Optical depth retrievals from Delta-T SPN1 measurements of broadband solar irradiance at ground

Delta-T Devices

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Summary

Similarly to the aerosol optical depth (AOD), the Total Optical Depth (TOD) can be used for representing the total extinction produced by gases and aerosols in the atmospheric column. State of the art spectral instruments such as PFR, CIMEL and PREDE sunphotometers allow a strict derivation of the spectral TOD and AOD with a good accuracy (±0.01-0.02 uncertainty) although they need to rely on solar trackers, that are expensive, heavy, and must be periodically maintained due to their moving parts. Therefore, they are the best suited for applications that need an accurate determination of the atmospheric extinction, such as the study of the aerosol properties or the radiative effects of the atmosphere components.

However, more simple and less-expensive instruments can still provide an estimation of the TOD and AOD for other environmental and energy applications. Our interest is addressed at retrieving an effective AOD with broadband instruments. In this work we have first tried a straightforward application of the Beer law on the Delta-T SPN1 instrument. The SPN1 is a robust but small, inexpensive and versatile instrument for the measurement of the broadband global, diffuse and direct components of the solar radiation at ground, without any mobile parts. Although it cannot compete with sunphotometer measurements, results show that the instrument still can provide valuable data for distributed solar energy applications.

The SPN1 radiometer

The SPN1 instrument is a high quality but inexpensive and versatile instrument for the measurement of the broadband global, diffuse and direct components of the solar radiation. It has no moving parts and does not need to be azimuthally aligned to track the sun.

The SPN1 estimates the three components by a combination of measurements performed by 7 different miniature thermopiles that are partially shaded by a computer generated shading pattern (Figure 1a). When the diffuse irradiance is subtracted from the total irradiance, the horizontal direct irradiance is obtained. In turn, the (broadband) normal direct sun irradiance can be determined.

The radiometer measures the solar irradiance between 400 and 2700 nm, and the nominal uncertainty for the individual readings is about 8% ± 10 W/m². Badosa et al. (2014) have shown it compares well against state-of-the-art systems (such as Kipp&Zonen tracked based sensors).

Figure 1. SPN1 instrument (http://www.delta-t.co.uk)

Methodology

In this preliminary study, the TOD-SPN1 has been simply retrieved by the straightforward application of Beer's law to the broadband normal direct irradiance (though the strict method should only be applied to monochromatic measurements). The computation was performed with an Excel spreadsheet provided by the manufacturer.

For its validation, a two and a half year database (2013-2015) from the co-located Cimel and POM instruments at the Burjassot/Valencia site were used (Figure 2). The sunphotometers database was processed with *sunrad* code version 0.93, with a modification in order to retrieve the TOD instead of AOD. AERONET calibrations were used for the Cimel sunphotometer. For the POM radiometer, monthly calibrations were obtained with the ILP method (Campanelli et al., 2004).

After the analysis of the TOD correlations between the SPN1 and the sunphotometers, we used a linear fit at the effective wavelength (~500 nm) to get a corrected TOD. In turn, the Rayleigh scattering term was removed from the TOD to estimate a rough AOD at 500nm, that was also compared to the strict determinations of the Cimel and Prede retrievals.

Further research will employ RT models in order to account for the effect of gas absorption (water vapor, ozone) in the 400-2700 nm interval.

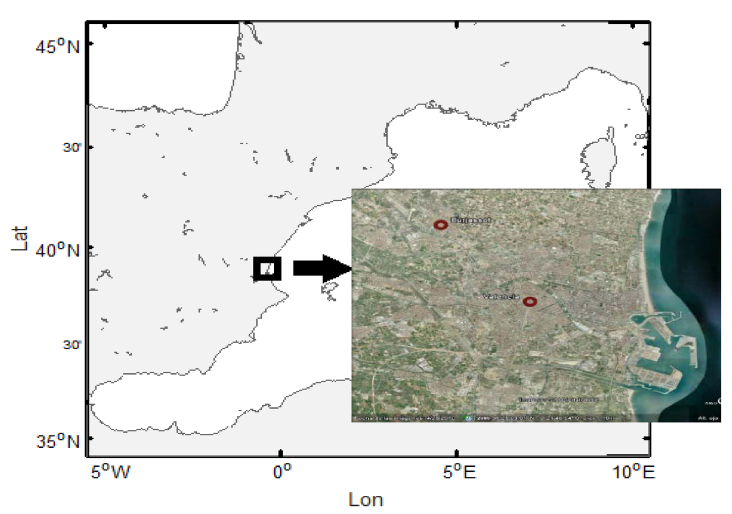

Figure 2. Burjassot/Valencia site in Eastern Spain.

