

## ***Interactive comment on “Intra-annual variations of regional aerosol optical depth, vertical distribution, and particle types from multiple satellite and ground-based observational datasets” by Bin Zhao et al.***

**Anonymous Referee #2**

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Title: Intra-annual variations of regional aerosol optical depth, vertical distribution, and particle types from multiple satellite and ground-based observational datasets

Summary: The paper combines retrievals and observations from multiple satellites (active and passive) and ground based (in-situ and remote sensed), in order to characterize the seasonal and diurnal variations of aerosol properties in three heavily-populated regions (EUS, WEU and ECC). The aerosols are separated into lower (< 800 m) and higher levels (> 800m), monthly averages are calculated, and annual cycles plotted. Analysis and interpretation and some speculation are presented. The main conclu-

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sions are that in all three regions, column AOD and higher level AOD all peak in the summer, whereas AOD in lower levels peaks during the winter. AOD from fine-sized particles peaks in the spring/summer and is attributed to anthropogenic sources. Dust and sea-salt peaks in the winter in WEU but are nearly constant in the other two regions. There appears to be larger nighttime/daytime AOD difference in summer than winter.

This paper is logical and easy to read. The English language usage is satisfactory. The idea of separating into low level (e.g. < 800 m; presumably a proxy for boundary layer) and higher level (> 800 m) is unique. I wish I could believe all of the conclusions. But I don't yet. Like I explained in the “initial quality” review, I have strong concerns about data sampling. For example, Colarco et al., (2014, [10.5194/amt-7-2313-2014]) explains that “sampling matters”, and that when we develop climatology from different types of orbits (and coverage), we need to deal with this problem. Because of this, I don't think that “the impact of the sampling issue is expected to be much smaller than that on the AOD retrieval in an individual month at a specific location” (Lines 162-167). If MODIS calculates monthly mean based on all 30 days and CALIPSO based on 2-4 times month (every 8 or 16 days, if lucky), then we don't expect the monthly means to match. Of course, if there are clouds, this could be MODIS making monthly means from, say 10 days, and CALIPSO making only one. One more paper to think about is Chin et al., (2014; [10.5194/acp-14-3657-2014]). Although they study multi-year data, they make points about comparing datasets with all kinds of sampling differences.

Of course, the low bias (Fig 2, lines 216-218) between CALIPSO -derived AOD and the other satellites (MODIS, MISR), can be because of assumed lidar ratios (Ma et al., AMT; [10.5194/amt-6-2391-2013]), or undetected aerosol layers (Kim et al., JGR, [10.1002/2016JD025797]). I guess that the Thorson (2017) reference already listed could be a reason as well.

Why the non-confident statements (“probably”) in lines 227-231? I think you should be able to find references. What are the sources of these SOA? What about long-range

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transport in the summer?

Considering lines 235-236, I again ask about sampling? Are the monthly means for AERONET and satellites computed based on the same days? Or is mean AERONET = mean (of AERONET data) and mean satellite = mean (of SATELLITE data)? We know from validation exercises that when actually collocated in space and time (both AERONET and satellite are free of clouds) that they match overall well (yes, sometimes small biases, e.g. Remer et al., 2005). However, I do not expect matches if using different samples (days). Note that the Remer et al., (2005) study has been updated for MODIS (Collection 5 and Collection 6), and there are also updates for MISR evaluations. The “instrument calibration issue” (lines 243-244) would not cause such a large bias.

I think it is a good idea that you are comparing low-level CALIPSO to ground level PM2.5 (lines 267-269) but I wonder about the temporal sampling. Also, PM2.5 is usually a “dried” aerosol measurement whereas CALIPSO is ambient RH.

I don't understand the arguments in lines 279-282, in that since CALIPSO can't detect thin aerosols, that the fraction of upper-level aerosols is smaller than at the surface, and that results in the CALIPSO AOD as being weighted toward lower heights. According to the Kim et al., paper (listed above), CALIPSO is likely to miss stuff close to the ground. Anyway, the point is I don't think you can say that CALIPSO is missing stuff, and yet it “provides valuable information with respect to intra-annual variations at specific height ranges” (line 289-290).

Thank you for adding many references in lines 292-304 to discuss why AOD seasonal differences should be different in lower versus higher altitudes. I don't know if I agree that “seasonal variations of AOD at different levels are influenced by variations of RH which affects hygroscopic growth” (Lines 301-303). Of course, RH influences AOD, but it is total column water vapor and not necessarily RH that changes drastically from season to season.

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I agree that comparing MISR-derived aerosol “types (size/ absorption)” and CALIPSO-derived aerosol “types” (sources) is ultimately useful. (lines 307-308). However, they are clearly different beasts, and I am getting lost reading this section (Section 3.3). Each paragraph has multiple sentences that are “A implies B, whereas (while / in contrast) sometimes C implies D”. It's hard to follow. I suggest a table, or schematic cartoons, or bullets.

I notice that regarding the aerosol typing as seen by CALIPSO, all of the regions (over land), have non-trivial amount of “clean-marine” aerosol (Fig 7). Is this transported marine aerosol to the entirety of the regional box, or should the marine aerosol be expected to be more dominant but confined only to the coastal areas of a region?

The section on daytime/nighttime variability is nice, but I think it is beside the point of the rest of the paper. Why would smoke AOD accumulate at night? Higher RH at night might make bigger aerosols, but if anything, fire activity is reduced at night. You might check the PM2.5 measurements here. I suggest leaving this section out, and thinking about the questions related to the other sections. “Intra-annual”, “vertical”, and “particle types” is enough for one paper!

In terms of figures. I can see why the authors do this (different magnitudes of AOD and or PM2.5 at different sites), but the varying y-axes within figure captions, and from figure-to-figure are distracting. But thank you for pointing out in the caption!

What is “upper air”? I see it a few places, and assume you mean > 800 m AGL? (e.g. Line 300).

The abstract suggests (lines 37-38) that results can “help to improve the current estimates of climatic and health impacts of aerosols”. Well maybe, but I would drop this from the abstract since there is no discussion in the paper.

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