

In this manuscript, the authors present a study showing the impact of assimilating dust extinction coefficients measured by CALIOP, and Dust Aerosol Optical Depth (DOD), separately and jointly, in a model called MONARCH. The study focuses on two dust source regions during a 2 months period and fields campaigns. The paper is well written and is scientifically interesting. However, there are parts in the article that need clarification. In addition, the paper is a bit long, and the number of case studies makes the paper a little hard to read and follow at times. I am not sure the DODsubset cases are useful in the first part since extinction profiles, and DOD does not contain the same information content; they overcrowd the figures to obtain conclusions that are kind of expected. The paper will gain clarity if you reduce the number of experiments in the main text and move some of them in the appendix if you want to keep them. I would keep the DODsubset experiments for section 3.3.

I recommend accepting it after addressing the following comments:

Title: I would update the title to be more precise. Your study focuses on particular regions of the globe, and your evaluation period is minimal. Therefore, your conclusions are based on comparisons to independent lidar observations measured during fields campaigns that are very limited.

Specific Comments:

Line 71: Please provide references to support both statements: ‘Dust is irregularly shaped’ and ‘most models assume dust...’.

Line 72: Since the assumption of optical properties is essential in your assimilation scheme, you need to provide more details on your dust optical properties. How do you derive them? Which spheroidal model are you using? Which refractive indices are you assuming? At least provide references if details come later in the paper.

L85:94: the first paragraph could be largely reduced; you are repeating what has just be said 177:80

L109:115: Please provide more details. On line 100, you specify that LIVAS provides averaged profiles of aerosol properties on a 1x1 degree grid resolution. On Line 109, you specify that you aggregate the profiles of LIVAS to the resolution of the model which is 0.66x0.66 degree grid resolution. It isn't very clear. What about the vertical resolution of retrievals?

L125-127: You mentioned ‘cover at least half of each model layer vertical thickness’; what is the vertical resolution of the model? This part is confusing and needs to be more detailed. Is the vertical resolution of CALIOP higher than the model one? How did you adjust the CALIOP profiles to the model resolution? They need to be on a similar vertical resolution.

Figure1: what is the purpose of the figure? The number of retrievals is over which period?

L144: CALIOP has a horizontal footprint of 100m and a horizontal resolution of 333m. From your description of CALIOP LIVAS retrievals, did you use 1x1 deg averaged profiles or L2 profiles you averaged at the model horizontal resolution?

L146: Can you provide more details about the collocation between the 2 datasets?

L152: What is SDS-WAS? I think you mean Appendix A?

L153-154: Please provide a reference to support your statement?

L189: For the dust emissions, you describe the four configurations listed in Table1, but why averaging 4 configurations? What is the gain of doing that instead of using one particular one? Would you please justify your choice?

Section 2.5: As stated previously, I think five experiments is a lot to follow, considering the gain in conclusion. It would help if you consider moving some experiments to the appendix.

The paper is a bit long, and the figures are crowded.

Figure 7: There are too many profiles per plot. The color scale makes it very hard to differentiate the cases. I would also increase the thickness of the lines. I am not sure the experiments with DDBsubset add any value to this plot.

L311: Contrary to the overestimation of the forecast and analyses without eLIVAS assimilation, do the analyses with eLIVAS assimilation seem to underestimate the extinction coefficient?

Figure 8: It is too small, and the color scale again does not help.

L399: “making the shape of the profiles similar to observed ones”: the way it is currently in Fig8, it is not easy to tell.

Figure 9: How did you process Figure 9? How many lidar profiles did you use? At Finokalia, it looks like there is no data during the dust event?

L405: “indicating that the assimilation of pure dust vertically resolved observations can provide a better vertical representation than those with only DOD”. It was expected since DOD is a column integrated parameter and consequently does not contain any information about the vertical distribution of aerosols. Again, I am not sure of the interest of the eDDBsubset experiment.

L412:414: Why does this line arrive so late?

L479: Section 2.2.2? I think you mean section 3.2.

Conclusion: L485: 'first time': how does CALIPSO-LIVAS extinction data differ from the CALIOP extinction products used in other published papers?

Minor comments:

L33-37: Please update your reference. The study from El Amraoui et al., 2020 <https://doi.org/10.5194/amt-13-4645-2020>, focuses on assimilating CALIOP extinction coefficients during a dust outbreak.

Please provide full names for each acronym: CALIOP, VIIRS, AERONET, CyCARE, LIVAS, IASI, NOA, TROPOS, ICAP, GEFS.....in the abstract but also in the text. The first time you use the acronym, you should provide the full name.

L182-185: The sentence is too long and needs to be rephrased.