



Interactive comment on “Direct-sun total ozone data from a Bentham spectroradiometer: methodology and comparison with satellite observations” by M. Antón et al.

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Author's answer to Anonymous Referee #1

The authors greatly acknowledge the anonymous reviewer (Referee #1) for carefully reading the manuscript and providing constructive comments.

Referee Comment: This reviewer finds the paper by Anton et al of interest to the community. It is not a paper accomplishing ground-breaking research, but does show interesting comparisons with satellite measurements. Those comparisons need to be explained in more detail than is given in this version of the paper mainly due to satel-

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lite footprint size and the resulting spatial averaging of sources that occurs over that footprint – the 3 satellites mentioned have very different footprints – should those measurements agree or disagree with the line-of-sight spatial average of the direct sun measurements.

Author's response: Thank you for the comments. We have tried to answer all your questions, see our detailed reply below

General Comments:

Referee GC #1: There needs to be an expanded description of the instrument used – e.g., it is a double, but is it scanned or does it have a CCD type detector with a large intermediate slit? Spectral resolution is confused in the text. What is the detector? Focal length? Is there scattered light in the UV region from longer wavelengths even in the double? Is there a filter in place to limit longer wavelength radiation scattering onto the detector? If scanned, how long does it take to make a scan (i.e. how many spectra taken in the 15-min observation period)? What, if any, has been the effects of fiber optic feeds on the instrument performance? What is unique about the instrument?

Author's response GC #1: An expanded description has been included in the new version of the manuscript. It is scanned, and the detector is a photomultiplier tube Hamamatsu R1527. The focal length is 300 mm. The detector has a blue filter which make that scattered light from longer wavelengths are not registered. A wavelength is scanned every second given a full spectra (280 to 400 nm every 0.5 nm) in 4 minutes, Three spectra are taken in 15 minutes, but just only one for direct irradiance (spectra of global and diffuse irradiance are measured too), therefore we have direct irradiance spectra (taken in 4 minutes) every 15 minutes. We consider that the optical fiber has not any effect over the measurements because we calibrate the full equipment with the optical fiber included. In fact we compared two measurements of the same lamp at noon and at sunset position and the differences between them were lower than 2%. The question “what is unique about the instrument?” is answered in the next comment.

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Referee GC #2: The authors continually refer to the Bentham spectrometer and, e.g., in the conclusions state that other Bentham systems could do similar work. Why is this data specific to the Bentham system? One is measuring an atmospheric parameter (TOC) and surely it should be instrument-independent if the measurement is made correctly. The authors never make any argument about the uniqueness of their particular system – is there any uniqueness to the Bentham system?

Author's response GC #2: To our knowledge, in Spain, there are three operative Bentham spectroradiometers; however only Granada's instrument records direct-solar spectral measurements, the others are only used to measure global spectral data. The Bentham instrument has not a particular uniqueness, but from our results, it has a high potential for the retrieval of reliable direct-sun TOC data, being a viable alternative to the widely utilized Brewer and Dobson spectrophotometers. Therefore, we encourage to research groups with operative Bentham spectroradiometers to work with this instrument in order to record direct-solar data and, thus, to derive total ozone measurements. At the end of the paper the next sentence has been included: "We encourage other researchers with operative Bentham instruments to use it for retrieving TOC measurements by means of the differential absorption technique."

Referee GC #3: The authors need to state what is new using their technique – why not just purchase a double Brewer, for example?

Author's response GC #3: We agree that the technique is not new since it is widely employed to derive TOC data from different types of spectrophotometers. The novelty of our paper is to explain in detail the steps to implement the method from the Bentham raw data and, in addition, to indicate the reliability of their TOC retrieval measurements by means of a detail comparison with satellite data. Regarding why not using a double Brewer, the answer is on the availability of the system. Brewer spectrophotometers are really expensive, so if a research group has a Bentham instrument, this device can be used to obtain reliable TOC data without the need to purchase other spectrophotometer.

