Referee No.		COMMENTS TO THE AUTHOR(S)	REPLY FROM THE AUTHOR(S)
Anonymous referee #3		Overall, the manuscript does a nice job in the description of the TuPS, although a few more details of its setup would be helpful (see below). The characterization of the TuPS is generally convincing and the example of application to Dobson instruments is helpful to understand the motivation for the development of the TuPS. What the manuscript is currently missing is to provide the reader with a frame of reference on how the TuPS improves operation of Dobson spectrophotometers, i.e. how the TuPS will improve the accuracy of ozone column data.The introduction also mentions the disagreement between Dobson and Brewer spectrometers as a motivation for the development of the TuPS. This is not further discussed in the manuscript and the reader will be left wondering if the TuPS does in fact solve this problem.Without discussing these issues, the manuscript lack a clear tie to the science the TuPS is intended to support, reducing its impact and making it less useful to the community. The topic of the manuscript is suitable to publication in AMT. However, without a more detailed	
	1.1.	Information on why a better characterization of the spectral characteristics would improve the consistency between Brewer and Dobson spectrometers would be helpful to better motivate the rest of the manuscript. Are the 3% difference due to difference in how absorption cross sections are derived for each instrument? Is this solely due to an imprecise characterization of the spectral characteristics of the two spectrometers?	The ozone absorption coefficient of all Dobson spectrophotometers are derived from the primary Dobson, defined as the World reference for the global Dobson network. This ozone absorption coefficient is obtained from the convolution of the line spread functions of each slit with the ozone cross sections at a particular ozone temperature. As shown in Koehler et al (2018), the difference in ozone absorption coefficients using either the nominal value or the ones obtained using the actual measured line spread functions can differ by up to 1%. *Köhler, U., Nevas, S., McConville, G., Evans, R., Smid, M., Stanek, M., Redondas, A., and Schönenborn, F.: Optical characterisation of three reference Dobsons in the ATMOZ Project – verification of G. M. B. Dobson's original specifications, Atmos. Meas. Tech., 11, 1989–1999, https://doi.org/10.5194/amt-11-1989-2018, 2018* . The 3% difference between the Dobson and Brewer results in part due to the use of a nominal instead of the actually measured line spread functions, as well as the inconsistency in the ozone absorption cross-sections used up to now (Bass & Paur, 1985). *Bass, A. M. and Paur, R. J.: The ultraviolet cross-sections of ozone. I. The measurements, II – Results and temperature dependence, in: Atmospheric ozone; Proceedings of the Quadrennial, 1, 606– 616, 1985.* As shown in Groebner et al., 2021 *(Gröbner, J., Schill, H., Egli, L., and Stübi, R.: Consistency of total column ozone measurements between the Brewer and Dobson spectroradiometers of the LKO Arosa and PMOD/WRC Davos, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2020-497, in review, 2021.)* the consistency can be significantly improved when using the actually measured line spread functions of a Dobson spectrophotometer, in conjunction with the cross-sections from IUP *(Serdyuchenko, A., Gorshelev, V., Weber, M., Chehade, W., and Burrows, J. P.: High spectral resolution ozone absorption crosssections – Part 2: Temperature dependence, Atmos. Meas. Tech. Discuss., 6, 6613–6643, doi:10.5194/amtd-6-6613-2013, 2013.)*
	1.2.	Why is it necessary to develop the TuPS? Could a small commercial monochromator not fulfill the same function? What makes commercial, or previously developed research grade, options unsuitable to solve the characterization problem?	The measurement of the line spread functions of a Dobson spectrophotometer require the use of a tunable radiation source, that is, a tunable monochromatic source that can be used to scan through the line spread function of a spectroradiometer. This was done with a tunable laser source in the laboratory (Komhyr, W. D., Mateer, C. L., and Hudson, R. D.: Effective BassPaur 1985 Ozone absorption coefficients for use with Dobson ozone spectrophotometer, J. Geophys. Res., 98, 20451–20465, https://doi.org/10.1029/93JD00602, 1993. And more recently Köhler, U., Nevas, S., McConville, G., Evans, R., Smid, M., Stanek, M., Redondas, A., and Schönenborn, F.: Optical characterisation of three reference Dobsons in the ATMOZ Project – verification of G. M. B. Dobson's original specifications, Atmos. Meas. Tech., 11, 1989–1999, https://doi.org/10.5194/amt-11-1989-2018, 2018. However this equipment is complex, cumbersome and requires the Dobson spectroradiometer to be moved to the laboratory. Instead, the TuPS allows the measurement to be performed at the location of the instrument, it takes less than 1 hour of measurements and has therefore nearly no impact on the normal operation of the Dobson spectrophotometer. Before the TuPS development started, we made a survay of the market on availability comertially avalable system meeting the TuPS requirements on its optical parameter and portability. To our best knowledge, there were no commercial monochromators available which could simultaneously meet the TuPS specifications for resolution, wavelength stability and size requirements. And such system is stillnot avalable on the market.