Figure 3. Close up on the SPN1 and sunphotometer at the site.

Results

In Figure 3, the evolution of the TOD estimated with the SPN1 radiometer and the Cimel/POM sunphotometers are represented. The general pattern has been correctly followed by the SPN1. The estimated TOD from the SPN1 is very similar to the strict retrieval of TOD at 500 nm, close to the effective wavelength of the SPN1 (550 nm). In Figure 4, scatterplots between TOD-SPN1 and TOD-sunphotometers have been plotted.

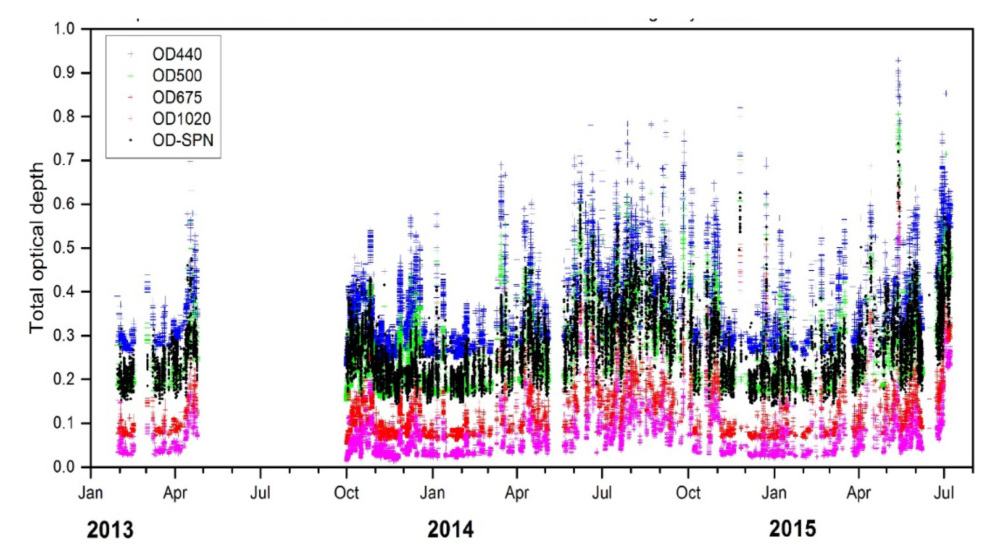

Figure 3. Evolution of the TOD during the period 2013 - 2015

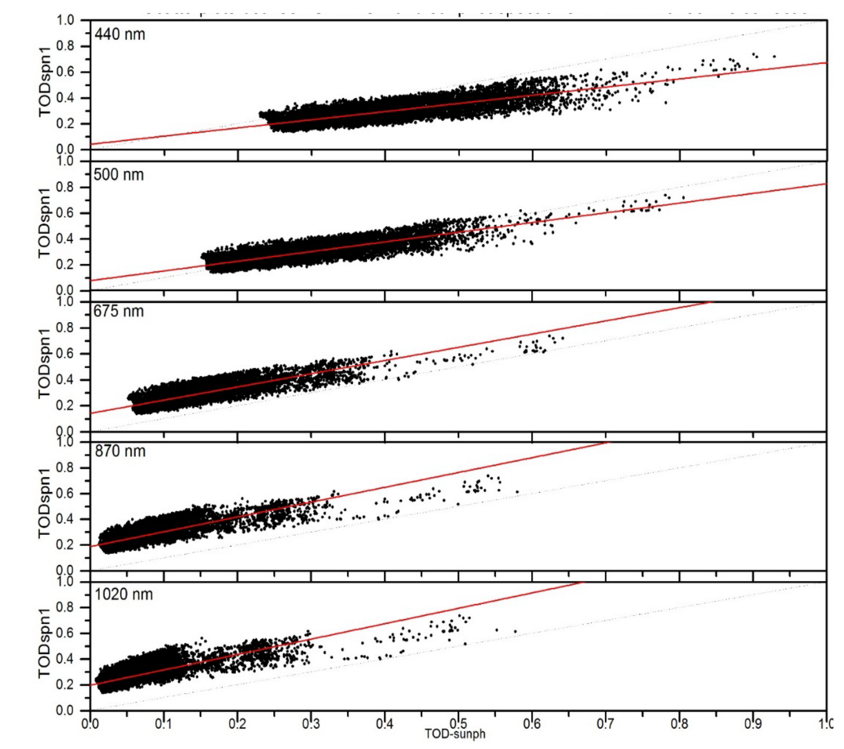

Figure 4. Scatterplot and linear fitting for channel 500 nm (number of matching pairs: 22112)

The fitting parameters for the lines in Figure 4 are shown in the Table below. The results are obviously dependent on wavelength. The Pearson R's are relatively high (~0.8) with the slope and intercept increasing with wavelength (0.63 to 1.2 and 0.04 to 0.20, respectively). There is also a noticeable scatter around the fitted line, possibly due to the higher effective field of view of the instrument.

λ (nm)	Slope	Intercept	R
440	0.631±0.003	0.0428±0.0010	0.82
500	0.750±0.003	0.0784±0.0008	0.84
675	1.015±0.004	0.1429±0.0006	0.83
870	1.152±0.005	0.1890±0.0004	0.82
1020	1.196±0.007	0.1973±0.0005	0.76

As an exercise, and given the equations in the Table, we can estimate a corrected TOD from the SPN1. In turn, the Rayleigh contribution for 500 nm can be removed from the TOD500, giving an approximation to the AOD500.