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Referee GC #4: The authors have compared their TOC values with satellite values from OMI, Scia, and GOME. As pointed out by the authors, these satellites all have a different footprint over the observation location. The ground data are clearly influenced by local urban conditions, as pointed out by the authors. But there is no discussion of several important points: (4a) What is the effect of the different spatial footprints on the comparison since clearly GOME, Scia, and OMI are very different in footprint size and thus in the spatial regions they sample regionally. GOME does far more averaging than OMI, for example. What effect does this have on the comparison? Does one expect agreement with these large differences over the observing site? Given the differences in spatial observational scales of these satellite instruments and the presence of tropospheric ozone some of which comes from urban areas, would one expect the satellite data to agree and serve as a standard of comparison for the ground instrument?

Author's response GC #4a: Thank you for this interesting comment. Different spatial footprints could slightly vary the noise (spread) of the comparisons between ground-based and satellite total ozone column data due to the influence of spatial gradients in the ozone field. Nevertheless, we think that this effect is small due to the well-known spatial homogeneity of the stratospheric ozone layer (main contributor to the ozone column), although the influence of tropospheric ozone at urban locations could be non-negligible as has been commented by the reviewer. In order to clarify this issue, we have included the following information in the text (Subsection 5.2 "Comparison against satellite observations"): —"In this work, the satellite pixel most closely collocated with the ground-based station is selected as the best match every day. The satellite overpass is selected such that the distance between the center of the satellite pixel and the location of the ground-based stations is always less than 50, 100 and 200 km for OMI, SCIAMACHY and GOME, respectively. This large difference in the spatial collocation criteria is related to the different satellite footprint ground pixel size of the three instruments: 13 x 24 km² (OMI), 60 x 30 km² (SCIAMACHY) and 320 x 40 km² (GOME)." —"The lower spread in the correlation for OMI than for GOME and SCIAMACHY could be partially related to the footprint ground pixel size which is substantial smaller for

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OMI than the other two satellite instruments as was pointed out in the previous paragraph. Although it is well-known the spatial homogeneity of the stratospheric ozone layer (main contributor to the ozone column), the influence of tropospheric ozone at urban locations could be non-negligible.”

GC(4b)The authors do not discuss the relative vertical sensitivity of the various satellite instruments to ozone – their averaging kernels. None of these instruments when used in the uv sees to the surface of the earth due to increased scattering from N₂/O₂. So the satellite sensitivity to surface ozone is not very good. What effect does this have on the comparison of the ground data with the satellite data, and the different averaging kernels between the 3 satellite instruments?

Author’s response GC #4b: We agree with the reviewer in the relevance of the vertical sensitivity of the UV measurements of satellite spectrometers such as OMI, GOME and SCIAMACHY. The sensitivity of these instruments to the ozone density is strongly height dependent in the troposphere (see figure 1 in Anton et al., 2011), so the satellite sensitivity to surface ozone is really poor. But not only the surface ozone, also the derivation of tropospheric ozone column is not a trivial issue and remains a major challenge. Nevertheless, the three satellite instruments used in this paper to comparison purposes present a maximum sensitivity in the stratosphere where the larger amount of ozone is located. Therefore, in our opinion, the influence of the vertical sensitivity of the satellite spectrometers on ground-based-satellite comparison is small. We think that quantify this effect goes beyond the objectives of our paper.

Anton et al., (2011) “Validation of the MetOp-A total ozone data from GOME-2 and IASI using reference ground-based measurements at the Iberian Peninsula”, Remote Sensing of Environment, 115, 1380–1386.

Specific Comments:

Referee SC #1: Please remove “Bentham” from the title of the paper – what spectrometer is used does not need to be in the title.

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Author's response SC #1: Referee is right, but we think that the title must include the word "Bentham" since, to our knowledge, this paper is the first that explain in detail the steps to implement the differential absorption method for deriving TOC data from direct-sun spectral irradiances recorded with a Bentham spectrometer.

Referee SC #2: 8132/26 – to say that ozone has a substantial influence over the weather and climate on regional to global spatial scales is a gross exaggeration unless one is referring to the entire ozone layer in the stratosphere and even then the effect is not especially large. The authors are talking in the context of greenhouse gases and greenhouse gas changes, and the ozone contribution to the greenhouse effect is fairly small ($\sim <10\%$).