	1.3.	Since the scientific problem identified here seems to be the comparison of Dobson and Brewer spectrometers, why was the instrument only developed for Dobson systems?	In contrast to the Dobson spectrophotometer network, each Brewer spectrophotometer is characterised spectrally at regular intervals using a set of spectral emission lamps (mercury and cadmium as the most common). These measurements are then used to define the line spread functions and thereby to calculate the individual ozone absorption coefficient of the brewer spectrophotometer. It therefore does not require a tunable radiation source like the tups to determine its spectral characteristics. Nevertheless, the methodology employed by the Brewer was validated by measuring the characteristics of one Brewer spectrophotometer belonging to the reference triad of the Regional Brewer Calibration Center-Europe (RBCCE) (Redondas et al., Redondas, A., Nevas, S., Berjón, A., Sildoja, M.-M., León-Luis, S. F., Carreño, V., and Santana-Díaz, D.: Wavelength calibration of Brewer spectrophotometer using a tunable pulsed laser and implications to the Brewer ozone retrieval, Atmos. Meas. Tech., 11, 3759–3768, https://doi.org/10.5194/amt-11-3759-2018, 2018. However the Tups is flexible enough so it could also be applied to the Brewer spectrophotometer if the need would arise.
Methods	2.1.	Line 48. Define 'OR'	Typo. This will be corrected to 'or'
	2.2.	It would be helpful to add a table with details of the optical components, such as diameter and focal lengths of mirrors, size and blaze angle of grating, etc.	Same comment has already been responded to Anonymous referee #1. The information requested by referee will be added in the Chapter 2 . *- added in line 57 of manuscript:* It consists of a 100 µm input pinhole (IP), a 100 µm output slit vertically oriented (OS), two identical 90° off-axis parabolic mirror 25 mm diameter, 203.2 mm effective focal length (PM1 And PM2) and 3600 grooves/mm grating optimised for a spectral range of interest. Radiation from the input pinhole is collimated by a parabolic mirror and illuminates the grating 25 mm across. The resulting diffracted radiation is focussed by the second parabolic mirror forming a spectrum across the exit slit. The central output wavelength is controlled by the angle of the grating, and the bandwidth by the width of the exit slit. A very small vertical shift in the image at the exit port is associated with the rotation of the grating. This shift is of no consequence to the subsequent use of the instrument other than that an exit pinhole may block some of the radiation as the image moves. Therefore, a vertical oriented exit slit is used instead. The input F/# is F/8.1. The output F/# varies with the wavelength. It ranges from F/11.2 at 300 nm to F/12.8 at 350 nm. The An optical fibre coupled high intensity broadband UV discharge lamp (http://www.energetiq.com/fiber-coupled-laser-driven-lightsource-long-life-compact.php) was used as input radiation source. The system was designed such that the FWHM of emitted radiation didn't exceed the value of 0.1 nm for whole spectral range of interest.
