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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comparison of the optical depth of total ozone and atmospheric aerosols in Poprad-Gánovce, Slovakia" *by* Peter Hrabčák

Anonymous Referee #1

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GENERAL COMMENTS

The manuscript by dr. Peter Hrabčák presents a long dataset of total ozone and aerosol optical depth (AOD) measurements taken by a Brewer spectrophotometer at the site of Poprad-Gánovce. The optical depth of these two atmospheric constituents are calculated and compared. A basic statistical analysis of the annual averages is presented, which supports a statistically significant decrease of the AOD. Comparisons with satellite estimates and zenith sky measurements are also briefly reported.

An in-depth analysis of such a long dataset (23 years) is certainly of interest and useful for the atmosphere and climate communities. However, I don't support the publication

of the manuscript until major revisions are made, in particular:

1. the language must be definitely improved for ease of reading;

2. the statistical analysis is too simplistic:

- an in-depth examination of the measurement uncertainty is essential to trust the quality of Brewer measurements and to correctly calculate the trend significance, however it is missing in the manuscript. The calculation of the statistical significance was performed on the basis of the natural/instrumental variability from the data themselves. Instead, systematic errors and drift uncertainties should be included in the calculation of the trend uncertainty and its statistical significance. Furthermore, the paper would certainly benefit from comparison to co-located (or close) photometers, if available;

- the observed decrease in the AOD series seems to be mainly introduced by the first two years of data (Fig. 3-4). Since "instability of ETCs during the 1st calibration period" is reported in Sect. 3.1 and the trend abruptly changes after 1996, I'm wondering if use of a single trend for the full series is justified and what the statistical significance of the trend would be by considering only the 1996-2016 period;

- the results of the analysis are not properly supported by a complete understanding and explanation of the physical phenomena at their base. The reported trends are not compared to the existing scientific bibliography.

These remarks are elaborated in the next sections (specific comments and technical corrections).

SPECIFIC COMMENTS

- Sect. 1 (p.3, l.5): the Langley plot method should be explained in Sect. 2.3 instead of the Introduction. Instead, a list of previous publications about AOD and Brewers and trend calculations would be welcome in Sect. 1;

- Sect. 2.1 should be rewritten in a more rigorous way. Use bibliographic references

and/or formulae instead of a qualitative description. Moreover, zenith sky measurements should be introduced and explained here and the ZS retrieval algorithm should be presented (how was the ZS polynomial determined?);

- Sect. 2.1: possible uncertainties due to the use of a single monochromator should be discussed. The sources of the deviations from the Angostrom law of the AOD measured by single Brewers at the shortest UV wavelengths (e.g., Fig. 5) are known since a long time (cf. Arola and Koskela (2004), "On the sources of bias in aerosol optical depth retrieval in the UV range"). Uncertainties arising from polarisation effects and temperature changes inside the instrument should also be mentioned;

- Sect. 2.3 and 2.4: some inconsistencies can be found in the use of different cross sections datasets in the manuscript. Effective IUP cross sections are used for the calculation of ozone optical depths, while ozone retrievals are performed using Bass&Paur (cf. Redondas et al., 2014). Bodhaine et al., 1999, is used for AOD calculations, while the Brewer operational Rayleigh cross sections are used to retrieve the ozone optical depth, causing a bias of about 3 DU (cf. Carlund et al., 2017). The authors should explore those issues;

- Sect. 2.4 (p.6, l.6-19): explain why all those thresholds were chosen. Explain that an iterative approach was used;

- Sect. 2.4 (p.7, l.5): the figure content should be fully explained in the text;

- Sect. 2.4 (p.7, l.13-19): with no thresholds for the minimum number of data for a month and a year, the annual average becomes very sensitive to potential gaps in the series and their distribution throughout the year (due to the seasonal cycles of both ozone and AOD). The author should explain how he dealt with gaps in the series. The calculation of the linear trend uncertainty as described in the manuscript only takes into account the natural and instrumental variability. However, also instrumental systematic errors (e.g., radiometric calibration drifts) contribute to the uncertainty of the measurements and the trend and should be taken into account to determine the trend

significance. An extensive treatment and description of measurement uncertainties is lacking in the current manuscript;

- Sect. 3.1: according to Fig. 2, the logarithm of ETC jumps by more than 0.2 at several points. The author should prove that a two-year "piecewise" series of calibration constant is suitable for the calculation and explain why a moving average wouldn't be better. "Instrument instability", "straylight effects" and "instrumental problems" reported in Sect. 3.1 should be better explained and quantified. Furthermore, could you plot the ETCs obtained by transfer from IOS in the same figure and check whether they agree with the values obtained from LPM?