Author's response SC #2: We agree with this comment. Thus, we have replaced "Additionally, acting as a major greenhouse gas, the ozone has a substantial influence over the weather and climate on regional to global spatial scales" by: "Additionally, ozone is a greenhouse gas, so change in its column abundance may contribute to global climate change."

Referee SC #3: 8133/7 – should specifically mention the global Dobson network and why it is not sufficient for this application.

Author's response SC #3: According to the reviewer's suggestion, we have added the following comment to the text: "For that, the well-established, worldwide network of Brewer and Dobson spectrophotometers is a crucial tool (Komhyr, 1980; Basher, 1982; Kerr et al., 1984; WMO, 1996, 2008). However, this ground-based network cannot provide global daily maps which are supplied from satellite instruments. To assess the quality of remote sensing observations, the intercomparison of satellite products with reliable ground-based measurements is an essential activity (e.g., Fioletov et al., 2002; Balis et al., 2007; Antón et al., 2010; 2011)."

Referee SC #4: 8134/1 – not clear what "this specific issue" is? Do the authors refer to a system that records the entire spectrum as the Bentham does from 280-600nm si-

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multaneously or by scanning (not specified at this point in the paper), as opposed to, e.g., the Brewer system which looks only at specific wavelengths? If a multiplexing detector is used, is the spectrograph an imaging one, or does the image quality (i.e. spectral resolution) vary significantly across the detector? The instruments mentioned on 8133 all look at the sun. The paragraph on top of page 8134 is very unclear – are the authors referring only to measurements by Bentham type instruments, which seems peculiar since TOC should not depend on type of instrument used.

Author's response SC #4: The sentence has been changed by: "However, to our knowledge, there are not any publications in literature about the TOC retrieved using direct-sun measurements from Bentham spectroradiometers". The instrument scans the irradiance wavelength by wavelength, and this property has been commented in the previous sentence in the manuscript.

Referee SC #5: 8135/5 – resolution is specified as 0.48nm and then FWHM of a spectral line is given as 1.05nm. If the FWHM of a laser line is 1.05nm, then the spectral resolution of the instrument in the given application is 1.05nm, not 0.48nm. What exactly does the 0.48nm refer to?

Author's response SC #5: Referee is right, so we have removed the resolution of 0.48 nm, which is given by the manufacturer.

Referee SC #6: 8135/7 – what is the response of the diffuser used for global irradiance? Should be a cosine-like angular dependence. What is the effect of the use of fibre optics – what type is used, what are special characteristics, what effect does, e.g., movement of the fibres have on the measured direct solar irradiance. The global diffuser system is not mentioned anywhere later in the paper and its discussion should be removed from the paper – it is irrelevant to the discussion.

Author's response SC #6: The global diffuser is just mentioned in the text, in order to give all characteristics of our Bentham instrument. We only comment that two diffusers are connected to the monochromator. In our opinion, it is relevant know that beside

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direct irradiance measurements, global and diffuse irradiances are also measured by Bentham system. Thus, the reader can understand the time (15 minutes) between consecutive direct irradiance measurements (a direct measurement just takes 4 minutes; what happen in the next 11 minutes? Global and diffuse spectra are recorded).

Referee SC #7: 8135/22 – the use of a triangular slit function implies a scanning system – is this a scanner? Being a double system it likely is, but not necessarily (the intermediate slit could be quite large to accommodate a multiplexing detector)

Author's response SC #7: Yes, it is a scanner. It is clearer in the new version of the manuscript.

Referee SC #8: 8135/24 – what is an “expanded uncertainty”? Why does the pointing of the collimator tube combined with the Åbre optic depend on solar zenith angle (i.e. pointing angle of the telescope)? This would seem to only be true for a global diffuser, not a simple open collimator with an embedded diffuser

Author's response SC #8: The expanded uncertainty is the standard deviation multiplied by two, and it means a 95% confidence interval (similar explanation has been included in the new version of the manuscript). Following the work of Bernhard and Seckmeyer (1999), we have different sources of uncertainty. The uncertainties of cosine error and levelling are not considered in our work, because they are associated with global diffusers, as has been commented by the reviewer. However when the SZA increases, the signal reaching the spectroradiometer is lower and, then, the ratio between signal and noise increases given higher uncertainty (the noise signal is the same but the measured irradiance is lower). The uncertainty caused by the noise signal is related in Bernhard and Seckmeyer (1999) and they claimed that it increases with SZA.

