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

Synopsis:

This manuscript which analyses two long-term datasets from Aerosol Optical Depth observations in the Alps is a valuable contribution to the assessment of aerosol trends in mountainous areas.

General comments:

- The manuscripts lacks a description of the dataset concerning measurement uncertainties, especially concerning long-term stability of the observations and possible biases.
  Regular calibrations of the PFR in Innsbruck, conducted in Davos, have shown remarkably stable calibration coefficients for the 501 nm channel over the past 17 years, with relative changes ranging from -0.5% to +0.7%.

- I suppose that the AERONET sun photometer in Davos has been regularly calibrated according to AERONET standards. There is no information about the instrument in Innsbruck, concerning instrument type and associated uncertainties. Please provide information about the uncertainties of both instruments and a summary of the calibrations performed during the 17-year period.

  We added this paragraph:

  Precision Filter Radiometers (PFRs) are engineered to assess background aerosol conditions and have participated in sun photometer intercomparisons, like the CIMEL devices used in the global AERONET network to ensure data quality assurance. The discrepancies between PFRs and CIMEL devices used in the global AERONET network (Holben, 2001), consistently fall within a +/- 0.01 AOD range. The Innsbruck PFR performed even better during the intercomparison campaign in Davos in October 2021 (Kazadzis, 2023). Long-term analyses confirm the excellent traceability of AERONET AOD measurements to the World AOD standard at 500 nm (Cuevas, 2019). Furthermore, regular calibrations of the PFR in Innsbruck, conducted in Davos, have shown remarkably stable calibration coefficients for the 501 nm channel over the past 17 years, with relative changes ranging from -0.5% to +0.7%.

- Please provide a (very brief) introduction into how AOD is defined and about the general measurement principle of sun photometers, as there might be readers who are not so familiar with these topics.

  This paragraph was added in the introduction chapter:

  It quantifies the cumulative effect of aerosol scattering and absorption along the path of sunlight through the atmosphere. AOD is unitless and provides an indication of atmospheric clarity,essential for climatological and environmental research. The

primary method for determining AOD is through the use of sun photometers, which measure the direct solar irradiance reaching the Earth's surface. The basic principle behind these measurements is the Lambert-Beer law, a fundamental equation that relates the intensity of light to the properties of the material through which it is passing.

$I = I0(R) \cdot e20 - \tau(\lambda) \cdot m$ (1)
with

– I is the observed intensity of sunlight after passing through the atmosphere
– I0(R) is the original intensity of sunlight before entering the Earth's atmosphere, dependent on the sun-earth distance R
– τ (λ) is the optical depth at wavelength λ, which includes contributions from aerosols, gases, and other atmospheric constituents
– m is the optical air mass, a factor that accounts for the path length through the atmosphere, which depends on the solar zenith angle ($m \sim \cos(sza)$)
A detailed description of the retrieval of AOD from sunphotometer measurements in Innsbruck is given in Wuttke et al.
(2012) and in Sinyuk et al. (2020) for the AERONET AOD retrieval respectively.

- As you have data only from about 80% of the months: Are these missing months equally distributed over the year? And what is the main reason for missing months? Are the gaps caused by instrument failures or calibration periods? Because I could imagine that you get nearly every month 5 cloud-free days where you can derive AOD. Please comment on that!

  In addressing the data availability concerns raised, it is important to clarify the distribution and causes of the missing months in our AOD dataset for both Innsbruck and Davos. If the sun photometer runs faultlessly from sunrise to sunset, it is indeed plausible to expect at least five cloud-free days per month for AOD data collection. The missing data, accounting for approximately 20% of the total dataset, are not entirely uniformly distributed throughout the year. Our analysis indicates that the gaps in the Innsbruck timeseries more prevalent during the winter months, primarily due to shorter daylight hours. The primary reasons for data gaps at both stations are twofold: instrument calibration and failures. Calibration periods are scheduled routinely to ensure the accuracy and reliability of our measurements but result in temporary interruption of data collection.

- I do not see any negative AOD trend after 2014 anymore (Fig. 8). Do you have an explanation for the decline until 2013, but no more change afterwards? Are the trends the same if you separate into winter and summer seasons?

  Thank you for your observations regarding the AOD trends. We also notice the apparent shift in trends post-2014, as mentioned. We see a similar pattern, when analyzing the summer and winter seasons separately. However, the time series is not yet long enough to be able to draw solid conclusions about the trend from 2013 onwards. Therefore, we did not start a discussion to this comment within the paper.

- What is the statistical significance of the trends? Please give some information on that!

  We calculated p-value and Person correlation coefficient (r) for all trends. The trend is considered significant if the conditions $p<0.05$ and $|r|<0.6$ are fulfilled.

Minor comments:

- Line 47 and Table 1: In the table you write for valid months: 83.2% and 79.4%, whereas in the text you give 73.3%/79.4%. Please check these values!

  The values in table 1 are correct., We changed the text (line 47) accordingly.

- Line 69: Do you think that there are more convective clouds "during the melting period"? I would rather say "after the melting period", as heating of the ground is inhibited as long as there is snow cover - at least in the higher parts of the Alps.

  We added "and after" *to the sentences. Of course, the heating of the ground is inhibited as long as there is a high albedo due to snow cover. However, a broken snow cover in spring guarantees sufficient warming and at the same time enough moisture for cloud formation.*

Technical comments:

- Line 8: typo in "latitude

  corrected"

- Figures 1,2: Please check the colors – I don't see the blue color of the individual measurements, for me the triangles for the monthly means look blue

  There is no blue color, after updating the figures we did not update the caption – sorry for our clumsiness. The cation and the figures are now in line.

- Figure 2 has another size than fig. 1: Please provide a larger version of fig. 2

  We combined figure 1 and 2 into one figure. The time series of Innsbruck and Davos are now better comparible