Figure 5 shows the scatterplot between the so estimated AOD500-SPN1 and the strict AOD from the sunphotometers. Of course, independent databases should be used for its validation, and the use of RT models is planned for a more correct retrieval of the effective AOD.

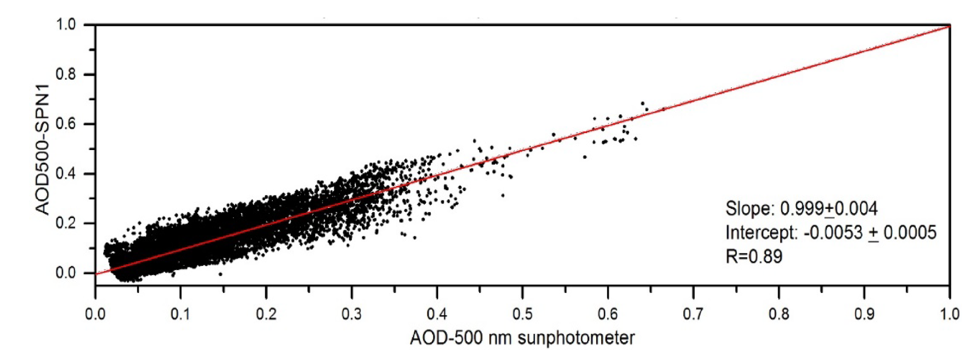

Figure 4. Scatterplot and linear fitting for channel 500 nm.

Conclusions

The Delta-T SPN1 pyranometer has been used in this study to estimate the total optical depth by the application of the Beer law to the broadband direct irradiances for the period 2013 -2015 in Valencia (Spain).

The TOD so obtained has been compared to the TOD measured from state-of-the-art sunphotometers, such as Cimel and Prede models. The correlation between both databases is reasonable, with a Pearson R coefficient of 0.84 for 500 nm.

Although these results cannot compare with the accurate determination provided by the current sunphotometers, the SPN1 radiometer is an inexpensive, versatile and robust instrument that offers the possibility of measuring the solar radiation components without using mobile parts and a good performance (see accompanying abstract). As an extra, a parameter for the monitorisation of the air turbidity can be also computed, showing a reasonable estimation of the total / aerosol optical depth. Further work is needed in order to improve these TOD and AOD estimations.

Acknowledgments

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