height? This discussion is very misleading. RH analysis can only be done when the RH for each detected layer is considered. A trajectory analysis would be much more appropriate to support the discussion of air mass origin.

Fig. 7: While the RH discussion is already strange, the provision of 2 decimal places is even more useless.

Sec. 3.4.2: Horizontal transport (according to trajectory analysis) and limitations of the typing scheme need to be considered in the discussion.

L533 ff.: Again, consider how smoke is assigned to a layer in the typing scheme and do not overinterpret the results. This discussion is mainly based on circular reasoning.

Sec. 3.5: As mentioned in major comment no. 4, it is unclear how the detection limitations at daytime influence the obtained differences. Detection thresholds, noise, and the influence of the quality control flags must be investigated, before conclusions can be drawn from the findings.

Fig. 10: Figure caption is wrong.

L575 ff.: Discussion on the influence of the diurnal variation of emissions is missing.

Fig. 11: Figure caption is wrong.

Conclusions: Reconsider your conclusions in view of all the comments above.

L654, “both flying on the Aqua satellite”: Really?!

Acknowledgements, “We also thank the reviewers of this paper for their valuable comments which helped improve the manuscript.”: Well, I do hope that this statement will become true.

Technical corrections

L146, "…we use of the MODIS": delete "of"

L187: typo in index 532nm,unc

L265: North China Plain (not Plan)

L349: certain (not certainly)