Anonymous Referee #1

The authors present an aerosol/cloud 'climatology' based on EARLINET, AERONET and CALIPSO retrievals of wavelength dependent aerosol properties. The main emphasis is on the spectral dependence of the extinction and backscatter of representative aerosol types which can be used to convert CALIPSO profiles to other wavelengths (Figure 9, but not referred to in the text). The CALIPSO aerosol classification is the basis for LIVAS. For those aerosol types for which no information is available from EARLINET or AERONET the information is provided through other sources. The LIVAS 'climatology' is developed for use in the development of satellite instruments, in particular lidars, working at wavelengths from the UV/VIS to the SWIR. The 'climatology' is developed to replace the current ESA reference atmosphere model (RMA) which was developed for a limited region using data from a limited period. The LIVAS data base seems very useful and the MS is in general well written and suitable for publication in ACP. However, reading in detail, there are some questions arising which require correction, see my suggestions below.

General comments.

I object to calling this data base a 'climatology' because it is based on data sets which are too short to be of climatological relevance: EARLINET since 2000, only over Europe and for only three observations per week at scheduled times; CALIOP since 2006. Should LIVAS be called a 'data base'?

We agree with the reviewer and we changed the "LIVAS climatology" to "LIVAS database" throughout the MS.

Following the title, an aerosol/cloud climatology is provided, but the paper is for 99% on aerosols and clouds are mentioned in only 3.5 lines in section 3.5. Should clouds be in the title?

It is true that the work presented in the MS is mostly about the CALIPSO spectral conversions related to the aerosol optical properties, which is the real challenge for LIVAS. For clouds we assumed a neutral wavelength dependence for their optical properties, and thus, the related discussion is limited. However, LIVAS provides a cloud database as well. For this reason we think that the description of LIVAS as an "aerosol/cloud" database should remain in the title.

The main focus is on the spectral dependence of extinction and backscatter coefficients through the Ångström relation (eq. 1). However, the Ångström Exponents, usually referred to as AE, are called here 'conversion factors'. Why confuse the literature with inventing new names for the same parameters? I strongly suggest to replace 'conversion factor' with Ångström Exponent or AE throughout the MS. In this review I mostly use AE rather than conversion factors, except where I refer to conversion factors for clarity in connection with the MS

We agree with this remark and we changed accordingly the “backscatter conversion factor” and “extinction conversion factor” to “Backscatter-related Ångström Exponent (BAE)” and “Extinction-related Ångström Exponent (EAE)” throughout the MS.

I also miss the starting point for conversion, or are only CALIPSO data used? When we have the AOD or other aerosol properties at a certain wavelength we can use the AE to convert to another one.

The starting point in producing LIVAS products at 355, 1570, 2050 nm is the conversion of the 532 nm CALIPSO backscatter and extinction products, using aerosol-type-dependent BAEs and EAEs, respectively. The aerosol type is indicated by CALIPSO and the respective BAEs and EAEs are taken from our LIVAS aerosol model, which is developed utilizing EARLINET, AERONET or literature. This spectral conversion is exactly the same as when applying the Ångström law for AODs, however it is applied on the backscatter and extinction of the separated aerosol layers instead of atmospheric columnar values, as these are identified in the CALIPSO profiles and characterized regarding the aerosol type correspondingly. This procedure is written in the methodology part in the MS and described in page 2255, lines 10-24.

Although references are given to the aerosol models used, it would be useful and convenient for the readers if a table would be provided with the parameters describing the size distributions and the optical properties, as well as an example of the occurrence of aerosol types across the world, which was the first driver to extend the ESA RMA and develop LIVAS.

We thank the reviewer for this suggestion; we include now the LIVAS model microphysical and optical parameters in two new tables (Table 1 and 2).

Regarding the “global” nature of LIVAS and the driver for its development as an ESA RMA: we consider this database to have a global representativeness and this comes from the fact that we used extensive aerosol/cloud properties as these observed by CALIPSO worldwide. Although the LIVAS aerosol model applied for conversion to other wavelengths than 532nm is mostly based on European EARLINET data, we consider it to have a good performance worldwide, as shown from the final evaluation of LIVAS vs. global AERONET AODs at UV.

Furthermore, the evaluations of the different results show the large discrepancies with other approaches. To evaluate these discrepancies, please provide uncertainties in your results, in particular in table 1.