Also, Langley plots in urban areas are prone to errors: the ETC variability could originate from AOD curvature centred at noon, which cannot be filtered by any quality criteria (e.g., Marenco 2007 and Diémoz et al. 2016). Are in-situ measurements (e.g., PM) available in the investigation area to exclude such an effect?

- Sect. 3.2: the AOD trend in the first three years of measurement is about -0.1/year (Fig. 3). Does the author have a reasonable explanation for this large decrease? A reference to Arola and Koskela (2004) should be included to explain the observed AOD dependence on wavelength. The seasonal variability of ozone is a well-known phenomenon, however the general behaviour drawn in Fig. 6 should be better explained in the text and appropriate references provided. Similarly, the AOD seasonal cycle (Fig. 7) should be explained, the physical reasons for the observed two peaks searched for and the general behaviour in Fig. 8 explained. The AOD results should be compared to analogous data already published in the scientific literature;

- Sect. 3.3: instantaneous measurements from the Brewer should be compared to overpassing satellite estimates instead of daily means. Also, why DS and ZS are not directly compared? This would answer the question raised in the Conclusions ("The reason for this is _probably_ the systematic error of the ozone determination using ZS measurements"). The data selection criteria for the OMI-Brewer comparison (223

days) should be better explained (distances in space and time to Brewer measurements). How were the satellite data obtained (e.g., GIOVANNI)?

- Conclusions: the match between OMI and the Brewer is defined "very good", however the linear correlation index is only 0.5. Some bibliographic references should be provided to prove that the agreement between both instruments is satisfactory compared to similar data in the existing scientific literature;

TECHNICAL CORRECTIONS

- p.1, l.17: replace "terrestrial" with "ground-based" throughout the manuscript. The name of the satellite radiometer (OMI) should be specified in the abstract. Some statistical scores should be included in the abstract to quantitatively support the "very good match" claim;

- p.1, l.19 "systematically higher values": the value of the bias should be written;

- p.1, l.26 "Adverse effects have higher doses of UV radiation...": the words order is wrong;

- p.2, l.1 "Very necessary" -> "Necessary";

- p.2, l.2 "functioning of the human body": be more specific. "The anthropogenic effect": what effect? Please, reformulate the sentence;

- p.2, l.5 "about 5%": specify the considered latitude belt. "even lower": why "even"?

- p.2, l.17: "it affects" -> "they affect". "ones" -> "one". "aircraft flight" -> "emission from aircrafts";

- p.2, l.20: "the significant" -> "a significant";

- p.2, l.22-32: I would remove this paragraph, which is too didactic and a bit off topic, since bibliographic references were already introduced;

- p.2, l.33: "have a significant role to play" -> "play a significant role";

- p.3, l.1: it should be better explained that AOD is not the only quantity describing the radiative effects of aerosols;

- p.3, l.2: "AOD obtained results... and satellite measurements" please rephrase the sentence;

- p.3, l.4: "Brewer allows" -> "Brewer spectrophotometers allow". "Optical depth" of what?

- p.3, l.8 "there is required...": rephrase the whole sentence;

- p.3, l.10: "zenith angles" -> "solar zenith angles";

- p.3, l.12: it should be explained why lower latitudes are better and what are the "certain limitations in middle and ... higher latitudes";

- p.3, l.17: "previous method" -> "the previous method";

- p.3, l.23: "The Brewer ozone spectrophotometer";

- p.3, l.25: "different" from what?. "after pass" -> "after passing";

- p.3, l.26: notice that the DOAS method refer to continuous spectral measurements nowadays, while the Brewer only measure irradiance at five wavelengths;

- p.3, l.28: "predetermined wavelengths" -> what wavelengths exactly, and how many?

