Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., referee comment RC1
https://doi.org/10.5194/amt-2021-328-RC1, 2021

Comment on amt-2021-328

Anonymous Referee #1

Referee comment on "Bayesian uncertainty quantification in aerosol optical depth retrieval applied to TROPOMI measurements" by Anu Kauppi et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-328-RC1, 2021

The paper discusses a Bayasian approach of model selection in satellite AOD retrievals. Aerosol model selection in single-view satellite aerosol retrievals is the largest source of errors, and a method to better control the selection of different aerosol optical properties would be very benificial for AOD retrievals using spectrometers and imagers. In this paper the spectral information is used to select aerosol models and estimate the goodness-of-fit. Instead of one aerosol model, a mix of models can be found which can better fit the observations with noise.

The subject of the paper is interesting, however, there is a lack of clear new information about the approach, the applicability and results. The paper extensively describes the AOT retrieval approach and established procedures, but lacks in the escription of the new method and results. Up to section 3, the paper is well structured and reads like an AOD retrieval paper, but from section 4, the description becomes unclear and limited. Several times, the authors refer to the method like in OMI, without signifying what the benefit is for new instruments, like TROPOMI in this case. Since only a few cases are presented, which show often the limitation rather than the benefit of the method, the use for TROPOMI or other instruments is difficult to establish.

One thing is at least unclear: The retrieval of AOD may improve from using a statistical mix of aerosol models, over selecting only one model. However, would the retrieved SSA and Angstrom exponent also be determined from the mix? I did not find this in the paper, while especially the derived microphysical properties are derived from the chosen aerosol model, and hence especially sensitive to changes.

The paper lacks a clear comparison of cases with and without the new approach. Although the selected cases do compare the new approach with the aproach without model error, the cases are often extreme cases, that fail to show reasonable results and the difference between the new and old approach is difficult to establish. Moreover and more importantly, the new approach is given as is (and not too well described) and it is unclear

what the various possibilities and uncertainties of the approach are. A sensitivity study with varying parameters may help to show the limitations of the new approach.

The use of English should be improved.

Specific comments:

P8l231-l238. The description of the Gaussian variorum model is not comprehensive and difficult to understand. It's not properly explained how the values of the parameters λ,σ0 and σ1 are derived. However, this is the core of the paper: the correlation found by the statistical spectral dependence between the aerosol models determines the added value of the Bayesian uncertainty quantification. It seems to me that the way the approach is set up is essential for the study results. A proper description of the derivation of these essential parameters seems to be the least to demand, and a sensitivity study of the results based on various settings would also be proper.

P9l246: " ..the ratio of successful retrieval was □ 39 %." It is not clear what ratio is referred to here, it is not described. However, I suspect from the next sentences that it is something like the number of aerosol models that deliver a valid retrieval within the noise range. Again, this is essential for the method that is the subject of this paper and should be much more elaborated on.

P9 l253: "We will present only the main idea here as the methodology based on the Bayesian inference is explained thoroughly in the papers (Määttä et al., 2014; Kauppi et al., 2017) when applied to the OMI measurements. " If only a few sets of TROPOMI measurements were processed, and no new methodology is introduced, what is the added value of this paper?

P10 l302: The difference between the MAP AOD estimate and the weighted sum MAP AOD is difficult to determine from the text and the figures. The red line is the mode from the averaged posterior distribution. However, the black line is the sum of the weighted MAP estimates of the individual models (I assume the same (number) of models that make up the averaged posterior distribution. Then how does the difference come about? By the different order of averaging? Or something completely else that I might be missing? What is the significance of the two?

P11: l305: I understand the AOT is some kind of weighted average from the selected best models. However, these best models can be very different types, WA and BB. Are derived

aerosol property retrievals like SSA and Angstrom exponent also derived from the same mix of models?

P13: The retrieval around Pilar Cordoba of AOD > 4 where the AERONET retrieval is only 0.7 seems unlikely, especially so far from the source, although the high UV aerosol index does indicate something highly absorbing here. It is a clear failure of the satellite retrieval. This is particular true for the non-model error approach, which retrieves generally, and also now, higher values. However, I don't understand why in this case only one aerosol model is selected in the Bayesian approach, resulting in a high AOT retrieval. The authors state that the range of AOT is large, with much lower AOT 'a little bit further', which is not very satisfactory, and that the range of BB models is insufficient. This is a clear lack of the approach then, when the strength should be to include the differences between many different models. Would an easy solution not be to include a few aerosol model with extreme values outside the current aerosol properties, instead of using 66 models with only very small differences between them?

P15 l457: "As a special feature in this study we have included aerosol models of dust type with non-spherical shape of particles. The particle shape can have a large effect on the scattering properties. " Unfortunately, this is not further investigated in the paper, it is only noted in the paper that some non-spherical models are sometimes selected.

P15 l558: "It is expected that the aerosol properties included do not cover all the possible aerosol scenarios." I agree to this statement. I think this would be worthwhile to investigate further and use the Bayesian inference to use it properly.

P16 478: "We need to do more retrieval exercises and verify the results e.g. with the ground-based AERONET data before we can make conclusions about the retrieval accuracy. " I agree. In the paper a few case were selected to study the effects of different models, and understandably extreme cases of smoke and dust were selected. However, it seems that especially these cases are not well represented by the aerosol models. It might make sense to select more moderate cases, that make up the majority of satellite retrievals, and see how the specific new approach of using Bayesian interference improves the majority of the cases.