Reply to Dr. Collaud Coen

The authors thank Dr. Collaud Coen for her detailed comments and thoughtful suggestions about the methodology used in the revised manuscript. We have carefully considered the comments and revised the manuscript and the supplementary accordingly, including applying the 3PW prewhitening method to remove the autocorrelation before trend analysis, and utilizing monthly medians to calculate trends. A point-by-point response to the comments is presented below.

Methodology for trend analysis:

- The authors now correctly described the MK test for the significance. They also wrote a very complete answer to my comments, but with few changes in the manuscript. First, there is no mention of the potential error due to the autocorrelation. The authors wrote in their answer that they are now using yearly medians, which is not described in Sect 2.3. In order not to use prewhitening methods, the absence of ss autocorrelation has to be proven, since yearly data can still be autocorrelated.

We thank the reviewer for the suggestion. In this version, we have utilized monthly data, and applied 3PW prewhitening method (Collaud Coen et al., 2020) to remove the autocorrelation before trend analysis. We have added the description about prewhitening in the MS in Sect. 2.3:

> *It should be noted that the MK test requires serially independent data, necessitating the removal of autocorrelation from the time series before calculating trends (Collaud Coen et al., 2020; Kulkarni & Storch, 1992; Li et al., 2014; Yue et al., 2002). Several prewhitening methods are available to remove serial correlation, with Collaud Coen et al. (2020) providing a comprehensive comparison of these approaches. In this study, we apply the 3PW method developed by Collaud Coen et al. (2020) to eliminate autocorrelation before computing the trend.*

- It is clear that a lot of time series do not pass the homogeneity test. The confidence level for homogeneity can then be decreases. The results for each season is however given, even if the homogeneity test is not passed. Finally, the annual trend can be easily computed since it corresponds to the median of the seasonal slopes. I still find that the use of a prewhitening method with daily or monthly data should be preferred. You could then represent the yearly trend with some different symbols is the seasonal trends are not homogeneous and give an explanation about the consequence of inhomogeneity between the seasons.

We thank the reviewer for the suggestion. We have applied the 3PW prewhitening method with monthly data in trend analysis, and have added the related description in Sect. 2.3:

It should be noted that the MK test requires serially independent data, necessitating the removal of autocorrelation from the time series before calculating trends (Collaud Coen et al., 2020; Kulkarni & Storch, 1992; Li et al., 2014; Yue et al., 2002). Several prewhitening methods are available to remove serial correlation, with Collaud Coen et al. (2020) providing a comprehensive comparison of these approaches. In this study, we apply the 3PW method developed by Collaud Coen et al. (2020) to eliminate autocorrelation before computing the trend.

The seasonal homogeneity is also shown in the yearly trend maps (Fig. 4, 6, 10, 12), with magenta boundaries representing trends passing homogeneity test. The discussion about seasonal homogeneity have been added in sections of seasonal analysis.

- To further weight the previous comment, Fig. 5, 7, 11 and 13 (former Fig. 4 and 6) is much less convincing and provides less information than in the previous version.

The time series figures (Fig. 5, 7, 11, and 13) have also been replaced by monthly time series.

- I thank the authors to have modified the seasonal pattern, that is presently only described in the caption of Fig. 8. I think that it could be worth to add some global description in Sect 2.

Thanks for the suggestion. We have added the description about the seasonal pattern in Sect. 2.3:

> *Aerosol parameters typically exhibit strong seasonality, which should be taken into accounted in the analysis. We conduct seasonal MK tests and calculate seasonal trends on the prewhitened time series, and then derive the annual trend as the median of seasonal trends (Hirsch et al., 1982; Hirsch & Slack, 1984). The homogeneity of seasonal trend is also tested, and the results are marked in the annual trend maps. The definition of the seasons is primarily based on regional climatic characteristics. Specifically, seasons for South Asia are diveded into pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter (December-February). For the Arabian Peninsula, the seasons are categorized as pre-peak (November-February), peak (March-June), and post-peak (July-October) (Habib et al., 2019). In West Africa, the seasons are classified as Harmattan (November-March) and summer (April-October) (Balarabe et al., 2016; Nwofor et al., 2007). For the other regions, the standard seasonal divisions of spring (March-May), summer (June-August), autumn (September-November), and winter (December-February) are applied.*

- Homogeneity in the time series: I thank the authors for their answer to my comments, where they explain how they check and improve the homogeneity in the time series. A complete answer with a description on how they handle the mentioned potential problems at some stations (I mention 27 stations and they give information on 8 stations) is however missing. I do not have time to verify their work by opening the numerous files of the supplement, so that I trust them to have accomplish this fastidious work. Anyhow, it is necessary to better describe this quality control and the applied rules in Sect. 2. For exemple at line 94, the way outliers are estimated should be reported.

Thank you for your suggestion! In our previous response, we systematically checked all the stations, including the 27 stations highlighted by the reviewer. Indeed, we addressed the identified issues for 22 stations, and listed detailed description in the previous response. Fourteen stations (11 stations concerning discontinuity data and 3 stations concerning outliers) were categorized and combined, and the other eight stations with complicated problems were listed separately. Records of the other five stations appear to be resonable. Here we copy the response to these 14 stations with common problems mentioned in our previous response:

> *Only those years with at least 8 monthly data were retained to calculate annual and seasonal means. Consequently, the updated results significantly improve the continuity and homogeneity of the data. Time series of the following stations mentioned in the comment concerning discontinuity data have been greatly improved: Cabauw, Chen-Kung, Davos, Fort-McMurry, Hamburg, Shirahama, Mexico-city, Missoula, Beijing, Lille, and Rome.*
>
> *We also removed outliers for the records, thus time series of the following sites having doubtful values have been improved: Canberra, Ceilap, and Ilorin.*

We have detailed the quality control criteria in Sect. 2.1:

> *Long-term trend analysis necessitates homogeneous time series, and outliers would influence the result. We first check the records, removing invalid and abnormally high or low values (such as SSA below 0.7 for all stations, and AOD above 2.0 for low AOD stations) from all-point measurements.*

We have also revised the description about the measures to ensure data continuity in Sect. 2.1:

> *To ensure adequate records and data continuity in trend analysis, we require the data to have at least 10 years of records with no less than 8 monthly measurements for each year during the 2000-2022 period. Years with less than 8 monthly data and seasons with less than 10 years of records are discarded due to poor annual and seasonal representation. We also remove the first or last several*

months from the time series of certain stations (Canberra and Ilorin), where discontinuities were identified relative to adjacent monthly records.

References

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