- p.3, l.29: "It is possible to determine the total amount...";

- p.3, l.30 "by following a comparative analysis in the mathematical model...": the sentence is totally obscure to the reader that doesn't know how a Brewer works;

- p.3, l.32 "feasible": explain why it is possible only at those wavelengths;

- p.4, l.1 "0.006+- 0.002 nm": notice that this is the wavelength increment (1 microstep) rather than the accuracy, which depends on temperature changes inside the instrument and frequency of hg tests;

- p.4, l.2: "undergoing" -> "has been undergoing";

- p.4 l.6: Sect. 2.2 should be the first section, in order to keep the description of the instrument (now 2.1) and of the algorithm (2.3) close to each other;

- p.4, l.9 "The content of aerosol in the air, whether...": please rephrase this sentence, which is not clear;

- p.4, l.11 "In rare cases, it can also be...": rephrase;

- p.4, l.14 "relatively windy": relatively in comparison to what?. A figure with a map with the position of the site (e.g., including a wind rose) would be helpful;

- p.4, l.17 "Measured total ozone values... we used...": wrong words order;

- p.4, l.19 "density" -> "power density" or "irradiance";

- p.5, l.1 "It is used to using so called an effective": rephrase;

- p.5, l.10 "Rayleight scattering" -> "Rayleigh scattering". Please, specify here which dataset was used, e.g. Bodhaine 1999;

- p.5, l.17-22: the description of the Brewer data reduction is not clear at all to the unaccustomed reader. Please, rewrite this part or replace with bibliographic references;

- p.5, l.23 "the arithmetic average is then calculated": how is the effective airmass for the average of those 5 measurements calculated? Remember that air mass doen't vary linearly with time;

- p.5, l.25: "zeniths" -> "zenith angles";

- p.5, l.29: "angels" -> "angles";

- p.5, l.30: "determine unknown" -> "determine the unknowns";

- p.6, l.1-5: rewrite this paragraph in a more ordered way;

- p.6, l.30: provide a reference for the airmass formula;

- p.7, l.7: "received" -> "ended with";

- p.7, l.13 "characteristics ... progressed": the sentence is unclear;

- p.7, l.18: "standard deviation" of which quantity?

- p.8, l.8 "is the highest for the shortest wavelength": rephrase. "Variation coefficient" -> "The variation coefficient";

- p.8, l.11: "A graph also shows ETCs values which characterize entire" -> "The graph also shows the ETCs values which characterize the entire";

- p.8, l.12 "25 ETCs were used on average": 25 in a year?. "Strict conditions met" -> "were met";

- p.8, l.15: "the chosen criteria are the optimal compromise". "Directly affects the resulting values";

- p.8, l.16: what are the "weather effects"? Does the author refer to the clouds?

- p.9, l.14-18: provide bibliographic references of previous studies;

- p.9, l.17 and 18: "what" -> "which". Line 21: "than" -> "that". Lines 21-23: several "the" are missing;

- p.9, l.24: "the comparison". L.27: "the mentioned". L.28: "in studied" -> "at the studied";

- p.10 Fig.3: use the same wavelengths for ozone and AOD optical depths;

- p.11-12, Fig. 6-7: draw AOD and its standard deviation on the same scale, e.g. using boxplots;

- p.11, l.19: "it occurs" -> "occurs". Line 20: "characteristic" -> "characterized";

- p.12, l.12: "in particular";

- p.13, l.8 "once a day": provide overpass time;

- p.13, l.9 "scored specific place": rephrase. Line 10: "the square" -> "a square";

- p.13, l.13: "is illustrated comparison of the annual averages..." -> "the comparison of the annual averages of total ozone is illustrated in Fig. 9". "it was the comparison of values obtained ... obtained": rephrase;

- p.13, l.20: is 3.9 DU a "significant" difference? Line 21: "It can be said that...": please, explain better which sources of systematic errors have to be considered;

- p.13, l.24: what value for the "Angstrom exponent" was used? Why?

- p.13, l.27 "only AOD values smaller than 1.5": how was this threshold established?

- p.13, l.28: I would say that a correlation index of 0.5 is moderate, not strong;

- p.14, l.10: "was" -> "were". "so it is a period" -> "i.e. for a period".

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