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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluation of climate model aerosol trends with ground-based observations over the last two decades – an AeroCom and CMIP6 analysis" *by* Augustin Mortier et al.

Augustin Mortier et al.

augustinm@met.no

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"The authors derived trends of total aerosol optical depth, small particle optical depth, large particle optical depth etc. from ground based observations and models. The authors analyzed these trends separated by regions and from 2000 through 2014. The authors show that a limited spatial coverage of ground based observations leads to the AOD trend derived from them not representing the trend over most of the regions except for Europe where ground based observations are most densely populated. The authors also compared observed trends with trends derived from models. In addition,

using one of CMIP6 models, the authors show regional trends as well as global trends.

I have two major issues on the current version and one suggestion. Once the paper emphasizes sampling issues in ground based observations in an application of validating global models, the topic discussed in the paper is relevant within the scope of ACP. The authors did a sensitivity study to test how well the trend derived from ground-based observations represents the trend for the entire region. The result shows that only the AOD trend derived over Europe and Australia represents the entire region (i.e. f factor discussed in Section 3.3 is less than 0.5 so that the true trend falls within a 60% confidence interval). The result of this sensitivity study is only presented as thick black borderlines in Figure 5. In addition, the result of the sensitivity study is not treated the uncertainty in Figure 6. Because the sampling uncertainty is a part of the uncertainty in observed trends, the error bar attached to the observation need to include this sampling error. When the sampling error is included as the uncertainty, the error bars of the observed trends are much larger. I suggest including the sampling uncertainty in the error bar. Then significant modeled trends consistent with observations are those within the error bar. "

The authors appreciate the two major comments and the suggestion of the reviewer. We believe that the intended objectives of the paper were not precisely enough described in the manuscript. We added some transitions to reinforce the connections in between the different sections and clarified the objectives of the paper in a revised introduction.

The aim of the representativity study is to assess whether the single use of ground-based observations can be utilized to derive representative trends over regions during the considered time period. The result of this study shows that most of them do not actually permit the derivation of such accurate trends due to partial coverage in time and space. However, those observed computed trends can still be used for the evaluation of the model trends, when co-locating the dataset in time and space with available observations. Figure 6 describes how well the models can reproduce the observed

trends, whether these trends are representative for the whole region/time period or not. For this reason, the authors decided not to include the representativity study as an uncertainty in the Figure 6 since the models are co-located with the observations and are computed with the same amount of data.

"The second point is related my comment above. The connection between the first paragraph of the Section 4.3.1 and second paragraph is weak. The first paragraph seem to conclude that regional trends derived from limited number of ground based observations can lead a misleading trend. Then why do the authors need to discuss global trends where ground based observations even represent less? Could you elaborate more the reason for discussing the global trend without showing any observations to compare (given the point the authors made in the first paragraph)? One cannot even estimate the uncertainty in the global trend other than perhaps discussing spreads among the models. But the spread is not the uncertainty in the modeled trends. Moreover, Section 4.3 focuses on mostly one model (NorESM2). Furthermore, the authors mention briefly that the ADO trend agrees with the trend derived from MODIS but the trends derived in this study are from 2000 to 2014 while the study by Zhang and Reid was published in 2010, i.e. their period is shorter than the period used in this study. Therefore, I do not think that their result cannot compare with the trend derived from 2000 to 2014 data. "

The end of the first paragraph of the Section 4.3.1 indeed relates the lack of observations for describing accurate regional trends for most of the parameters considered in this study. The assessment of the global trends is performed in this section, without the use of observations since, as indicated in the first paragraph, the partial coverage of the observations in space and time do not permit derivation of such global trends. The single model used in this section (NorESM, as being the only model for which all of the nine parameters were available for this study) provides data at the global scale and for each timestamp of the study period. All of the model data (grid boxes and timestamps) are used to derive the global trends presented in this section. While only one model is

used in this section, Figure 6 shows that NorESM2 presents, for most of the parameters/regions, similar trends to other models. This suggests that the use of this single model would probably not deliver a wrong picture of the aerosol global trends. While the authors agree to the fact that no uncertainty can be associated with the derived global trends due to the lack of observations, the authors also provide global trends of AOD for all of the models used in this study (l448). The spread of the global trends (which is indeed not similar to an uncertainty) indicates that 90% of the models reveal increasing global AOD over the study period. In addition, while the study period is not the same, the comparison of the global AOD trend with MODIS is (+0.003/decade against +0.0028/decade) also tends to confirm this global slight increase, that the authors do not expect to change dramatically within 4 years.