Referee SC #9: 8136 – see comments on the applicability of the various satellite data in the Årst section of this review – these are important points the authors need to consider

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Author's response SC #9: Please read author's responses GC #4a and GC #4b

Referee SC #10: 8142/8 – the value 0.410 should be 0.41? due to significant figures?

Author's response SC #10: It has been changed in the new version of the manuscript.

Referee SC #11: 8142/22 – please expand on the problems with, e.g., chemical changes in atmospheric ozone and the applicability of the Langley method to determine ETC. What is meant by “atmospheric disturbances”? Chemical changes will not be random.

Author's response SC #11: According to the reviewer's suggestion, we have included the following comment in the manuscript (Section 4 “Extraterrestrial constant”): “It is well-known that the correct application of the Langley method needs that the optical depth remains constant during the measured period. Nevertheless, Marengo (2002) showed that if a sufficiently large number of cloud-free half-days is available, a reliable ETC can be performed even at locations characterized by non-negligible short-term variability (disturbance) of atmospheric conditions. This author exhibited that these atmospheric variations act as random processes, so their influence on ETC may be minimized by averaging over a sufficiently large number of cloud-free half-days. In this sense, the average ETC value (-0.071) obtained from the 30 daily values may be assumed as representative for the real constant of the Bentham instrument, and, therefore, this mean value may be considered as the extraterrestrial constant in equation 2.”

Referee SC #12: 8144/20 – monotonic

Author's response SC #12: Done.

Referee SC #13: 8144/21 – the 50-60 DU increase is explained as local pollution, but the satellite averaging kernels are very small at the surface, so how does this urban increase compare with comparisons to satellite data? Please discuss the interplay of satellite sensitivity to ozone vs altitude and the line of sight measurements made by

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the ground instrument.

Author's response SC #13: We think that the increase of TOC values from midday to sunset (that can reach up to 40-50 DU in summer) only produce a slight effect in the ground-based – satellite-based comparison. The reason is that we have used hourly average of the Bentham TOC data measured each day around satellite overpass. Please read the author's response SC #14.

Referee SC #14: 8146/4 – the authors average the ground data from 11-13h for comparison with the satellite data, but, e.g., OMI overpasses are typically between 13:30 and 14:00h. Why not use the ground measurements for comparison at the appropriate satellite overpass time?

Author's response SC #14: We decided to use the same the daily average value of Bentham TOC data (from 11-13h) in the three ground-based – satellite-based comparisons. However, according to the reviewer's suggestion, in the new version of the manuscript, we have used the ground-based measurements at the appropriate satellite overpass time. Thus, the inter-comparison results given in Table 2 and Figure 3 vary slightly. Additionally, the following information has been added in the text (Subsection 5.2 "Comparison against satellite observations"): "In addition, the OMI overpass time (~13:30 GMT) differs with respect to overpass times for SCIAMACHY (~10:30 GMT) and GOME (~11:00 GMT). In this sense, to comparison purposes, the Bentham TOC data derived each day between 13:00 and 14:00 GMT are averaged to be compared against punctual OMI data while the average Bentham data between 10:00 and 11:00 GMT are used to be compared against both SCIAMACHY and GOME data. Only those hourly TOC averages with a SD smaller than 10 DU (~ 3%) are assumed as valid and, therefore, utilized for intercomparison purposes. This restrictive threshold guarantees an unobstructed solar disk during the four direct solar spectrums measured within one hour."

Referee SC #15: 8158/řAg2 – mention the half days at AM.

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Author's response SC #15: In the plot's caption, we have replaced "...for the 30 selected cloud-free half-days." by "... for the 30 selected cloud-free half-days (morning period)."

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 8131, 2012.

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