	2.3.	Provide more detail on the motorized rotation stage. What is its angle interval per step, repeatability (precision), etc. How does the stage determine its absolute position, does it have a reference point that is used determine the absolute position at start-up?	The motorized stage is equipped with an high resolution 32-bit relative angular encoder. The absolute position is derived by calibrating the stage to its reference point at the start up. The smallest angular step is limited by the reading noise from the encoder which is in the order of 2e-4 part of a degree.
	2.4.	Figure 1 and 2: Add a scale to these figures to provide some sense of the size of the TuPS.	The scale is going to be mantioned in the text of this chapter. To facolitate the readers comfort better, it will be added to the Fig 1 and Fig 2 description
	2.5.	Throughout the manuscript please ensure to consistently use a decimal point or a decimal comma, but not both.	It will be done
Results	3.1.	Line 109: What does "(k=1)" mean?	The standard uncertainty of measurement has been determined in accordance with JCGM 100:2008 document *(Evaluation of measurement data — Guide to the expression of uncertainty in measurement, BIPM, JCGM, 2008, https://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_F.pdf).* The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k corresponding to a coverage probability of approximately 68 %, which for normal distribution corresponds to a coverage factor k = 1.
	3.2.	Line 110: More information on the difference of the calibration before and after in-field use would allow the reader to better assess the stability of the TuPS.	This information is given in detail in Chapter 6, 'TuPS temporal stability'. Specific reference to chapter 6 will be added to the line 110: It is worth noting that the TuPS wavelength scale is recalibrated before and after each in-field measurement campaign (as reported in chapter 6 below) and the two linear interpolation parameters are readjusted according the calibration results
	3.3.	Line 115: Where is the temperature measured? Is this measurement built into the TuPS or are ambient air temperatures used? How long does it take for the TuPS to stabilize thermally? How is the temperature dependent wavelength scale used?	During the temperature dependence measurement the ambient temperature in the climatic box was measured with a Pt100 temperature sensor.One hour period was give to reach thermal equilibrium of the system before each wavelength scale calibration. During that time ambient temperature kept stable within 0,1 °C. Even though a very small temperature sensitivity of 0,007nm/°C was measured, it can be used as a correction factor for TuPS if the ambient temperature differs signifficantly from the temperature during the TuPS in-lab calibration.

	3.4.	Line 117: I don't understand this sentence.	It refers to the experimental experience that the mechanical symmetry of optical setup typically exhibits lower temperature sensitivity caused by the thermal expansion.
	3.5.	Lines 118 – 121: This is a repeat of the prior five lines.	It will be corrected
	3.6.	The discussion of temperature dependence also begs the question on the dependence on atmospheric pressure, especially considering that some of the Dobson Instruments are located in mountain observatories.	All grating spectrometers are sensitive to air pressure as they discriminate spoectrally the optical radiation based on the actual wavelength. The changes of the actual wavelength in respect to the vaccum wavelenth is then corrected according the Edlen formula for refrective index of air. See for exapmle web-page: http://emtoolbox.nist.gov/Wavelength/Documentation.asp#EdlenorCiddor. These corrections are autamitically aplied in TuPS measurement process as they are for Dobsons too. Additional atmospheric pressure sensitivity can be inducesd by pressure contraction of the grating, which we consider as neglagable and dont take it into account.
	3.7.	Figure 5: Provide the errors of the linear fit as a measure of the precision of the wavelength determination.	it will be provided in final version
	3.8.	Figure 6 would be easier to understand if plotted vs. wavelength rather than angle. Alternatively, a second x-axis could added.	it can be done
Comparison	5.1.	Line 155 "curried" should be "carried"	It will be corrected
	5.2.	Figure 9 shows the same data as Figure 10 and can be deleted.	No, it doesn't show the same data. Fig 9 shows Dobson #074 slit functions measured by the Tups-based in-field characterisation. Fig. 10 shows the results of comparison of in-field TuPS based calibration and CMI laboratory-based calibration of Dobson #074.