We agree with the reviewer however we think that it is almost impossible to provide uncertainties for our model. This is because all different methodologies followed aimed to deliver a typical size distribution and refractive index for each CALIPSO aerosol type and did not take into account the associated variability or uncertainty. Moreover, even if we tried to estimate the related uncertainties, we would not have the necessary information to do so, since uncertainties of the AERONET inversion products or the OPAC data used are not provided.

For some aerosol types no data are available from EARLINET and models are used from the literature. Could the authors evaluate what the consequences are, i.e ., what uncertainties are associated with this approach? If literature values are good enough for certain aerosol types, why is it then needed to analyse the experimental data? My preference would be to provide the results based on EARLINET etc., rather than the model results. The use of the models seems to be beyond the scope of providing this data base, although I understand that they need to be included for completeness and to provide info for future satellite instrument development. However, the model results do not seem to be in any way related to the original aim of the work which is observational based. I think that the authors should make that clear in the discussion.

In order to convert the CALIPSO products to UV and IR wavelengths, BAEs and EAEs are needed for all the aerosol types considered in CALIPSO classification scheme. Literature and other models are initiated to fill the EARLINET and AERONET gaps in terms of typical EAEs and BAEs for specific types like marine and clean continental. It is not possible to exclude these aerosol types from LIVAS database, since, for example, excluding the extinction values for a certain aerosol type during averaging will result in extinction biases in our final product.

Detailed comments

2256, 2: Methodology for the derivation of AE is schematically illustrated in Figure 1. However, the starting point in Fig 1 is the LIVAS AE data base which feeds into EARLINET measurements and / or models and does not go anywhere from there. Likewise for IR conversion factors feeding into AERONET data from which 'conversion factors' (are these again AE?) are derived which are validated with EARLINET measurements and then ...(do these AE determine the aerosol type?) : I really don't understand, should the direction of the arrows be inverted so that we end with LIVAS AE? Where does CALIPSO come in? (line 10)

We agree with the reviewer's remark and we changed the schematic diagram so the data and methods used are more clearly presented. We changed also the Figure 1 caption: "Figure 1. The data and methods used for the derivation of LIVAS BAE and EAE in the UV and IR."

2256, 10: aerosol models with typical microphysical and optical properties are derived for each CALIPSO aerosol type: as in my general comments, why are these results not reported? The title of S3.1 is 'aerosol model for the derivation of spectral conversion factors', but I see no description of any aerosol model, please provide. Instead the AE are mainly derived from multi-wavelengths EARLINET measurements (line 13-14). Only for the IR AE the models are used, based on CALIPSO definitions, and this is not a straightforward task (line 26). So please share the results with the readers.

As mentioned above, we added two new tables with the microphysical and optical properties of the different aerosol types in LIVAS model (Table 1 and 2).

The CALIPSO aerosol type properties are listed to some extend in Table 1 which however is referred to only on p. 2258: could these properties be provided here, and also a reference? This would invalidate several of my comments in this review where I continue to ask for the provision of the parameters describing the aerosol physical and optical properties. In the last para of p. 2256 some more is said, and a reference is given, but since this is the core of the paper, some more detail would be appropriate.

We thank the reviewer for this comment, the new Table 2 satisfies this request as well.

2257, 25 a summary of what was said in this S3.1, but I still don't know what the characteristics of the aerosol types are and at the end of the para I am referred to the next sections.

Provided in new Tables 1 and 2.

2258, 3: header: use UV-VIS consequently, rather than VIS-UV, when you refer to the spectral region;

We changed it accordingly throughout the MS.

2259, 15 For the VIS-IR conversion aerosol models are used. Have the authors evaluated this method versus the use of experimental data? I suggest to do this for the UV-VIS region and compare the model vs EARLINET results to have some ideas of the validity of the method. As mentioned on 2260, 12, the results should be consistent at the UV-VIS range

This is truly what we did in order to validate our calculations in the IR. Please see page 2259, lines 18-24: "The criterion for selecting between different approaches for each aerosol type was the consistency of the calculations in the UV-VIS spectral region with the ESA-CALIPSO measurements, which were the reference for any conversion made in LIVAS. More

specifically, we checked the consistency of our calculations with ESA-CALIPSO for the 532-to-355-nm EAE and the 532-to-355-nm, 1064-to-355-nm and 1064-to-532-nm BAE."