The authors have reinforced the connection between the first and the second paragraphs of the Section 4.3.1: l441: 'At the opposite of observations, models provide data at a global scale and along the whole study period. The completeness of those datasets offers the opportunity to derive global aerosol trends. '

"Given my two comments above, my suggestion is to significantly shorten Section 4.3 and focus on analysis of the representativeness of ground based observations. The results of Section 3.3 are only briefly presented in Figure 5 and are not discussed in detail. The number of ground sites was dramatically changed during the period analyzed in this study (2000 to 2014) as shown in Figure 1. The authors seem to have done the analysis of the impact so why not discus in detail? "

According to our previous answers, the authors would like to preserve the structure of the document by not emphasizing the representativity study as the main part of this paper. This study intended to bring the attention on the potential artificial trends produced by the lack of data. We believe that a more detailed analysis of this representativity issues could be the subject of a separate dedicated paper.

"Some minor comments Section 3.3. The description of the method needs to be given

more. For example: Line 230 to 236, the authors say “collocation”. But I did not understand what was collocated with what till I read the caption of Figure 4. Figure 4 only shows two regions. Perhaps include a table showing “f “factors for all regions? " Reviewer#1 also mentioned the lack of clarity in these definitions. The manuscript has been reworked as follows in order to make the text more intelligible: Former version: Time representativity study Reftime: Collocation in space and time Exptime: Collocation in space using complete time-series Space representativity study Refspace: Collocation in space using complete time-series (=Exptime) Expspace: All grid-points in region using full time-series Updated version: The reference dataset corresponds to the model data co-located to the available observations while the experiment dataset uses all model points. Time representativity study Reftime: Model data collocated in space and time with available observations Exptime: Model data collocated in space with available observations using the complete model time-series Space representativity study Refspace: Model data collocated in space with available observations using using the complete model time-series (=Exptime) Expspace: All of the model grid-points in the region using the complete model time-series

"Also it is not clear how the number of points shown in the top plots of Figure 4 is related to the number of observations. " The Figure 4 caption has been completed as follows: Former version: Ref_{time} corresponds to the model output collocated in space and time to the available observations. Exp_{time}/Ref_{space} corresponds to the model output collocated in space to the stations providing measurements, using the complete time series from 2000 to 2014. Exp_{space} corresponds to the model output in the whole geographic region (see \ref{fig:map_obs}) without any collocation to the observations. Updated version: The blue color (Ref_{time}) corresponds to the model output collocated in space and time with the available observations. The upper graphs show an overall increase in the number of available observations (more stations) combined with a seasonal cycle (less AOD available in wintertime). The orange color (Exp_{time}/Ref_{space}) corresponds to the model output collocated in space to the stations providing measurements, using the complete time series from

2000 to 2014. The green color (Exp_{space}) corresponds to the model output in the whole geographic region (see \ref{fig:map_obs}), using all of the grid boxes without any collocation to the observations.

"Line 362. “sign” instead of “direction”? " Agreed: Former version: the models show trends in the same direction as the observations [...] Updated version: the models show trends with the same sign as the observed trends [...]

"Line 400 to 402. The statement might be true, but it is also possible that AE is less sensitive to the change in a relative sense. " The authors agree with that remark and updated the manuscript as follows: Former version: the trends are usually smaller than for AOD in the respective regions, meaning that the amount of the particles is more subject to variations than the size (type) of these particles. Updated version: the trends are usually smaller than for AOD in the respective regions. This can mean that the amount of the particles is more subject to variations than the size (type) of these particles but could also illustrate that AE is less sensitive to the change in a relative sense.

"Conclusions stated in the conclusion section need to be more specific. For example, please state the regions instead of saying “some observations”" Agreed. Some specifications have been added to the manuscript: i.e., “Significant decreases are found in Europe, North America, South America, North Africa and Asia”

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