	5.3.	Line 169: Provide more detail about this comparison. When were the measurement made? Was the Dobson instrument transported in-between the measurements?	A detailed description of the laboratory based chararcterisation of Dobson #074 is given in the paper (Köhler, et al., 2018), which is referred in line 157. This measurements were performed on CMI in 2016 using primary double-monochromator facility, a complex and combersome system of more than 150 kg in total, which is not portable. For this reason the Dobson itself needed to be treansported to CMI laboratory and all characterisation campaign took five days in total (mentioned in the manuscript in lines 157-160). To be noted that the in-field TuPS based characterisation took place in CHMI Hradec Kralove in Dobson #074 place of measurement in 2017, more than half a year later, in that case without the need of moving the Dobson. All this information is given in the paper, only the dates of both measurement was missing and we are going to add it in the lines 157 and 160 as follows: *This laboratory-based calibration measurements carried out in 2016 requested typically* .... and *Compared to that, the in-field calibration in 2017 requests approximately 30 minutes time for installation 160 of TuPS system ...*
	5.4.	Line 171: I don't understand this sentence	It is typo. The sentence will be corrected as follows: Despite of a half a year time gap between both measurements the difference between both measurements did not exceed the value of 0.01 nm in terms of the central wavelength and 0.02 nm in terms of the spectral bandwidth for all 6 Dobson spectral bandpasses
Temporal stab.	6.1.	Line 174: This is confusing. The TuPS participated in 5 field experiments and was calibrated before and after each experiment. However, data is only shown for three calibrations in Figure 11.	Good comment, thanks for it. There has never been ambition to demontrate all recalibration datam in this paper, we onlly wanted to present these two 'worst cases', the largest differencies measured in pre- and post- campaign TuPS calibrations in CMI. We submit to reformulate the sentence in line 174 and change the Figure 11 caption as follows: Line 174: The largest differences of both at about 0.025 nm has been recorded after the measurements in AEMET Izana in Spain and the Deutscher Wetterdienst (DWD) in Hohenpeissenberg in Germany campaigns, both over a time interval of approximately 45 days. The TuPS was ground shipped in its protective transportation plastic box in some cases even together 180 with a number of Dobson spectrometers (for the international Dobson comparison in Izana conducted in September 2017). These two results for calibrations before and after each campaign are reported in Figure 11. Figure 11 caption: The largest differencies measured in pre- and post- campaign TuPS wavelenth scale calibrations in CMI. Dobson comparison campaign in AEMET Izana in Spain (Orange circles) and capaign in he Deutscher Wetterdienst (DWD) in Hohenpeissenberg in Germany (grey circles)
	6.2.	Line 177 and Figure 11: Can you explain the difference of wavelength calibration of 0.04 nm?	The same comment has already been asked and responded/explained to Anonymous referee #1. See below: This part is actually explained in the original manuscript in lines 112-115: It is worth noting, that the TuPS wavelength scale is recalibrated before and after each in-field measurement campaign (as we report below) and based on the calibration results the two linear interpolation parameters readjusted. Potential differences are then accounted as a temporal stability uncertainty contribution into uncertainty budget associated with that in-field calibration campaign. To clarify the text in Chapter 6, we have made following changw of the text in lines 178 -179: - Before and after each measurement campaign the TuPS wavelength scale has been recalibrated and re-adjusted in CMI laboratory using the OPO laser facility as describe above (see Chapter 3.1, line 112)
	6.3.	Line 181: I do not understand this sentence.	That means that during the campaigns TuPS was operated either on Dobsons in-field measurement sites equipped by small shed with abmient temperature control - laboratory environment - or on free space placed Dobsons.