2260, 3: AERONET microphysical retrieval is restricted to AOD values higher than a certain threshold. How does that influence the current results? As reported a few lines below, the results may be not reliable and all data which are not within the range of typical ESA-CALIPSO values are rejected. The constrained data set is subsequently used to produce size distribution and refractive index: what are the results?

We agree with the reviewer, it is true that AERONET suggests that the inversions should be trusted for AODs higher than 0.4. However, if we were about to constrain the AERONET dataset as such, the data volume would not be representative, especially for certain CALIPSO aerosol types of low AOD footprint (e.g. marine). We have to consider here though that the dataset is already constrained by considering typical ranges of lidar ratios and Ångströms compatible with ESA-CALIPSO, thus controlling the microphysics delivered by AERONET for consistency with ESA-CALIPSO. The inclusion of low-AOD cases in our AERONET dataset would mostly impact the uncertainty in the refractive index but we do not expect much impact on the size distribution. This approach was the best we could follow considering the lack of other datasets of such global representativeness. A similar approach is followed also for the studies mentioned in our MS and compared to our model (i.e. Omar, 2009; Sayer, 2012). The authors of those studies did not constrained AERONET in respect to AOD as well.

2260, 14: define size parameter

We provide the definition ($\frac{2\times\pi\times radius}{wavelength}$) in the new MS.

2260, 27: summarize criteria for AERONET/CALIPSO collocation

We added in the new MS (page 2260, line 29): "More specifically, the spatial collocation required the CALIPSO overpass to be closer than 80 km from the AERONET station and the measurements to take place with maximum 30 min difference."

2261, top: how do AERONET and CALIPSO classification criteria compare? What are the differences?

To our knowledge AERONET dataset is not classified per aerosol type and there is not such a classification scheme available. Our AERONET-CALIPSO approach described in 2261 page classifies AERONET data based on the CALIPSO classification scheme, by collocating AERONET with CALIPSO measurements. Thus, we expect that the AERONET data classified by

this way would be representative to the respective CALIPSO aerosol types, independently of the quality of the classification criteria.

2261, 18: what are the consequences of the use of OPAC: suggest to compare OPAC results versus some cases for which experimental data are available. A comprehensive evaluation of OPAC is clearly not the scope of this MS, but when different methods are used in different cases, the consequences should be evaluated for at least a few example cases.

We think that this is clearly not the scope of this MS, even if such work would be of high interest. OPAC output can be much variable, depending on the chemical composition that the user defines for each aerosol type. The chemical composition is not known for either AERONET, EARLINET or CALIPSO datasets and it is unlikely that we could come up with a reasonable comparison. For the clean continental aerosol type, we had to initiate OPAC since no information was available from EARLINET or AERONET.

2262: Section 3.13 header: LIVAS aerosol model still has not been provided, so how can it be evaluated?

LIVAS model is now provided in Tables 1 and 2.

2262: Figure 2: fonts are quite small, esp along the y-axes: please enlarge

We revised the Figure accordingly.

2262, 26: replace reinforce with support

We replaced it in the MS.

2264: section 3.1.4 : Here the microphysical properties are graphically presented, but it is hard to reconstruct the size distribution from the figures: this could be a good place to represent the parameters, and then also the optical parameters in the same table.

Please see the new Tables 1 and 2.

Considering that CALIPSO is used as a reference (2262, 3) the large discrepancies between both the size distributions and the optical parameters used in LIVAS from those in the CALIPSO reference is a big concern. The discrepancies and disagreements are discussed but I miss a conclusion as regards the consequences.

CALIPSO is used as a reference regarding its final L2 product, namely the backscatter and extinction profiles. It is a bit confusing, but the CALIPSO aerosol model does not necessarily correspond to CALIPSO measurements, since it is actually derived from AERONET measurements. Thus the discrepancies between the CALIPSO and LIVAS aerosol models do not necessarily imply discrepancies between CALIPSO and LIVAS products.

The CALIPSO model is not used as a reference in our work because (as we also state in our MS) the backscatter-related lidar properties such as the lidar ratio or the BAE cannot be adequately retrieved by AERONET, since this sunphotometric instrument does not perform a direct backscatter measurement (see for example Figure 7 – upper-left). Since the backscatter is a lidar-derived quantity, we used an aerosol model from EARLINET, for aerosol types measured by the network (ESA-CALIPSO database).

