Review for "Extended Aerosol Optical Depth (AOD) time series analysis in an Alpine Valley: A Comparative Study from 2007 to 2023" by Wagner et al. (discussion 30 Jan 2024)

Valuable results in a well written paper. Very few mountain sites with such a long records of AOD. Methodology, clear and simple. Data at both sites (Innsbruck and Davos) have sufficient statistics and can be comparable. Already for this comparative aspect and the trends obtained for the AOD variability - it is worth publishing.

However, I'd like authors to rethink following:

Trends as both sites are provide as linear fit, maybe non-linear would be better? Why should one expect the linearly declining trend for the entre period? From the point of view of the low-elevation sites (AOD dominated by boundary layer aerosols) one maybe could expect that with the dimming (improving air quality in last decades) we get less AOD. For the mountain site the AOD is related rather to the long-term aerosol transport, which at both sites can be expected significant, if not completely dominating. I feel this could be more properly addressed. I would less focus of the "remarkably similar trends" but try to explain better the differences and similarities in Fig.8 in a way to explain why it is so.

Thank you for your insightful observations regarding the use of linear versus non-linear models to analyze AOD trends at the two sites. The decision to employ linear regression in our analysis was guided by several considerations, primarily the length of the dataset and the preliminary nature of observed trends.

As noted, a typical climatology study often relies on datasets spanning at least 30 years to robustly characterize and interpret atmospheric trends. Given that our dataset covers approximately 17 years, it indeed presents limitations for a comprehensive climatological analysis. Within this shorter timeframe, linear regression provides a straightforward initial approach for identifying basic trends and patterns in the data, acknowledging that these results are preliminary and might change with the inclusion of more data over time.

Furthermore, the linear trend approach was selected due to its simplicity and transparency in interpretation, which is suitable for establishing a baseline understanding of the AOD dynamics at each site. However, we agree that the aerosol optical depth trends could be influenced by complex factors that a simple linear model might not fully capture.

At the low-elevation site in Innsbruck, AOD is significantly influenced by boundary layer aerosols, which have been shown to decrease in response to improved air quality measures over recent decades. This could suggest a non-linear response of AOD to ongoing environmental policy and technological changes. At the high-elevation site in Davos, long-range aerosol transport plays a more prominent role, potentially leading to different trends that could also be non-linear, influenced by changes in global aerosol emissions and atmospheric circulation patterns.

Addressing your point on the similarities and differences between the sites, it is evident that a more nuanced approach might better elucidate the distinct processes at each site. In future analyses, as more data become available, employing non-linear models or segmented linear models could be more appropriate to capture the potential phases of AOD changes due to both local management practices and global environmental shifts.

In conclusion, while the current study employs linear regression due to dataset constraints and aims for initial trend assessment, we acknowledge the need for more complex models to fully understand the temporal dynamics of AOD. Future work will aim to integrate longer time series and apply more sophisticated statistical techniques to better represent and understand the underlying processes affecting AOD at both sites.

Limitations of the study in terms of not being ably to estimate of which % of AOD load is form boundary layer aerosols and which form free troposphere is not discussed. Taking into account that the Davos rural site measures only in free-troposphere (can this be assumed?), the Innsbruck urban site has a strong contribution form boundary layer aerosol. So are they comparable and to what extend. Are the similarities at both sites due only to high-tropospheric aerosol? Taking into account the latter site being one of the ACTRIS sites, it would be good to mention that continuous lidar observations of aerosol extinction profiles could help in such distinction.

In terms of the aerosol source and distribution, it is plausible to consider that the Davos site, located at a high altitude, predominantly measures aerosols in the free troposphere. This assumption is based on its elevation and remote setting, which generally limits the influence of local boundary layer sources. Conversely, Innsbruck, situated in an urban valley, is significantly impacted by local emissions and boundary layer aerosols, which contribute to its AOD measurements. The similarities observed in the AOD trends at both sites may indeed be influenced more by high-tropospheric aerosols. However, we cannot investigate this hypothesis using the presented AOD-timeseries. Continuous lidar observations of aerosol extinction profiles could provide a clearer distinction between boundary layer and free tropospheric aerosols. Such measurements, which are part of the ACTRIS (Aerosol, Clouds, and Trace gases Research InfraStructure Network) activities at some sites, allow for the vertical profiling of aerosols and could significantly enhance the understanding of their spatial distribution and temporal dynamics. We are working on this topic in an ongoing project.

We have added this section to the results section:

Continuous lidar observations of aerosol extinction profiles could provide a clearer distinction between boundary layer and free tropospheric aerosols.

And change a sentences in the conclusions and outlook section:

Further investigations taking local emissions and land use changes into account are worthwhile.
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For a better understanding of the aerosol behaviour, it is essential to distinguish between boundary layer aerosols and aerosols in the free troposphere and additionally investigations on local emissions and land use changes are worthwhile.

minor/technical comments:

Please check reference Tiw 2023, line 13

corrected

Fig.1 and Fig.2 Caption - pls check denoted colors are not in the figure

Corrected, after updating the figures we did not update the caption – sorry for our clumsiness

Longer data gaps occur at both sites de to device failures or calibration - can you quantify (e.g. 24 days due to X and 45 days due to y) to betetr assess on the instrument reliability?

We added two horizontal colorbars for a better visual detection of the data gaps. Our approach in Innsbruck has been to categorize these gaps into broader categories reflecting the primary causes, such as device failures, calibration, maintenance periods and measurement campaigns at a different location. In Innsbruck, we estimate that significant data gaps due to notable hardware and software issues encompass approximately 50% of the total measurement period, with the remainder largely attributed to planned maintenance and operational transitions at a different position (measurement campaigns.

Fig.5 the black dots are no visible

There are no black dots – we decided to omit the black dots for a clearer visualization, but again forgot to update the caption

line 64 and 76 - same info, pls avoid repetitions (please check also elsewhere)

We omit the sentences: "The average AOD in Davos (0.054) is about half as high as in Innsbruck (0.115)." and "This type of display is particularly suitable for daily data monitoring if the current data is also displayed in the graph."

It is a comparative study, so it would be better to plot Figs.1 and 2 as one figure with two panels one above other. Similar for e.g. Figs. 5 and 6, I would plot one next to other. This way you will reduce the length of paper and also ease reader life.

Thanks for the suggestion. We combined figure 1 and 2 and figure 5 and 6 accordingly.

Also, the most important result is the trend in Fig.8 but you have too many figures and this message gets lost.

By reducing the number of figure, we hope that the main message – the declining trends are – is now more visible