	6.4.	Lines 184-186: I am not certain what the authors want to convey here. Does this demonstrate that the TuPS is stable or that the Dobson spectrometers are all well calibrated?	As written in the line 184 it demonstrates the variability of individual Dobsons charaterised by TuPS during one campaign in El Arenosillo in Spain in September 2017
	6.5.	This entire section could use a more detailed description of the various measurements, shipping, calibrations in order to convince the reader that the TuPS is in fact as stable as needed for in-field calibrations. Also, this may be a good place to discuss how the use of the TuPS as an in-field calibration helps in making the Dobson data more accurate.	A detailed description of the TuPS shipping to and from the in-filed campaigns is given later on in section 6. To highlight that the TuPS is in fact as stable as needed for in-field calibrations, we will add the following text earlier in the chapter: lines 173 -180: The temporal stability of the TuPS light engine was investigated over a period of 2 years from 2017. During the year 2017 the TuPS has participated to five measurement campaigns where it performed the complete characterization of a total of 14 Dobson spectrometers. The TuPS was ground shipped in its protective transportation plastic box in some case together with a number of Dobson spectrometers (for the international Dobson comparison in Izana conducted in September 2017). Before and after each measurement campaign the TuPS wavelength scale has been recalibrated in CMI laboratory using the OPO laser facility as describe above. The results of the calibrations before and after each campaign are reported in Figure 11. The largest differences of about 0.025 nm has been recorded after the measurements in AEMET Izana in Spain and the Deutscher Wetterdienst (DWD) in Hohenpeissenberg in Germany campaigns, both over a time interval of approximately 45 days.
Conclusion	7.1.	Line 198-199: Elaborate how the TuPS will improve the determination of effective absorption cross sections for Dobson instruments. Did you see a difference between the one currently used and those that would be calculated based on the TuPS measurements? How will this help to decrease the inconsistency with the Brewer spectrometer?	the text of the response to the referee very forst comment will be added to the Conclusion chapter in the line 200 and the list of referencies will be updated as follows: Line 200: The ozone absorption coefficient of all Dobson spectrophotometers follows the one of the primary Dobson, defined as the World reference for the global Dobson network. This ozone absorption coefficient is obtained from the convolution of the line spread functions of each slit with the ozone cross sections at a particular ozone temperature. As shown in (Koehler et al, 2018), the difference in ozone absorption coefficients using either the nominal value or the ones obtained using the actual measured line spread functions can differ by up to 1%. Köhler, U., Nevas, S., McConville, G., Evans, R., Smid, M., Stanek, M., Redondas, A., and Schönenborn, F.: Optical characterisation of three reference Dobsons in the ATMOZ Project – verification of G. M. B. Dobson's original specifications, Atmos. Meas. Tech., 11, 1989–1999, https://doi.org/10.5194/amt-11-1989-2018, 2018. The 3% difference between the Dobson and Brewer results in part due to the use of a nominal instead of the actually measured line spread functions, as well as the inconsistency in the ozone absorption cross-sections used up to now (Bass & Paur, 1985). Bass, A. M. and Paur, R. J.: The ultraviolet cross-sections of ozone. I. The measurements, II – Results and temperature dependence, in: Atmospheric ozone; Proceedings of the Quadrennial, 1, 606– 616, 1985. As shown in Groebner et al., 2021 (Gröbner, J., Schill, H., Egli, L., and Stübi, R.: Consistency of total column ozone measurements between the Brewer and Dobson spectroradiometers of the LKO Arosa and PMOD/WRC Davos, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2020-497, in review, 2021.) the consistency can be significantly improved when using the actually measured line spread functions of a Dobson spectrophotometer, in conjunction with the cross-sections from IUP (Serdyuchenko, A., Gorshelev, V., Weber, M., Chehade, W., and Burrows, J. P.: High spectral resolution ozone absorption crosssections – Part 2: Temperature dependence, Atmos. Meas. Tech. Discuss., 6, 6613–6643, doi:10.5194/amtd-6-6613-2013, 2013.)