ESA-CALIPSO has been tested in the past, showing that can be used for CALIPSO optimization. For example, Amiridis et al., 2013, utilized ESA-CALIPSO instead of CALIPSO aerosol model to optimize CALIPSO retrievals for dust. The results showed an improvement of CALIPSO retrievals, which after the respective corrections found to be consistent with both AERONET and MODIS, correcting the CALIPSO underestimation of AOD reported by many studies in the literature. Thus, we believe that EARLINET can provide a lidar-based aerosol model that is appropriate for space-borne lidar missions like CALIPSO but also future EarthCARE and ADM ESA missions.

2266, 27: the authors criticize that the effective radius is not provided by Omar et al., but they do not give such numbers either, why not?

The effective radius is included in the new Table 2.

2268, section 3.2: the use of discrete conversion factors leads to jumps in the extinction profiles since they are used on discrete and well-defined layers.

This is true, jumps on the extinction profile may be observed in LIVAS, especially regarding the CALIPSO L2 product of 5km horizontal resolution, upon which the conversions are applied (e.g. Figure 8). However, these 5km profile jumps are averaged over a 4 year period and on 1x1 degree aggregates. The final averaged profiles do not show any unrealistic vertical distribution of the extinction in terms of shape (no jumps). From our comparison of the integrated extinction at 355 and 532 nm to collocated AERONET AODs, it seems that the final profiles are in agreement.

2269, 6: suggest to consequently use either CALIOP or CALIPSO, depending on whether the mission or the instrument is meant

We changed the MS accordingly.

2270, 5-6: add 'aerosol'

We changed the MS accordingly: "The final LIVAS aerosol/cloud database contains multi-wavelength 4-year averaged vertical distributions and statistics for a global grid of 1x1 degree."

2271, first para: when averaging LIVAS extinction profiles and averaging AERONET data (for the same 4 years?) for comparison, was an attempt made to use only collocated data? Figure 12 shows quite large discrepancies for some regions across the world, and an example is given of the effect of elevation (but what is here the AERONET AOD in comparison with that derived from CALIPSO? Is the problem the exact collocation of CALIPSO and AERONET?). Figure 15 shows biases, but these are hard to see. The colour scale does not allow for easy discrimination of green from blue dots: suggest the use of warm (red) colours for positive biases and cold (blue) colours for negative biases, in a gliding scale.

In Figure 12 we show the magnitude of the bias between LIVAS and AERONET AODs over the 4-year period. Specifically and as we mention in the text: *"LIVAS mean AOD was calculated by the integration of the 4-year-averaged extinction profile, while AERONET AOD was calculated by averaging all available station data."* Furthermore, we made sure to use AERONET stations that provided measurements for all these 4 years, even if not continuously. We did not use only collocated CALIPSO/AERONET measurements, since this comparison aims to show the level of representativeness of the 4-year LIVAS AOD product in respect to the average aerosol load of the 1x1 degree cell area.

One conclusion of Figure 12 is that we observe large absolute biases when the 1x1 degree average is over a region with high elevation slope, and appropriate explanation is given in Figure 13 for this effect. The aim of Figure 12 is to give a first impression on the representativeness of LIVAS.

Colour scales for the discrimination of positive against negative biases are used in Figure 15. The colour scale has been revised following the reviewer's suggestion.

2273, Figure 16: the high Pearson correlation coefficient and the slope smaller than 1 reveal a very good agreement and a slight underestimation. I disagree with that conclusion: looking at the data in Figure 16, almost all data are below the equality line, for both wavelengths. The authors ascribe the LIVAS underestimation at 532 nm to CALIPSO and provide references. However, the lower left panel of Fig 16 shows that for 355 nm the underestimation is about twice as large and thus the conversion factors amplify the differences. This seems strange since the conversion factors are derived directly from observations using EARLINET. What could be the reason? And what are the consequences for the use of LIVAS in instrument development and evaluation? I would ask the same question for the IR, for which the authors acknowledge that the results are not encouraging. The main reason seems to be the choice of aerosol models used in the conversion. Would it be possible to use experimental data also

here, for instance from multi-wavelength transmission measurements extending into the infrared, over relevant areas with different aerosol characteristics?

We disagree with the reviewer on this one. If we re-plot the scatter plots with different ranges for the x/y axis, the 532 and 355 comparison supports our conclusion that the conversion using LIVAS aerosol model did not alter the CALIPSO underestimation. We have a similar Pearson's r in both correlations and the slope is exactly the same. This is not the case however for the IR as we also state in our MS.